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AGRICULTURAL PRODUCTIVITY AND ENVIRONMENTAL QUALITY

DOCUMENTS

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JOINT HEARINGS

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES AND ENVIRONMENT

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

AND THE

SUBCOMMITTEE ON CONSERVATION AND CREDIT

OF THE

COMMITTEE ON AGRICULTURE U.S. HOUSE OF REPRESENTATIVES

NINETY-SIXTH CONGRESS

FIRST SESSION

JULY 25, 26, 1979

[No. 96]

(Committee on Science and Technology)

Serial No. 96–VV

(Committee on Agriculture)

Printed for the use of the Committee on Science and Technology and the Committee on Agriculture

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AGRICULTURAL PRODUCTIVITY AND ENVIRONMENTAL QUALITY

WEDNESDAY, JULY 25, 1979

U.S. HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON NATURAL RESOURCES AND ENVIRONMENT, COMMITTEE ON AGRICULTURE, SUBCOMMITTEE ON CONSERVATION AND CREDIT;
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:23 a.m., in room 2325, Rayburn House Office Building, Hon. Ed Jones (Chairman of the Agriculture Subcommittee on Conservation and Credit) presiding.

Present: Representatives Jones, Ambro, Brown, Harkin, Hance, Marlenee, Walker, and Hopkins.

Staff present (from the Subcommittee on Natural Resources and Environment): Ian Marceau, staff director and David Clement, technical consultant.

Mr. JONES [presiding]. The Subcommittees on Conservation and Credit of the Agriculture Committee and the Subcommittee on Natural Resources and Environment of the Committee on Science and Technology will please come to order.

We are here today for the purpose of hearing witnesses on Agricultural Productivity and Environmental Quality.

I am Ed Jones, Chairman of the Subcommittee on Conservation and Credit, along with the Chairman of the Subcommittee on Science, Research, and Technology and Jerome Ambro, Chairman of the Subcommittee on Natural Resources and Environment.

We are delighted to have the privilege of joining together and also the privilege of hearing the witnesses for today and tomorrow and will take them in order if they are here.

Before we begin, I have a statement that I would like to make and then I yield to my colleagues who are chairmen of other subcommittees for whatever they might have to say.

These hearings and the related congressional research service report have come about as a result of the need perceived by Representatives Brown and Ambro and myself to examine more clearly agricultural and environmental relationships.

As I see it, our effort is educational and exploratory in nature rather than legislative. I feel that some of these issues can be examined in a more thoughtful manner by Members of Congress at this time if they are not tied to legislative proposals. By removing the need to tailor the testimony of witnesses and the questions of Members to policy and program matters, I am hoping for a very open give-and-take discussion.

This morning our session will cover the area of Technology, Productivity, and Environment. We have a distinguished panel of witnesses and I want to welcome each and remind you that we have seven witnesses to hear and I ask you to keep your remarks to 10 minutes or less so that we can move ahead to the question and answer session. In any case, your entire statement will be made part of the official record.

The format for hearing the witnesses will be that we will hear all seven of them first and call you back to the witness table as a panel for questioning by members of the committees.

At this time I would like to yield to my good friend and member of my Subcommittee on Conservation and Credit also, George Brown of California.

Mr. BROWN. Thank you very much, Ed. I just want to point out that work in preparation for these 2 days of hearings began quite a few months ago in the last session of Congress; began with commissioning a major study by the Library of Congress, Legislative Research Branch, and that it was based on a recognition which Ed Jones has expressed and Mr. Ambro will express of the fact there is a close relationship between the health of agriculture and a productive and wholesome environment for all of our population, both urban and rural and we want to explore these interactions and impacts between urban and rural development and see if we can do something to improve them.

I just want to express my thanks to Chairman Jones and Chairman Ambro for carrying through on this work. I think it will be a contribution to the policy decisions of the Congress for many years to come and I am looking forward to hearing from all of the distinguished witnesses we have over the next 2 days.

Mr. Chairman, I ask unanimous consent to submit a formal statement for the record.

Mr. JONES. Thank you, George.

Without objection, your formal remarks will become a part of the record at this point.

[The statement of Mr. Brown follows:]

STATEMENT OF HON. GEORGE E. BROWN, JR., CHAIRMAN, SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

I would like to acknowledge the fine work that Chairman Ed Jones and Chairman Jerome Ambro have done in bringing about this hearing. These two days of hearings are significant for a number of reasons. First, these are joint hearings between subcommittees of two different full committees, providing an opportunity to bring two different jurisdictional perspectives to bear on the important issues under consideration. Second, these hearings do not focus on a specific piece of legislation but look at a broad range of issues that we have examined in the past and will see again in the future. By looking at these different areas in the same session we will be better able to relate them to each other and perhaps find common solutions to problems that were previously considered separate issues.

Finally, these hearings are focused on the interactions between sectors of our society that in the past we have dealt with as separate entities. During the next two days we will be examining the relationships between rural and urban areas, between agricultural productivity and environmental concerns. I think that we will find many common points, many links that we have not fully understood or have failed to recognize during our legislative consideration of these areas.

The danger of overlooking the interactions of these areas has shown itself time and again. The water supply and quality problems being experienced in the

Southwest exemplify the complex interrelationships that we must pay attention to. Increasing urban development causes increased demands to be placed on water supplies already overtaxed from agricultural demands. The development of synthetic domestic sources of energy will require large amounts of water that likewise will have to come from existing allocations. Increased use of water will exacerbate salinity problems, necessitating agronomic changes or the development of new technologies to deal with this problem. Upon close examination of this one area, the complex maze of interactions reveals itself and, when related to other environmental and agricultural areas, the complexity is multiplied.

I look forward to the benefit of the oral and written testimony that will be presented on these areas and hope that my colleagues will take full advantage of this unique opportunity.

Mr. JONES. Now I yield to the Subcommittee Chairman on Natural Resources and the Environment, Jerry Ambro.

Mr. AMBRO. Thank you, Ed. Thank you, George. As the anchor to this mutual admiration society, I, too, would like to express my deep thanks to Ed Jones and George Brown for developing these hearings.

Although much research has been done and many statements made about the impacts of agricultural practices, fertilizers, pesticides and herbicides on the quality of the environment, there has been little attention paid to the impacts of urban and industrial activities on the productivity of agriculture.

Recent experience has shown that the impacts on agricultural productivity of expanding urban settlements, with their competing demands for limited water supplies and for the land itself, are severe.

At least equal in importance to the direct competition for resources between urban and industrial activities and agriculture are the effects of the effluents of the urban/industrial worlds.

Of particular concern to the Subcommittee on Natural Resources and Environment are quality water supplies for agriculture; and the effects of oxides of sulfur and nitrogen, which form acid precipitation on crop production. Another air contaminant adversely affecting agricultural production in parts of the United States is ozone.

An area of possible beneficial interaction between agriculture and urban areas is in the use of treated sewage sludge as an organic fertilizer and soil conditioner on some croplands.

At present, urban areas are faced with ever increasing problems in disposing of sewage sludge by incineration, landfilling or ocean disposal. In some areas of the United States the spreading of sludge on farmland is practiced and there is research underway to convert the sludge to methane for use as a fuel.

In the event that methanation became widespread, the methane gas could be used to substitute for natural gas fuels, thereby freeing them for fertilizer production.

All of these matters will be discussed during the sessions this afternoon and tomorrow morning. I look forward to what the experts testifying will have to tell us.

Thank you, Mr. Chairman.

Mr. JONES. Thank you very much, Jerry.

Now, I would like to take the time and yield to our good friend and colleague, a member of the Subcommittee on Conservation and Credit, Mr. Ron Marlenee.

Mr. MARLENEE. Thank you, Mr. Chairman.

Mr. Chairman, I have no statement, comments, or questions at this time.

Mr. JONES. We are delighted you are here.

Our first witness is Dr. Sylvan M. Wittwer, Director, Michigan Agricultural Experiment Station.

Dr. Wittwer, if you have someone with you that you would like to bring to the witness table, you may do so.

STATEMENT OF DR. SYLVAN H. WITTWER, DIRECTOR, MICHIGAN AGRICULTURAL EXPERIMENT STATION

Dr. WITTWER. I have none.

Mr. JONES. Thank you for being here. We are delighted that you took the time to come down and you may proceed.

Dr. WITTWER. Four years and one month ago today I appeared before similar subcommittees of the Committee on Science and Technology of the House of Representatives of the U.S. Congress as the first witness on Special Oversight Hearings on Agricultural Research and Development.

I emphasized then, as I want to reemphasize now, the gross neglect that has occurred in public support of mission oriented basic agricultural research relating to the enhancement of food production.

I referred to research on the basic biological processes that control and limit crop productivity and food production. Reference was made to technologies that are nonpolluting and environmentally benign—technologies that would literally add to and preserve the resources of the Earth and would result in stable production at high levels and be sparing of resource inputs, and not be subject to ever-increasing regulatory constraints.

Reference was made then to what I have since designated as the "Next Generation of Agricultural Research."

These research initiatives are outlined in the attached table I and appeared in an editorial in Science of January 27, 1978, a copy of which is attached. To me it is inconceivable why Congress, the White House, and the Federal agencies that have the responsibility for supporting agricultural and food research continue to essentially ignore these suggestions. It was pointed out in 1975 that scarcely more than $15 million was then being expended in the United States on the combined total for research on photosynthesis, biological, N_2 fixation, and cell culture approaches to plant breeding that related to agricultural productivity. The United States was not then the world's leader in research in investments in these areas, nor is it today.

As an example, 4 years later, our best estimates are that support for biological nitrogen fixation research in the United States has gone up from $5 million in 1975 to $7.5 million in 1979—scarcely more than inflationary increases. Yet, in the USDA–SEA Competitive Research Grants Office alone, over 100 proposals were received this year amounting to requests totaling over $13 million for support of new research on biological nitrogen fixation. Proposals calling for $4.8 million were recommended, but the total funds available were less than $2 million. The talent and human resources exist, but the funding is totally inadequate.

Chemically synthesized nitrogen fertilizer represents the largest single industrial input into agricultural production. One-third of the fossil fuel energy consumed in food production is from this single resource. Each pound of synthetic nitrogen fertilizer requires an input of 30 cubic feet of natural gas.

In other words, a nitrogen fertilizer factory consumes approximately 1 cubic meter of natural gas for each kilogram of nitrogen it produces as ammonia. It is inconceivable that we continue to neglect this important research area, along with a failure to support photosynthesis research; wherein with the same USDA–SEA competitive grant program there were 118 proposals in 1979 with requests totaling over $17 million and only 25 can possibly be funded at a total level of $1.9 million. Solar energy is clean, it is renewable, and it is nonpolluting. Agriculture is the only major industry in the world that processes solar energy or farms the Sun. Plants are literally biological sun traps, and we ought to invest at least a few more millions of dollars to increase the efficiency of a trapping process that now seldom exceeds more than 1 percent, in view of the billions of dollars now being expended in energy research.

It is true that a minimal competitive grant program was initiated 2 years ago in the USDA, but it has always initially been at the expense of formula Hatch funding.

Why is it so difficult to get congressional, White House, and Federal agency support for these and the other neglected agricultural research areas so basic to our future economic welfare, food, security, and the preservation of a wholesome environment?

The recommendations of the several reports of the World Food and Nutrition Study—1975, 1977—the International Conference on Crop Productivity—Research Imperatives, and Food Advisory Committee of the Office of Technology Assessment have essentially been ignored, at least we know they are not being implemented.

Let me make reference to the chart "Fates of Nitrogen in Soils." We are annually losing up to half of the nitrogen fertilizer that we apply for crop production. These enormous losses occur from both nitrification, or leaching, and denitrification, or atmospheric loss.

One of our highest priority research efforts should be directed toward reducing these losses. Such losses pose serious economic, resources management, and environmental consequences. Biologically fixed nitrogen is the most energy efficient way of providing nitrogen to plants. There is little loss from leaching and no environmental pollution. This was documented in an editorial in BioScience of September 1978.

I refer to additional tables attached to my statement. We further need an assessment of all future and current technologies relating to Agricultural production in terms of their input or impact on the regulatory environment. Table II lists some of the recently imposed regulations upon agricultural research and farm productivity. The rising costs of regulations, relating to farm productivity and agricultural research, constitute one of the most inflationary components of our economy.

The decade of the 1970's is essentially behind us. Important events have transpired during the past 10 years. There have been many transitions; and more are in progress. They relate to agricultural technology, productivity, resources, and the environment.

The biggest transition is one from a resource based to a science based agriculture. Agricultural output per person in the United States is the greatest in the world, but not without enormous resource, capital, and management inputs. The agricultural output per unit resource input is much less in the United States than in most other industrial-

ized nations, including Japan and most all northern European countries. As we move toward a more science based agriculture, environmental issues emerge with greater intensity and frequency.

Note the "Composite Index of Crop Yields, 1880–1978." Observe the lack of change from 1880 to 1940. Note, also, the precipitous rise that occurred in the 1950's and 1960's. These two decades might be referred to as the "golden era" of agricultural productivity. They were characterized by abundant and cheap resources, and few environmental constraints. Note particularly the plateauing of agricultural productivity in the 1970's. Many reasons could be given. Some are listed in table III.

The year 1970 saw the peaking out of the rate of worldwide population increase. It was the year domestic oil production peaked in the United States. The environmental movement received its greatest visibility in the early 1970's.

A southern corn leaf blight devastated American corn fields in 1970 and made us aware of genetic vulnerability.

In 1972, we saw a plateauing of fish harvested from the oceans, and there were massive shipments of grain to the Soviets. The year 1972 saw the initiation of uncertainties, volatilities, and unpredictabilities in the prices of major food commodities at the marketplaces not before experienced in this generation. There were alternative food shortages and surpluses. The early 1970's saw a major drought in the Sahel. There was an oil embargo in 1973. The price of imported oil has risen by a factor of almost 10 during this decade. Finally, we are in the midst of a massive transition from the use of nonrenewable to renewable energy resources.

What of future agricultural productivity and environmental quality?

What should we look to for the 1980's?

Table V provides a grouping of resource sparing technologies that could insure a safe environment and with great potential for increasing the stability and magnitude of agricultural production.

We should seek after production technologies that will have the least impact on the regulatory environment, and there are many to choose from. See table V attached to my statement.

Note that reduced tillage and allelopathy are in the list, but with qualifications for each. Reduced or zero tillage conserves water, soil, energy, and organic matter—all of which have favorable environmental impact, with one exception. Zero tillage normally requires a herbicide. We have now found there are plant associations where food crops produce chemicals that are toxic to weeds, thus resulting in weed control. This is allelopathy. When these good crops are used as mulches in conservation tillage their residues may control weeds as an alternative to the use of chemical herbicides.

One of the most controversial and debated issues relating to agricultural production, resources, and the environment is the role of livestock and animal agriculture for the 1980's and the 21st century in meeting human needs.

We are pleased to announce that the Agricultural Experiment Station of the College of Agriculture and Natural Resources of Michigan State University and the College of Veterinary Medicine are jointly sponsoring with the U.S. Department of Agriculture, Winrock Inter-

national, the American Association for the Advancement of Science, the Environmental Protection Agency, and the four professional animal science societies, a national conference. It is scheduled for May 4 through 9, 1980 at Boyne Mountain, Mich. The focus will be on research imperatives relating to resource, or energy, inputs, economics, health and nutrition, environmental concerns and issues, biological efficiency, and the sociopolitical problems. We hope to have some congressional representation.

Thank you, very much.

[The various tables and charts presented to the subcommittees by Dr. Wittwer follow:]

TABLE I - NEXT GENERATION OF AGRICULTURAL PRODUCTION RESEARCH

Greater photosynthetic efficiency
Improved biological nitrogen fixation
Genetic improvement and new cell fusion technologies
Greater resistance to competing biological systems
More efficiency in nutrient uptake and utilization
Reduction in losses from nitrification and denitrification
Greater resistance to environmental stresses
Identification of hormonal systems and mechanisms

TABLE II - RECENTLY IMPOSED REGULATIONS
UPON AGRICULTURAL RESEARCH AND FARM PRODUCTIVITY

Occupational Safety and Health
Human Subjects Requirements
Union/Management Relationships
Personnel Relations
Affirmative Action
Equal Opportunity
Waste Handling and Disposition
Chemicals Handling and Disposition
Laboratory Animals
Building Codes, Ordinances, Standards
Accountability
Budget Management
Freedom of Information
Acts - Clean Water, FIFRA, Toxic Substance, Clean Air, RPAR

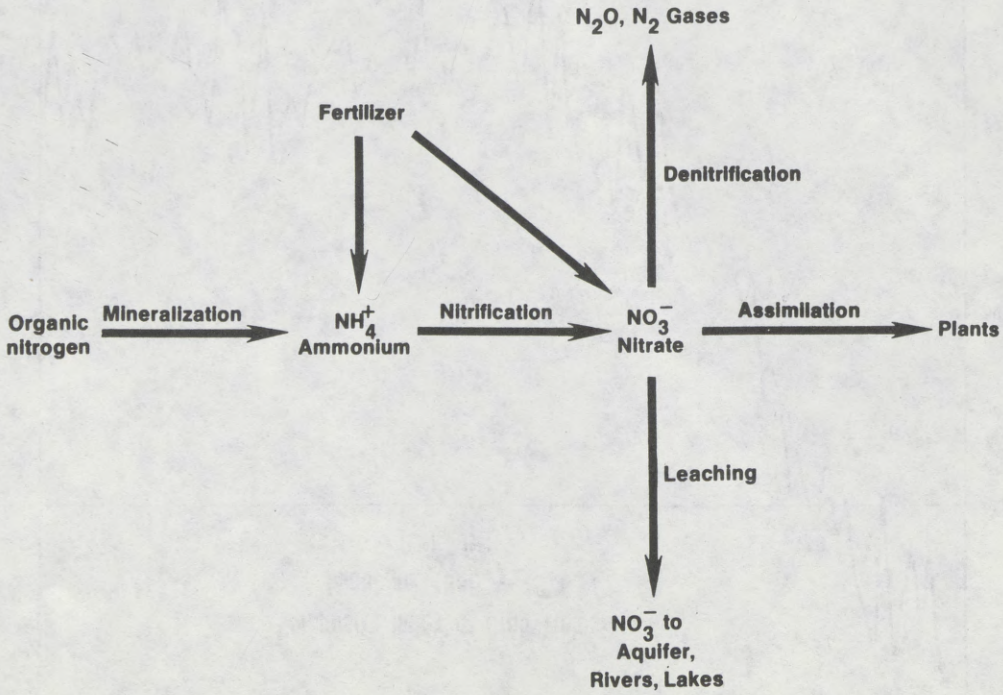
TABLE III - CAUSES OF PLATEAUING IN AGRICULTURAL PRODUCTIVITY

Soil erosion - Loss of topsoil
Loss of organic matter - Soil compaction
Chemical soil residues - Air pollution
More less-productive land under cultivation
Increased pressures on productive land base
Fewer options for water, fertilizer, pesticide uses
Climate and weather fluctuations
Increased regulatory constraints
Decreased support for agricultural research

TABLE IV - SYSTEMS OF INTEGRATED PEST MANAGEMENT

Inputs	Outputs
Natural enemies	Increased production
Resistant varieties	Production stability
Cultural practices	Improved environment
Chemicals (pesticides)	Cost reduction

Fates of Nitrogen in Soils



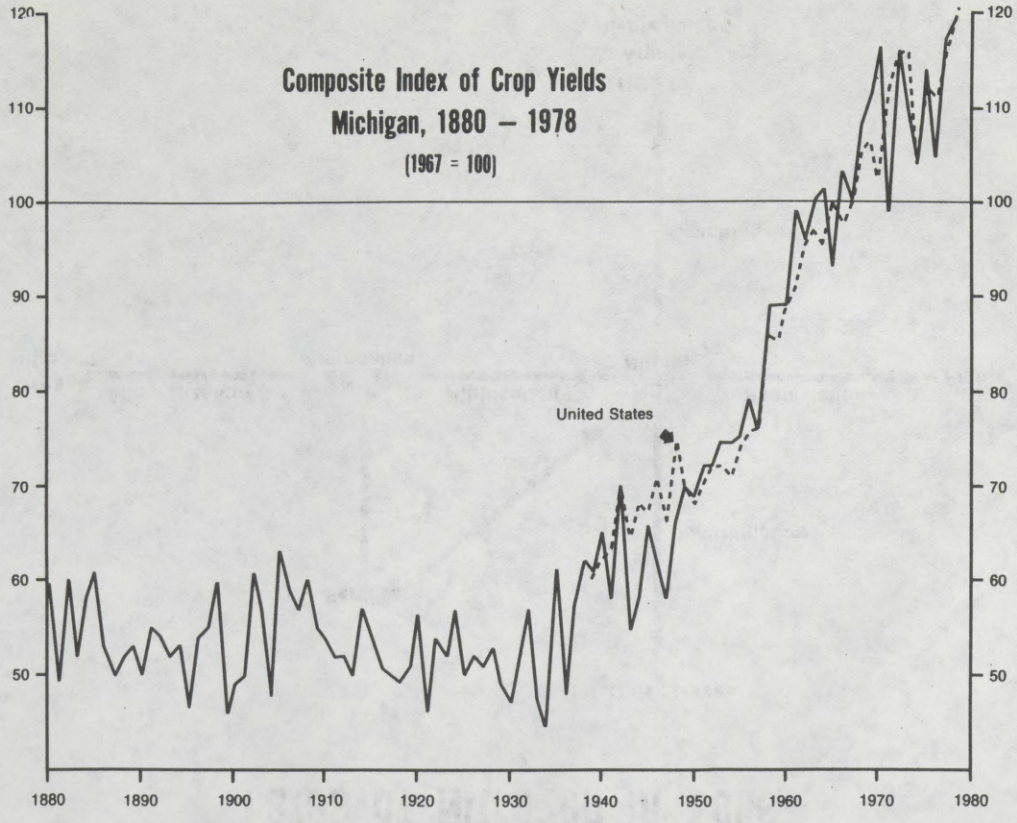

Composite Index of Crop Yields
Michigan, 1880 – 1978
(1967 = 100)
United States
120
110
100
90
80
70
60
50
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980

TABLE V - RESOURCE SPARING TECHNOLOGIES WHICH COULD PROVIDE A SAFE ENVIRONMENT WITH SUFFICIENT AGRICULTURAL PRODUCTION OUTPUT

TECHNOLOGY	REGULATORY NEUTRAL	REGULATORY PROBLEMATIC
Improved photosynthetic efficiency	x	
Improved biological nitrogen fixation	x	
Chemical and hormonal regulation of crop growth and metabolism		x
Genetic improvements - tissue culture techniques		Recombinant DNA
Integrated pest management		On balance fewer regulatory constraints
Allelopathy		Possible toxic plant components
Nitrification and denitrification inhibitors	x	
Adaptation of plants to problem soils	x	
Microbial enhancement of nutrient uptake by plants	x	
New soil, water, and energy conservation and management technologies	x	
Technologies conserving of resources and useful for small farms	x	
Reduced tillage	x except for herbicides	
"Blue Revolution" - drip irrigation	x	
Cloud seeding - increased snowpack; cumuliform clouds		x
Expansion of irrigated agriculture - total water management systems		x
Genetic adaptation of crops to salt and brackish waters		x
Improved livestock productivity		
. improved production and utilization of feeds		x
. better disease control		x
. genetic improvement		x
Controlled environments for lambs, beef, and dairy cattle	x	
Solar energy technologies		
. abiotic nitrogen fixation	x	
. greenhouse heating	x	
. livestock housing	x	
. crop drying	x	
. irrigation	x	

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The Next Generation of Agricultural Research

Productivity of the major food crops has plateaued. Yields of wheat, maize, sorghum, soybeans, and potatoes in the United States have not increased since 1970. This is true of maize, potatoes, wheat, and cassava in Latin America. World grain yields have declined. Increased production has been achieved largely by cropping more land.

This phenomenon needs careful analysis. Farm yields rose rapidly in the United States following World War II. These were accompanied by technologies requiring massive inputs of fossil energy channeled to the farm as fertilizer, pesticides, irrigation, mechanization, and new seeds. Greater production efficiency was the goal. The result was plentiful food at low cost. All of these external inputs, with the possible exception of genetic improvements, are becoming increasingly costly, subject to more constraints, and less available. Some come from nonrenewable resources. Meanwhile, soil erosion continues unabated nationally and globally. After 40 years of a U.S. soil conservation program no more than 25 percent of our farmlands are under approved conservation practices. Topsoil continues to be lost at an enormous rate. Soil organic matter is being reduced. There is greater compaction from excess and untimely tillage. Air pollution is becoming more severe. Additional land areas brought into cultivation may be less productive. With increasingly greater pressures on the productive land resource base, the options for use of water, fertilizer, pesticides, and mechanization become progressively less.

Some would credit the recent plateauing of crop yields to adverse and fluctuating climate and weather. Season-to-season variations, however, are far more significant than any identifiable long-term trends. Regulatory and financial constraints on the use of labor, chemicals, water, and energy are increasingly costly and stifle production. Finally, there has been a 12-year erosion of the federal investment in agricultural research, not only in manpower but in new equipment and facilities. Enrollments in the colleges of agriculture in the land-grant universities have tripled in 10 years with little if any increase in faculty. Scientist years in support of agricultural research have not changed since 1966. Teaching needs had to be met. Research was left behind.

This brings us to the next generation of agricultural research. There are technologies that will result in stable food and fiber production at high levels, are nonpolluting, will add to rather than diminish the earth's resources, be sparing of capital, management, and nonrenewable resources, and are scale neutral. The time strategy, however, requires more than a 3- to 5-year plan. These technologies depend on mission-oriented basic research relating to the biological processes that control and now limit crop and livestock productivity. It is research that will address the problems of enabling plants and animals to more effectively utilize present environmental resources, through (i) greater photosynthetic efficiency; (ii) improved biological nitrogen fixation; (iii) new techniques for genetic improvement; (iv) more efficient nutrient and water uptake and utilization, and reduced losses of nitrogen fertilizer from nitrification and denitrification; and (v) more resistance to competing biological systems and environmental stresses. These are the areas identified in recent National Academy of Sciences–National Research Council reports and elsewhere as grossly underfunded; where we no longer exercise world leadership, and where the United States with its vast human, financial, and natural resources could make its greatest contribution to the agricultural development of Third World nations. Such technologies would be economically, socially, and ecologically sound. They could ease the inevitable transition we must make from nonrenewable to renewable resources. We must address ourselves to them.—S. H. WITTWER, *Director, Michigan State University Agricultural Experiment Station, East Lansing 48824*

Reprinted from *BioScience*

September 1978

NITROGEN FIXATION AND AGRICULTURAL PRODUCTIVITY

Chemically fixed nitrogen is a nonrenewable resource. It is also the largest single and most costly industrial input into agricultural productivity. Up to 35% of the total productive capacity of all crops is now accredited to this single input. Almost one-third of all fossil energy now used in agricultural production goes to chemical nitrogen fertilizer synthesis.

The global use of chemically fixed nitrogen fertilizer for crop production has grown precipitously. In 1905, 400,000 metric tons (tonnes) were produced. This increased to 3,500,000 tonnes in 1950 and to an output of 40,000,000 tonnes in 1974. The estimate for 1978 is 50,000,000 tonnes. Meanwhile, the contribution of biologically fixed nitrogen, estimated at 150–175,000,000 tonnes annually, has not changed.

The United States is the world's largest consumer of nitrogen fertilizer. More than 10,000,000 tonnes—almost one-fourth of the world's total—is applied to crops in the USA annually. Half goes to a single crop—maize. The average annual investment for nitrogen fertilizer for corn alone is $1 billion. It is $1.5 billion for all grain crops. The total for all crops approximates $2 billion.

Natural gas is the primary fuel (95%) used to produce anhydrous ammonia. It requires 30 cubic feet of natural gas to produce one pound of nitrogen. The current and projected natural gas dependency of chemically fixed nitrogen fertilizer remains as one of the most flagrant violations of good economics, use of a nonrenewable resource, and threatens a possible environmental disaster. It is inconceivable for us to continue to go this route.

The alternative is research directed toward enhancing biological nitrogen fixation. The many possible research frontiers and the inadequacy of current funding levels have been thoroughly documented by numerous National Research Council/National Academy of Sciences reports, assessments by several federal agencies, the U.S. Congress, national and international conferences and symposia, and this special issue of *BioScience*. The opportunities lie in the establishment of rhizobial technology centers. A return to research in farming systems specifically relating to cropping systems, making more extensive use of legume green manure and winter cover grops, forage legumes, and possible intercropping of legumes with nonlegumes, is suggested. A third initiative lies in genetic engineering for improvement of both host and microorganism. Symbiotic relationships now exist for legumes, the actinomycete-nodulated angiosperms, and in the *Anabaena-Azolla* combinations that enrich rice paddies. These relationships need to be optimized. Finally, there should be an effort toward improving the biological nitrogen fixation associations with grasses, cereal grains, and other nonlegumes. Biologically fixed nitrogen is slow-release nitrogen. Losses from nitrification and denitrification, which now approximate 50 to 65% of the fertilizer nitrogen, could be reduced by 50%.

Further research breakthroughs in biological nitrogen fixation, which will be important for enhancement of agricultural productivity, will be hastened if active linkages are now created between scientists engaged in basic fundamental research in the laboratory with those in mission-oriented, applied, and problem-solving areas under field conditions. There is a unique opportunity with research on biological nitrogen fixation to apply science to problems in agriculture and contribute mightily to the enhancement of food and fiber production. The economic, resource, and environmental stakes are too high to do otherwise.

SYLVAN H. WITTWER
Michigan Agricultural Experiment Station
East Lansing, MI 48824

Mr. JONES. Thank you very much, Dr. Wittwer. As I said, we do appreciate your testimony and we will call you back later for questions.

Our next witness is Dr. Samuel R. Aldrich, Assistant Director, Illinois Agricultural Experiment Station.

Welcome to the hearing. You may proceed.

STATEMENT OF DR. SAMUEL R. ALDRICH, ASSISTANT DIRECTOR, ILLINOIS AGRICULTURAL EXPERIMENT STATION

Dr. ALDRICH. Perhaps the most constructive role for me today is to supply insight into some consequences of using more or less chemicals.

The conflicts of agricultural production with environmental goals have received excessive attention during the past decade. I welcome this opportunity to clear up some common misunderstandings and to identify positive impacts of agricultural chemicals on environmental goals. The fact that little time will be spent on the negative aspects means only that I believe they are already well known. I shall develop examples of unknown or overlooked impacts of modern conventional agriculture in hopes of whetting an appetite for more information that is needed for wise decisionmaking.

Additional details on these and related subjects is contained in testimony submitted in these hearings by the National Association of State Universities and Land Grant Colleges.

The missions of agriculture to produce food and preserve the soil, and of other groups and agencies to protect the environment and assure food safety, are basically complementary rather than competitive.

In this so-called "chemical age" of agriculture, 95 percent of all chemicals used by farmers are ordinary plant nutrients supplied in commercial fertilizers, which support life rather than being toxic to it. Insecticides, weed killers, seed protectants, nematacides, antibiotics, and hormones make up only 5 percent of the total chemical usage. Some agricultural chemicals are natural and some are synthetic or "man-made". Either may be benign or toxic. Those that are potentially toxic may be hazardous or safe, depending upon how they are used.

Who benefits from efficient production?

Many persons outside agriculture appear to believe that farmers are prime beneficiaries of the use of chemicals. Surprising as it may be, aggregate farm income would likely increase as a result of a substantial shift away from agricultural chemicals. This is because each 1-percent decrease in crop production is likely to result in an average increase in farm gate price of 2 to 4 percent. Thus, a 10-percent decrease in agricultural output as a result of not using needed chemicals, would result in an estimated 20 to 40 percent increase in prices to the farmer and a 7.5- to 15-percent increase in average retail food prices.

I do not mean to imply that individual farms would willingly cease to use agricultural chemicals in hopes of greater income through higher prices. That would only happen if the change were made industrywide, and even then the advantage would not be equally shared because of differing degrees of dependence upon fertilizers and pesticides among crops and geographic regions.

What are some of the environmental benefits from optimum use of agricultural chemicals?

Many of the benefits which can be legitimately claimed for conventional agriculture are the result of higher yields, and thus less acreage of cropland required to meet food and fiber needs.

A study in progress by the Council for Agricultural Science and Technology will conclude that farming without chemicals would reduce per acre yields by 15 to 25 percent. Each 1-percent loss in yield on present cropland would require an additional 1.25 to 1.5 percent of cropland in order to maintain present levels of food and fiber production in the United States. The reason the replacement is not 1 to 1 is that most of the land available for expansion is not well suited for crop production because the soil is shallow, stony, wet, steep, or located in a region where there is too little rainfall or the growing season is short.

LESS EROSION AND SEDIMENT POLLUTION

In spite of a growing need for food, millions of acres of steep, erosive soils were retired from cropland between 1930 and 1950. As compared to slopes of 0 to 2 percent, erosion from slopes of 2 to 4 percent is 2.6 times greater, and from slopes of 4 to 7 percent 6.2 times in the central Corn Belt. The same principle applies to other regions with appropriate crops substitute for corn and soybeans.

If more sloping land had to be cropped in order to compensate for yield reductions due to less use of needed chemicals, erosion would greatly increase. Soil erosion results in sediment, the most serious water pollutant. Not only does sediment reduce the attractiveness of lakes and rivers but it fills reservoirs and destroys fish habitat. Furthermore, it is the main carrier of pesticides from cropland.

PRESERVATION OF WILDLIFE HABITAT AND RECREATIONAL LAND

Though intensive farming with optimal use of agricultural chemicals reduces the habitat for wildlife on cropland, it preserves other land for wildlife and for recreational uses.

Fortuitously land that is least suited to farming is usually as good as, or better than, present cropland for wildlife and recreation. The flat prairie land of the central Corn Belt is beautiful to farmers and to me, but the rolling hills are more attractive to backpackers, campers and canoeists.

PRESERVATION OF THE PRODUCTIVE CAPACITY OF SOILS

Most cropland has lost at least 40 percent of its original content of organic matter and nitrogen. In fact, our forefathers grew their crops largely upon the plant nutrients that were released when the soil humus that had accumulated over thousands of years, was destroyed when forests were cleared and prairies were plowed. Early agricultural systems also depleted the soil supplies of phosphorus and potassium.

In the transition period from early agriculture to the present intensive systems, many U.S. farmers grew nitrogen-fixing leguminous crops such as alfalfa, clover, and lespedeza and kept livestock from which manure was returned to the land. The use of commercial ferti-

lizers began in the Southeastern States and spread northward and westward, reaching the Corn Belt in quantity as recently as 1945 and even later in the Great Plains. The decline in soil supplies of phosphorus and potassium was arrested very recently, and these elements have now been rebuilt to higher than the original levels in many fields.

It is not feasible, in fact nearly impossible, to rebuild soil organic matter and nitrogen. There is much misunderstanding about the effect of conventional, high yield, intensive agriculture on soil organic matter. Many are under the impression, for example, that an intensive corn-soybeans system supplies less plant residues than did the former systems of corn-small grain-hay. In fact, the total amount of plant residues returned to the soil in the Corn Belt is now twice as great as it was in 1950 as the result of high yields from optimum fertilization. Similar statements could likely be made about other regions if I were more familiar with them.

CONSERVATION OF ENERGY

The role of agricultural chemicals in energy use is widely misunderstood. Because large amounts of energy are consumed in producing them, it is often assumed they are energy inefficient. Inasmuch as that is the topic of another panelist, only a few comments are presented here.

For each kilocalorie of fossil energy consumed in manufacturing nitrogen fertilizer, at least 5 kilocalories in the form of additional grain can be produced when the nitrogen is properly applied for corn. In the process, inedible gasoline or diesel fuel is converted to food or feed.

Wise use of fertilizers and pesticides on the most favorable soils favors high yields and minimizes the need to attempt to farm soils that have serious limitations previously mentioned—drouthiness, wetness, stoniness, or unfavorable growing season. This dimension of energy efficiency is not recognized in a simple comparison of conventional farms and farms that use little or no chemicals.

The energy required to manufacture herbicides is about equivalent to the energy required for cultivation to obtain comparable weed control. Their ability to control weeds when and where it is impossible to cultivate is a bonus for herbicides. In practice, a combination of chemicals and tillage is often the most effective strategy to control weeds.

Dispelling some myths about chemicals.

Several widely accepted myths about agricultural chemicals are false. There is no such thing as a "chemical fix" of soils which implies that, once a farmer begins to use fertilizers, his soil is like a drug addict who needs his regular "fix." That is a figment of the imagination of some freelance writer.

There is at the present time no widespread buildup in soils of any toxic chemical used in commercial agriculture. Most modern pesticides are biodegradable within a few weeks, and nearly all within 1 or 2 years. The amount of persistent chlorinated hydrocarbons in the soil, which are widely used during—I should say were widely used—during the 1960's, peaked about 1970 and has declined to less than one-third.

The term "superpest" applied to insects that have developed resistance to a pesticide is a misnomer. It indicates a misunderstanding of the nature of the basis for resistance and how it comes about. Excessive or long-continued use of any insecticide reduces the number of susceptible individuals in the total population with the result that those individuals which are tolerant to the specific active ingredient—whether a natural or synthetic compound—multiply and fill the ecological niche of the original native strain. The result is a strain which is resistant to one specific chemical or mode of action, yet may be no more resistant than the original population to other methods of control.

Conventional farmers currently use large amounts of pesticides, and the belief is widespread that they depend almost entirely upon man-made chemicals for pest control. In fact, many major pests are currently controlled with little or no pesticides. Crop rotations, residue management, and tillage are widely used to control insects, diseases, and weeds. The major means of disease control in nearly all field crops are:

One. Breeding crop plants that have genetic resistance to certain disease, and

Two. Proper crop rotation.

Chemicals cannot be classified as safe or unsafe on the basis of their origin. Toxic and carcinogenic chemicals may be "natural" or "synthetic" or both.

Danger to humans and the environment from these chemicals is a function of their properties and their use rather than their origin. For example, botulin toxin and aflatoxin, natural substances produced by living bacterial and fungal organisms, and dioxin, a synthesized substance, are among the most toxic substances known. On the other hand, thousands of both "synthetic" and "natural" chemicals are so low in toxicity that no known hazard results from normal usage.

DEALING WITH RISK

In order for citizens to have relative peace of mind in the modern chemical age we shall have to dispel an unreasonable fear of chemicals and improve the knowledge and understanding of the term "risk."

To illustrate, if someone were to propose that one or more of the following chemicals—acetone, acetaldehyde, methylbutyrate, ethyl caproate, hexyl acetate, methanol, acrolein, crotonaldehyde—be added to fruit as a preservative, or to enhance flavor or color, public alarm and opposition could easily be generated. In fact, all of these are found naturally in ripe strawberries whether grown organically or conventionally. And they are, of course, harmful if ingested in excessive amounts. Perhaps this example conveys the message that many chemicals, even those with exotic names and with which most persons are unfamiliar, occur naturally and are not necessarily hazardous to health.

The use of agricultural chemicals to enhance food and fiber production entails some risks, but imaginative research and adequate testing followed by careful use can assure that the benefits far outweigh the risks.

Thank you.

Mr. JONES. Thank you, very much.

Our next witness is Dr. William Lockeretz, senior agricultural scientist at the Northeast Solar Energy Center. You may proceed.

STATEMENT OF DR. WILLIAM LOCKERETZ, SENIOR AGRICULTURAL SCIENTIST, NORTHEAST SOLAR ENERGY CENTER, CAMBRIDGE, MASS.

Dr. LOCKERETZ. Thank you, Mr. Chairman.

As I am sure you realize, a great many alternatives to current agricultural practices are being advanced in many quarters. These ideas reflect a growing interest in finding ways of preserving environmental quality as much as possible without jeopardizing the high productive efficiency of our agricultural system.

I would like to talk today about just one such approach, namely organic farming, which is probably the most talked about of these alternatives, as well as one of the most controversial.

One of the reasons for the controversy—but not the only one—is that the contribution of pesticides and fertilizers to our agricultural system is a very complex subject. Given the rather small amount of research effort that has been given to organic farming so far—at least as far as research conducted on real farms actually operated by organic methods, not just small experimental plots where the fertilizers and pesticides were left out—given the small amount of research on this topic, it is hardly surprising that the field has been left open to all kinds of wild and unscientific claims and counterclaims.

Indeed, one of the outstanding characteristics of so much of what has been written about organic farming—whether critical or supportive, whether by agricultural scientists or by amateurs—is the glaring lack of reliable data.

In the past few years, there has been at least a start made in filling in this gap. In the time available to me I will not attempt to cover all of these efforts. Rather, I want to discuss just one project, the first study in the United States of full scale, commercial farms operated entirely organically, without any herbicides, insecticides, or manufactured fertilizers. This project begin at Washington University, St. Louis, in 1974, and is about to conclude its fifth and final year.

Before I summarize the main points of this work, I would like to mention that from its inception it has been supported by the National Science Foundation. Washington University, which is not a member of the land grant college complex, would have found it difficult, if not impossible, to undertake an agricultural research project of this kind had it not been for the NSF–RANN program of research grants dating back to the early 1970's. Several of these grants, including ours, went to institutions interested in pursuing agricultural topics not being covered in the much larger research program of the USDA and the land grant college complex. I believe that the considerable amount of interest shown in our work indicates the value of maintaining diversity in the support of agricultural research. According to what several researchers have told me, this work has had a fair amount of impact on planning for their own work, something which could not have happened, at least not that far back, of the National

Science Foundation had not been in a position to fund at least a small amount of agricultural research. Naturally, I am very pleased that support of further research on organic farming is one of the elements in NSF's proposed program on appropriate technology, as described in a plan prepared for the Science and Technology Committee.

To come back to the Washington University study, it has had several components, since we have tried to examine organic farming from a range of viewpoints, including economics, use of fossil energy, social implications, effects on soil quality and erosion, and effects on crop quality. All of this work has involved working farms in the Corn Belt.

The details of the data we have obtained so far are given in several reports that have been published in the past few years, two of which I have attached to my statement. I have also attached a list of the publications on this project, and a more detailed account of its various components.

Let me, therefore, only touch on a few of the highlights.

Mr. JONES. Before you do, the attachments you referred to will be made a part of the record at this point.

[The documents referred to follow:]

Attachments

1. List of the components of the Washington University organic farming study.

2. List of publications of the Washington University organic farming study.

3. "Motivations and Practices of Organic Farmers," by Sarah Wernick and William Lockeretz. Reprinted from Compost Science, Vol. 18, No. 6 (Nov.-Dec., 1977), pp. 20-24.

4. "Field Crop Production on Organic Farms in the Midwest," by William Lockeretz, Georgia Shearer, Robert Klepper, and Susan Sweeney. Reprinted from Journal of Soil and Water Conservation, Vol. 33, No. 3 (May-June, 1978), pp. 130-134.

Attachment 1. List of components of the Washington University organic farm study.

Completed work (reported in the publications listed in attachment 2)

1. Survey of 363 organic farmers in the Corn Belt who operate at least 100 acres.

2. Study of attitudinal factors, motivations, and social relations of 174 commercial organic farmers.

3. Three-year analysis of economic performance and energy requirements of crop production on 14 pairs of organic and conventional crop-livestock farms in the Corn Belt.

4. Measurements of soil nutrient levels, organic matter content, and other soil characteristics of 30 pairs of organic and conventionally managed fields.

5. Measurements of yield and protein content of corn grown on 26 pairs of organic and conventionally managed fields, and on a smaller number of wheat and soybean fields. (Soybean and wheat data in a paper in preparation.)

6. Studies of certain disease problems, and of insect pests and predator populations on organic and conventionally managed corn fields. (Reported in papers in preparation.)

Work being Completed

1. Two-year analysis of production, energy requirements, and profitability of crop and livestock production on organic farms in the Corn Belt.

2. Studies of the nutritive value of grains produced on organic and conventional farms.

Attachment 2. List of publications of the Washington University organic farm study.

Journal Articles

Economic performance and energy intensiveness on organic and conventional farms in the Corn Belt: a preliminary comparison. R. Klepper, W. Lockeretz, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. American Journal of Agricultural Economics 59(1):1-12 (Feb., 1977).

Motivations and practices of organic farmers. W. Lockeretz and S. Wernick. Compost Science 18(6):20-24 (Nov.-Dec., 1977).

Economic and energy comparison of crop production on organic and conventional Corn Belt farms. W. Lockeretz, R. Klepper, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. In Agriculture and Energy, W. Lockeretz (ed.). New York: Academic Press, 1977, pp. 85-101.

Field crop production on organic farms in the Midwest. W. Lockeretz, G. Shearer, R. Klepper, and S. Sweeney. Journal of Soil and Water Conservation 33(3):130-134 (May-June, 1978).

Technical Reports

A Comparison of the Production, Economic Returns, and Energy Intensiveness of Corn Belt Farms that Do and Do Not Use Inorganic Fertilizers and Pesticides. W. Lockeretz, R. Klepper, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. Report CBNS-AE-4, July, 1975. (NTIS #PB247-756/0GI)

A Comparison of Organic and Conventional Farms in the Corn Belt. W. Lockeretz, R. Klepper, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. Report CBNS-AE-6, July, 1975. (NTIS #PB248-135/6GI)

Organic and Conventional Crop Production in the Corn Belt: A Comparison of Economic Performance and Energy Use for Selected Farms. W. Lockeretz, R. Klepper, B. Commoner, M. Gertler, S. Fast, and D. O'Leary. Report CBNS-AE-7, June, 1976. (NTIS #PB255-458/2GI)

Semi-Popular Articles

Can We Take the Chemicals Out of the Corn Belt? W. Lockeretz. Horticulture, September, 1977, pp. 14-18.

Farming without Chemicals. W. Lockeretz. Garden, November-December, 1978, pp. 24-27.

MOTIVATIONS AND PRACTICES OF ORGANIC FARMERS

Based upon this research survey, the decision to use organic methods does not necessarily imply an overall approach to farming that sets midwestern organic farmers apart in a fundamental way from the conventional farmers who comprise most of midwestern agriculture.

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PURPOSE

MODERN AGRICULTURAL PRACTICES developed at a time when energy and other natural resources were abundant and inexpensive. But since the energy crisis of 1973, there has been growing interest in ways to make agriculture less dependent on energy-intensive chemicals like nitrogen fertilizer and synthetic pesticides. Also, in recent years, adverse environmental effects of pesticide and fertilizer use have become matters of increasing concern. Consequently, in 1974 the Center for the Biology of Natural Systems began a study of organic farming to assess its potential as a resource-conserving and less environmentally damaging alternative to conventional agricultural practices.

The results of this study have been reported in detail elsewhere.[1, 2] In brief, the performance of a selected group of commercial scale crop-livestock Corn Belt organic farms was compared with that of a matched sample of conventional farms. The organic farms studied had somewhat lower yields than the conventional farms but these were offset by lower input costs. On balance, the organic group appeared to do about as well in terms of net income per acre, with a considerably lower use of fossil fuel.

This study confined itself to macro-level questions, i.e., the performance of individual farm enterprises. We cannot draw inferences concerning total production or food prices. Even so, the fact that individual large-scale organic farms can be economically competitive challenges the belief that present day organic farmers can perform no better than farmers of forty years ago, and that they have no relevance to modern day agriculture.* Organic farmers therefore present an interesting case of unconventional management. They have rejected modern fertilization and pest control methods, which are generally considered indispensable to modern agriculture. Yet at the same time they try—with reasonable success, apparently—to attain a level of production and profitability that enables them to survive in competition with farmers who are using all the modern farm inputs. But the differences between organic and conventional management are of more than just academic interest. Environmental and energy factors may cause more farmers to make greater use of some techniques that organic farmers (as well as many conventional farmers) are already using, such as rotating forage legumes like alfalfa with row crops, and recycling of livestock manures to cropland. In a sense, then, these "old-fashioned" techniques are becoming fashionably modern. It is therefore interesting to consider why organic farmers—who now are making considerable use of certain methods that many other farmers eventually might adopt to a more limited degree—have chosen this system, and how this decision was related to other aspects of their approach to farming. To explore this topic we have made a survey of operators of midwestern commercial-scale organic farms.

*Perhaps the best-known statement of this view was made by former Secretary of Agriculture Earl Butz: "Before we go back to an organic agriculture in this country, somebody must decide which 50 million Americans we are going to let starve or go hungry."[3] [*Emphasis added*]

METHODS

Since there is no census of organic farmers, it was not possible to construct a random sample of the population. Instead, we attempted to locate as many organic farmers as possible within a five-state (Missouri, Iowa, Illinois, Minnesota, and Nebraska) area.

One problem in selecting farms to study is that the term "organic farming" has no standard meaning. Therefore we generally relied upon farmers' self-definitions. However, we eliminated farmers who used inorganic nitrogen fertilizer, acidulated phosphate, or insecticides. We did not exclude farmers who use muriate of potash or who selectively use herbicides, although many organic farmers find these inputs unacceptable. Although our criteria were all negative (i.e., materials that a farmer may not use if we are to consider him organic) we know from other studies[1] that organic farmers, as defined here, tend to use certain positive practices to a greater degree than do conventional farmers. For example, they have a greater proportion of their cropland in rotation meadow, and less in row crops, compared to con-

ventional farms. Manuring practices are similar on organic and conventional crop-livestock farms, but a larger proportion of organic farms have livestock.*

We mailed a brief survey to organic farmers already known to us and asked that they send us the names of others they knew. We sent the same survey and request to the farmers whose names we received in the first and later waves of responses. In all, 1135 brief surveys were mailed; 685 responses were received (60 percent).

A total of 302 farmers (44 percent of respondents) met the following criteria for inclusion in this study: they had to raise field crops primarily, farm at least 100 acres, and use organic methods on more than half of the land they managed. Most of the respondents who did not meet these criteria were not organic, or only partly so. Others had retired, or ran vegetable and fruit farms. A longer, more detailed questionnaire about attitudes and practices was sent to 250 of these respondents, excluding 37 who indicated that they did not wish to participate in further studies, plus 15 who were used in other components of the project.

We got responses to the longer questionnaire from 174 farmers (70 percent). Because 40 percent of the farmers did not respond to the brief questionnaire, and 30 percent didn't respond to the longer one, we can't be confident that our respondents represent a cross-section of midwestern organic farmers.* Moreover, our method for finding farmers—which relies on their being known to other organic farmers—probably biases our sample in favor of those who belong to organic farming organizations or attend meetings of organic farmers. This issue is discussed later.

Respondents managed a median of 244 acres. Five-sixths managed all their land organically. Twenty-three of the respondents had always farmed organically. For the remainder, the median year of conversion to organic methods was 1970. About three-fifths of the farmers were between forty and sixty years of age, with approximately equal numbers above and below that range.

The questionnaire was designed to answer the following:

1) What were the motives and decision-making processes of the farmers who had converted to organic management?
2) What inputs did they use and which did they avoid?
3) Apart from their non-use of certain chemicals, to what extent were their equipment and practices modern?
4) What contact did they have with other farmers and with agricultural institutions, both conventional and organic?

FINDINGS

The Decison to Farm Organically

One hundred fifty-one respondents had converted from conventional to organic management. We questioned them about their motives for this change, the advisors they had consulted, and the time frame in which the decision had been made. All respondents, including the 23 who had always been organic, were asked to indicate advantages and disadvantages of organic farming.

Motives for conversion to organic methods

Motives for changing to organic management varied considerably, although the reasons given generally fell into three categories: specific problems with conventional farming, ideological misgivings about conventional farming, and contact with an individual or organization suggesting organic farming as an alternative. Table 1 summarizes the answers most frequently given.

TABLE 1. Reasons for Converting to Organic Farming

	% of Respondents Mentioning Reason
Specific Problems or Concerns	
Livestock health	32
Soil problems	30
Cost of chemicals	25
Chemicals not effective	23
Human health	22
At least one specific problem or concern	75
Ideological Concerns	
Dislike chemicals	24
Environmental concern	9
Religious concern	5
At least one ideological concern	34
Contact with Proponents	
Dealer for organic fertilizers and soil amendments	30
Farmer	14
Organization	8
At least one contact	48

Problems with conventional farming were mentioned by three-quarters of the farmers who formerly used conventional methods. About a third had been concerned about livestock health. Nearly as many were persuaded to convert by deteriorating soil quality. Several respondents wrote "The soil was dead."

A third of the farmers expressed some ideological criticism of chemicals; less than one-tenth cited environmental or religious objections. For example:

> "I feel that I would be violating the Fifth Commandment 'Thou shalt not kill' if I would continue to use chemical fertilizers and chemical pesticides. It would be an indirect method . . . of killing my fellow man by means of undernourishment and disease from poor quality food and chemical residues . . ."

Contact with a proponent of organic farming motivated half the respondents to consider a switch, with about one-third mentioning organic farming product salesmen. As will be discussed later, these salesmen play an important role in supporting organic farming. For the most part, the farmers were predisposed to consider organic farming before contact with salesmen.

The typical scenario included all three elements. A generally critical attitude towards chemical inputs was galvanized by some specific problem with their performance. Subsequent contact with organic farming enthusiasts further convinced the farmer of these drawbacks and suggested an alternative.

Advisors on adopting organic methods

Once seriously considering or-

92 percent of the 302 organic farmers identified through the brief survey described later have livestock. The corresponding figure for conventional farms in the same five states was 82 percent in 1969. The 1977 figure is lower if the trend from 1964 to 1969 has continued.*

However, among farmers who were eligible for receiving the second questionnaire, the response rate for the brief survey was well above the overall rate of 60%. As needed, we sent the brief survey a second or third time to those who didn't respond. Of those responding to first, second, and third mailings, the proportion meeting our eligibility criteria were 52%, 36%, and 16% respectively. (This declining proportion is to be expected, since persons for whom the survey was not appropriate—e.g., non-organic farmers—could be expected to be less willing to reply.) We can assume that of the 450 people who didn't respond even after three mailings, less than 16% would meet our criteria. Under this assumption, we conclude at most 72 otherwise eligible farmers failed to respond to the first survey, so that our actual response rate among the eligible group was at least 81% (302/373).

ganic farming, all those who formerly farmed conventionally sought some outside advice and assistance. As Table 2 shows, the organic farming product salesman was the most significant change agent. In contrast, few of these farmers had gone to more conventional sources of information: only five farmers had consulted the Soil Conservation Service (SCS) and just two talked with Extension agents. Marginal comments indicated that at least some of the respondents believe that the Extension Service and even the SCS are hostile towards organic farming and are inaccurate sources of information about it. (For example, one respondent wrote in, "They don't want to know about it.")

TABLE 2. Sources of Advice on Decision to Adopt Organic Methods

	% Who Consulted Indicated Source
Salesman for organic farming products	84
Organic farmer	72
Books or articles	61
Soil Conservation Service	3
Extension Service	1

Timing of conversion to organic methods

Of organic farmers who formerly used chemicals, four-fifths converted to organic methods within the past decade, with the median date being 1970. Virtually all of these farmers began using organic methods the same year that they first considered the change, and most converted all their land by the first or second year.

Eighteen percent indicated that their net income dropped temporarily after they began farming organically. Sixty percent reported no drop, while the remaining 22 percent were uncertain, either because their records were incomplete, or because losses appeared to have been caused by drought or other adverse farming conditions unrelated to the conversion.

Perceived advantages and disadvantages of organic farming

The farmers studied were highly committed to organic farming. Of the 32 who had not converted all their land, 16 planned to do so, while 10 of the remaining 16 could not convert rented land because of the owners' objections. Obviously, a decision to become organic can be readily reversed. Twelve percent had considered (then decided against) returning to conventional methods, most frequently because of low yields or weed problems.

The fact that most of these farmers have never even considered giving up organic methods and that most are or will be managing all of their land organically indicates a strong commitment to this way of farming. Therefore, it is not surprising that these respondents reported considerably more advantages than disadvantages to organic farming. When presented with lists of both, a mean of 13.3 advantages were checked, but only 2.8 disadvantages. Tables 3 and 4 show the advantages and disadvantages they considered most important.

TABLE 3. Perceived Advantages of Organic Farming

	% Indicating That This Was One of the Three Most Important Advantages
Healthier for the farmer and his family	54
Healthier for livestock	48
More wholesome, in harmony with nature	28
Better for the soil	26
Better for the environment	25
Closer to the way of farming in the Bible	20
Lower production costs	18
Higher net income	12
Higher quality product	11
Tillage easier	10
Yields suffer less under adverse conditions	9
Consumes less energy	8
Less dependence on outside suppliers	7
Fewer insects	6
Crop dries better	4
Fewer weeds	4
Total hours of labor less	1
Yields higher	1
Organic products command a premium price	1
Work more evenly spread through the crop year	0

The safety of organic farming, for both livestock and farmer, is its most significant advantage in the opinion of these respondents. Of the four most frequently mentioned disadvantages, only one—weed problems—is agricultural. The other three problems—finding suitable markets and up-to-date information, and the negative attitudes of others—reflect the social context of organic farming. These difficulties suggest some of the reasons they have turned to organic farming institutions, a subject considered later in the paper.

TABLE 4. Perceived Disadvantages of Organic Farming

	% Indicating That This Was One of the Three Most Important Disadvantages
Difficult to find a market for organic products	22
Weed problems worse	16
Fewer up-to-date sources of information	16
People look down on organic farmers	14
Difficult to get enough manure	10
Greater expertise needed	9
More labor required	8
Can't have all land in cash crops	5
Harder to get loans	5
Lower yields	4
Lower profits	2
Pests worse	2
Organic farming requires livestock	1
No time to take vacation	0
No disadvantages	13

Check Acceptability of Inputs Used

Although small-scale certification programs do exist, there is no universally recognized standard of organic farming. Therefore, we sought to determine the degree of consensus about the acceptability of certain inputs in organic crop and livestock operations.

We asked respondents whether they had used, might use, or would not use certain inputs on their organic cropland. The results are presented in Table 5.

TABLE 5. Acceptability of Selected Inputs for Organic Cropland

Substance	% of Respondents Who Would Never Use Indicated Substance*
Anhydrous ammonia	93
Insecticides	85
Herbicides	75
Urea	70
Super phosphate	60
Grain silage preservative	45
Sewage sludge	37
Potash	27
Rock phosphate	21
Trace minerals	8

*It is possible that some farmers did not understand the question and included inputs on non-organic land they manage, or referred to their practices before conversion to organic methods. When it was clear from marginal notes that such misunderstandings had occurred, the respondent was eliminated from the tally unless the answer could be extracted from the comments.

Chemical fertilizers, insecticides, and herbicides—substances used by the vast majority of conventional farmers—are, of course, unacceptable to most organic farmers we surveyed. Farmers who had more contact with organic farming institutions—dealers, organizations, or publications—more frequently in-

dicated that they would never use these inputs.

One hundred fifty-four (89 percent) of the farmers raised livestock for sale. All but 10 farmers considered their livestock organic, but only 27 percent of the livestock producers marketed any of their livestock through organic channels. However, there are few clear differences between the substances that farmers feed to livestock marketed through organic and conventional channels, as shown in Table 6.

TABLE 6. Substances Fed to Livestock by Organic Farmers (N = 131) *

Substance	% Feeding Indicated Material: Not Considered Organic by Producer (N = 10)	Organic, Marketed Through Conventional Channels (N = 57)	Organic, Marketed as Organic (N = 34)
Own chemically grown crops or feeds	30	7	0
Purchased chemically grown crops or feeds	20	43	21
Mineral supplements	90	87	91
Vitamins	50	58	59
Hormones	10	2	3
Antibiotics	3	11	3

* 20 farmers sold market livestock, 13 did not provide adequate answers to questions about either markets or substances

In contrast to the situation for organic crops, there appears to be no generally agreed-upon definition of organic practices for livestock. This is consistent with our finding that, unlike with crops, for livestock there was no relationship between management practices and contact with organic farming institutions.

Modern Equipment and Practices

This study focused on farmers who had decided, for a variety of reasons, to reject certain modern farming inputs. It is of interest to see if this decision was general or selective. Data on their use of other practices and equipment are summarized in Table 7.

TABLE 7. Equipment and Practices

	% Who Have Adopted Practice or Who Have Indicated Equipment
Practice	
Soil testing	73
Nutritional analysis of crop	42
Plant test plots to compare materials or practices	40
Keep records of yields	
For at least some of farm	41
For entire farm	12
Have some registered livestock	10
Equipment	
Silos	
Glass-steel	15
Bunker or trench	15
Upright concrete	33
Hay handling system used:	
Big bales	12
Small bales	71
Tractors	
At least one 50 hp or more	82
At least one 100 hp or more	33

While there was considerable variation in this regard, the majority of the farmers had adopted at least some modern equipment and practices.

RELATIONSHIP WITH FARMERS AND AGRICULTURAL INSTITUTIONS

Relations with conventional farmers

Two-fifths of the farmers reported as a disadvantage of organic farming that others tend to look down upon this management system. As mentioned earlier, 14 percent considered this one of the three leading disadvantages. Nevertheless, over four-fifths said that they did discuss organic methods with conventional neighbors. According to the respondents, most neighbors were indifferent or skeptically interested in organic methods; only 14 percent said that most of their neighbors were hostile.

tween organic and conventional farmers can be strained by problems arising from differences in management. On the one hand, organic farmers can be plagued by drifting chemical sprays or chemicals in runoff water. On the other hand, organic farmers may be viewed as sources of weed or insect pests. We asked respondents to tell us (in a necessarily one-sided report) if they had experienced such difficulties. Nearly half (46 percent) said that they had had some problem from a conventional neighbor, usually drifting spray. Those who marketed crops through organic channels were more likely to report this. Only 5 percent reported complaints against themselves, mostly about weeds.

The landlord's attitude is important to farmers who wish to manage rented land organically. Fifty-nine farmers rented land, about half of them from relatives. As reported above, 10 respondents who rented land were unable to complete conversion to organic methods because of the insistence of the owner that they farm conventionally. However, nearly half of the owners, most often relatives, actually favored organic farming.

Contact with conventional farming institutions

Almost half (47 percent) of the respondents had had some formal conventional agricultural training, usually through high school courses (33 percent), GI farm training (16 percent), or college courses (9 percent). Moreover, they reported about as much contact with conventional as with organic farming institutions; these farmers are not isolated as individuals or as a group. Table 8 gives data on three different kinds of contact with farming institutions: magazines, organizations and meetings. The more institutional contact a farmer had, the more likely he was to be using modern equipment and practices. A few of the farmers stated in marginal comments that they read conventional magazines for an unconventional reason: "to see what the enemy is up to."

TABLE 8. Contact with Agricultural Institutions

Form of Contact	Organically Oriented	Conventionally Oriented
Mean number of magazines read	1.7	2.4
Mean number of memberships in organizations	.8	.3
Mean number of meetings attended in 1976	1.1	1.2

Relationship with organic farming institutions

Although contact with organic agricultural institutions did not preclude contact with conventional farming institutions, it clearly played an important role in supporting these farmers' activities. Table 8 has already shown the degree of contact that respondents had with other organic farmers through magazines, organizations and meetings. Four-fifths read at least one organic farming magazine; half belonged to at least one organic farming organization; and three-fourths had attended at least one meeting related to organic farming in 1976.*

Since our method of finding respondents depended on their being known to other organic farmers, our sample may have an unrepresentatively large proportion of farmers who are highly involved with organic farming institutions. To explore this point, we tallied the number of times that each respondent's name was referred to us by other respondents to the first questionnaire. This was significantly related to degree of contact with organic institutions. Since we can assume that the organic farmers who were never referred at all are likely to be similar to those referred only one or two times, we conclude that the data are indeed biased in the anticipated direction. Comparable calculations showed that our sample is also biased towards farmers who follow commercial organic programs and who have changed to organic methods relatively recently.

We have already seen that commercial dealers for organic products, such as fertilizers and soil amendments, are a particularly significant ch ge agent. After a farmer adopts or anic methods, a dealer plays an important role as a source of inputs, advice, and encouragement. Just over half of the respondents had attended a farmer-dealer meeting sponsored by an organic product, and about one-third belonged to a particular organization of farmers who use one of these products. As Table 9 shows, nine-tenths of the farmers were using some purchased organic materials in their farming. Many companies supply not only their product, but also a complete management program, including suggested crop rotations, tillage methods, etc. About half of the respondents were following such a program without modification.

TABLE 9. Use of Commercial Organic Products and Programs

Use of Commercial Organic Product	% of Respondents
No use	11
Some use	89
Product only	19
Product and modified version of program	19
ct and full program	51

There was a significant relationship between the year a farmer adopted organic methods and his involvement with a commercial product: those who changed recently are more likely to follow a complete commercial program. Farmers who have always farmed organically are more likely to use no product at all, or simply to use a product without the rest of the program. Moreover, these farmers had significantly fewer contacts of any kind with organic farming institutions compared to farmers who converted.

It was stated earlier that the disadvantage of organic farming most cited by respondents was difficulty in finding an organic market for their products. Indeed, only a minority (33 percent) use special organic marketing channels at all, and just a third of these (12 percent of the sample) are able to sell at least half of their products this way. Of those who use special channels at all, five-sixths receive a premium price.

Because organic products command a premium on the retail market, it is sometimes assumed that organic farmers routinely receive higher-than-market prices for their goods, which is considered essential for them to survive economically. Actually, only 10 percent of the farmers were receiving premium prices on at least half of their crops or half of their livestock, and 18 percent were getting premiums on occasional sales (usually to individuals). It was clear that many more farmers would have used special channels had they been available.

Farmers who charged a premium stated that the higher price was not the result of higher production costs or extra expenses in marketing the product, such as special bagging. Rather, about four-fifths of these farmers said that the higher price was charged because of the superior quality of the product, and because customers were willing to pay more for organic merchandise. Given the farmers' readiness to charge higher prices, and the customers' willingness to pay them, it is reasonable to expect further development of special marketing channels, possibly through existing organic organizations. Although few of these organizations presently offer such a service directly, contact with organic farming institutions was significantly associated with a farmer's ability to locate an organic market for his output.

Organic farming institutions also compensate for two other difficulties reported by the respondents: lack of up-to-date information and the negative attitudes of others. These institutions offer technical advice and interpersonal support to the farmer whose use of organic methods precludes his seeking such help elsewhere.

DISCUSSION

Many people apparently have an image of organic farmers that is very different from what emerges from this study, judging by the correspondence we have received and the questions we have been asking in connection with our larger study of organic farming. It is sometimes assumed that organic farmers usually use animal power for tillage, that they mainly raise fruits, vegetables and specialty crops specifically for the organic or natural foods market, and that they tend to operate marginal, subsistence enterprises. It is also thought by some people that organic farmers represent a "back-to-the-land" movement that is an alternative to prevailing life styles and economic institutions.

While some organic farmers do fit this image, the overall picture of those we surveyed is very different. They raise field crops and livestock on a commercial scale, using mechanized methods. Most of their output is sold through conventional channels. Most farmed by conventional methods before changing to organic methods. Besides being involved with organic farming institutions, they tend also to maintain contact with conventional agricultural institutions, such as magazines and organizations. Their reasons for choosing organic methods generally were practical, that is, related to specific problems with conventional farming, such as possible adverse health effects of pesticides. Ideological or philosophical considerations also played a role, but to a lesser degree. In summary, it appears that for the type of organic farmer covered by our survey, choosing to use organic methods does not necessarily imply an overall approach to farming that sets organic farmers apart in a fundamental way from the conventional farmers who comprise most of midwestern agriculture.

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crop production
ganic farms
Midwest

:KERETZ, GEORGIA SHEARER,
PPER, and SUSAN SWEENEY

–We compared the economic performance of 14 organic farms ntional farms in the Midwest from 1974 to 1976. The market s produced per hectare of cropland averaged 11 percent less on rms, although net income per hectare was the same. The organic 0 percent less fossil energy to produce crops. Crop rotations on rms reduced soil loss by one-third compared with the soil loss on farms. The organic carbon content in organic fields was higher conventional fields by a small but statistically significant amount. yields in the organic fields were 3 percent lower than in the conds, but this difference was not statistically significant.

rganic fertilizers and syn- sticides generally is con- of the important factors to the increase in mid- cultural production since II. Recent developments attention to some possible sequences of the region's on these materials, how- pated increases in natural is well as dwindling sup- ighted by the shortages ed during the winter of could have a serious im- nitrogen fertilizer indus- ises natural gas as a feed- Use of certain pesticides rohibited or restricted for ns, an action that is being for more such chemicals. also growing over water oblems created by the loss nutrients in runoff water ching (3).

a reduction in agricultural se could produce several benefits, providing such a could be achieved without reducing food supplies or increasing production costs. The potential benefits have stimulated research on biological pest control, improved methods for storing and applying manure and other organic wastes, and enhancement of nitrogen fixation. Such techniques could reduce the need for certain agricultural chemicals. However, a small group of farmers who practice what is generally called organic farming have attained an even greater reduction in chemical intensiveness.

The term "organic farming" does not have a universally agreed upon meaning. We use it here to denote farming without synthetic herbicides and insecticides and without most modern fertilizers, including ammonia and nitrogen fertilizers derived from it, acidulated phosphates, and muriate of potash. Studying the performance of organic farms, because they are at one extreme on the spectrum of chemical intensiveness, can provide information on the practicality of reducing pesticides and chemical fertilizer use.

The existence and economic survival of full-sized, commercial organic farms surprises many people. These people assume that fertilizers and pesticides play a key role in modern agricultural production. High yields per unit of land are possible without these materials, at least on a small scale, if the operator is willing to use unprofitable alternatives, such as weeding and mulching with large amounts of hand labor. The farms we studied, which are at least 71 hectares (175 acres) each, are run as business enterprises by owner-operators. Labor is provided by family members and in some cases a moderate amount of hired help.

Although organic farmers do not use modern fertilizers and pesticides, they are not farming the same way farmers did before the introduction of chemicals. Many techniques they use are new. These include improved cultivation and tillage implements; new crop varieties; large tractors, in contrast to the much smaller tractors or draft animals; and modern harvesting equipment, such as corn combines, forage choppers, hay mower-conditioners, and big hay balers. Consequently, we cannot predict the performance of modern organic farms simply on the basis of yields obtained three decades ago or from older historical plots.

Our study was the first farm-scale study of modern commercial organic farming in the United States. The study was not designed to determine what would happen if all farmers adopted organic methods because a major shift to organic methods in the foreseeable future does not seem probable. Nevertheless, if organic farms are reasonably successful, this could have significant implications for other farmers interested in reducing fertilizer and pesticide use.

Economic Analysis

Scope and Methods

We examined crop yields and production costs on 14 organic farms and 14 conventional farms. The commercial, crop-livestock organic farms were located in eastern Nebraska, southern Minnesota, Iowa, Illinois, and northern Missouri. Each had been operated organically at least since 1971, except for one on which herbicides were used and another on which muriate of potash was used in 1976. Mean size of the farms was 172 hectares (425 acres), of which 101 hectars (59%) was cropland. The remainder was primarily permanent pasture, along with woodlots, building sites, and feedlots.

We matched each organic farm to a nearby crop-livestock farm on which conventional fertilizers and pesticides were used. The conventional farmers were identified as "top management" farmers by county-level personnel with the Agricultural Stabilization and

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Conservation Service and the Soil Conservation Service. Soils on the paired farms were in the same soil association and of about equal productivity. Mean size of the conventional farms was 194 hectares (480 acres), of which 141 hectares (73%) was cropland.

Crop production on farms in both groups was fully mechanized. For example, median tractor size was 89 and 94 horsepower for the organic and conventional farms, respectively. Both groups raised only field crops, primarily corn, soybeans, hay, wheat and oats. There were no specialty, vegetable, or fruit crops.

We collected data from both groups by interviewing each farmer the first year and by mail questionnaires in 1975 and 1976. Details on the methods used to collect and analyze the data, with results for 1974 and 1975, are provided elsewhere (4, 5).

We studied only the crop production component of each farm, although each farm also had one or more kinds of livestock. Our economic analysis covered operating expenses for crop production only. We excluded fixed or overhead costs. Because the two groups follow somewhat different rotations, we averaged energy use and economic performance over all cropland on each farm rather than comparing individual crops in the two groups. Used here, the term "cropland" includes not only land in row crops and small grains, but rotation hay and pasture as well. It does not include permanent pasture. We considered soil-improving green manure crops as cropland. There were no cases of land devoted to green manure crops for an entire growing season. The practice closest to this involved turning under what would have been the last cutting of hay. This practice was not common, however. When it was done, we included this land in the denominator when computing income per hectare. We also included the associated costs but credited no income for the unharvested crop.

Production practices varied considerably within both the organic and conventional groups. The labels "organic" and "conventional" are not intended to imply that our samples were selected from two homogeneous populations. The 14 pairs of farms should be regarded as case studies, each comprising a comparison of a particular organic farm and a particular conventional farm. The data should not be extrapolated to all conventional and organic farms. This is why we have not given any tests of the statistical significance of such an extrapolation.

Production Costs and Returns

Table 1 shows the value of crops produced per hectare of cropland for the crop years 1974, 1975, and 1976. We used statewide seasonal average crop prices in the calculations, regardless of whether the crops were sold or consumed by livestock on the same farm. When the organic farmer marketed crops through special channels, he was not credited with any premium he may have received. On the average, the market value of crops produced on the organic farms was 11 percent lower per hectare of cropland than the value of crops produced on conventional farms. This comparison reflects differences in yield and in the proportion of cropland in each crop.

We also calculated crop production expenses using statewide average prices (Table 1). This calculation included seed; fuel, lubrication, and labor for field operations (including manure spreading); grain drying; organic and conventional fertilizers; soil amendments; herbicides; and insecticides. The cost of manuring reflected application costs only because no farmers in our study hauled manure from off-farm sources. Fertilizers and pesticides as well as differences in crop mix accounted for most of the higher costs in the conventional group. Because both groups of farms were fully mechanized, labor requirements were relatively low—about 20 hours and 18 hours per $1,000 of production for the organic and conventional groups, respectively (4).

The difference between value of production and operating expenses, denoted here as returns to crop production, is a partial measure of the relative profitability of the two groups of farms. On the average, this net return was equal for the two groups, although individual farms varied considerably (Table 1).

Crop Yields

Table 2 shows the mean grain yields reported by farmers in both groups. We also compared each group's yield to the means of countywide yields for the same counties in the same years. For the four crops shown, the conventional group produced higher mean yields than did all farmers in the same counties. In contrast, the organic farmers had lower corn and wheat yields than did all farmers in the same counties, although their oat and soybean yields were higher. The percentage of individual cases in which conventional farmers had higher yields than the county average ranged from 56 percent for corn to 80 percent for soybeans. This suggests that we obtained an above-average group of conventional farmers to compare with the organic group.

The all-farms data in table 2 reflect the drought that affected portions of the region during each of the three study years. In 1973 the average corn yield for all farmers in the same counties was 6.40 metric tons per hectare (102 bu. a), 31 percent higher than the 1974-1976 average.

Resource Analysis

We also compared energy consumption, land use, and soil loss on these same 14 pairs of farms.

Energy Intensiveness

We computed the fossil energy consumption for crop production, includ-

Table 1. Mean economic performance of 14 organic farms and 14 conventional farms, 1974-1976 (interquartile range in parentheses).

Year	Value of Crops Produced		Operating Expenses		Net Returns	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
	$/ha					
1974	393 (348-469)	426 (346-501)	69 (49-84)	113 (96-131)	324 (264-380)	314 (249-383)
1975	417 (326-479)	478 (422-479)	84 (72-101)	133 (104-148)	333 (269-385)	346 (294-353)
1976	427 (371-534)	482 (407-524)	91 (70-109)	150 (128-164)	336 (282-427)	333 (270-377)
Average	412 (329-484)	462 (400-494)	81 (67-91)	131 (109-141)	331 (262-383)	331 (287-363)

ing equipment operation, corn drying, manure spreading, and the manufacture of fertilizers and pesticides. We excluded the manufacture of capital equipment.

In terms of fossil energy consumed per dollar of crop produced, the organic group used an average of 60 percent less energy—1,700 calories per dollar for the organic group versus 4,300 calories per dollar for the conventional group. This difference resulted mainly from the heavy use of fertilizers, especially nitrogen, by the conventional group, as well as from differences in the proportion of cropland in each crop.

Soil Loss

Because of different rotations, the organic group had relatively less land in row crops and more land in rotation hay and pasture than the conventional group (Table 3). Since row crops are more susceptible to erosion and meadow in rotation reduces erosion from subsequent row crops, we expected the two groups to differ in the rate of soil loss (*8*).

We estimated how the differences in rotations affected rates of soil loss through rill and sheet erosion on the two groups of farms by computing C, the cropping factor, in the universal soil loss equation (*8*). We calculated C as an average over all the cropland on each farm, assuming conventional tillage in all cases.

The mean value of C was 0.21 for the organic group and 0.32 for the conventional group. For a given set of physical conditions, therefore, the crop rotations on the organic farms resulted in an average of 34 percent less soil loss. The conventional farm had a higher C value than its matched organic farm in all except one pair. The higher C values on the conventional farms reflect differences in rotations, not the use or nonuse of chemicals.

Differences in tillage practices between the two groups would magnify the difference in erosion rates. For example, only 1 organic farmer of the 10 who raised soybeans after corn used the moldboard plow. Six of 11 conventional farmers plowed their corn ground. None of the 11 organic farmers who raised corn after soybeans used the moldboard, but 3 of 11 conventional farmers plowed their soybean ground. Most organic farmers used a chisel plow or disc, which buries less residue than the moldboard and, therefore, results in less erosion.

Land Use and Land Quality

As noted, the conventional group of farms had a larger fraction of land in crops. For the eight pairs of farms with soil maps available, an average of 78 percent of the Class I, II, III, and IV land (land suitable for cropping with varying limitations) was used as cropland on the organic farms, compared with an average of 85 percent on the conventional farms. How the farmer chose to use his land accounted for slightly less than half the difference in the ratio of cropland to farm size within these eight pairs. The remaining difference arose because the organic farms had a higher proportion of land suitable only for permanent pasture (Classes V, VI, and VII) and used the land for this purpose.

Consequently, our earlier economic calculations should be modified to include the additional land that organic farmers would crop if they used land in the same way as conventional farmers. At one extreme we can credit the organic farmers with no income from this land, but merely increase the cropland base by the appropriate factor (85%/78%). This lowers their production and return per hectare by 9 percent. However, they actually realized the grazing value from this land. At the other extreme, therefore, we can assume that production from this land, when grazed as permanent pasture, is the same as from their rotation hay and pasture. Crediting them with the corresponding income reduces their net return per hectare by 3 percent.

We also computed the average "corn yield potential under high management" (*2, 7*) for all cropland on each farm. For the eight organic farms this varied from 4.51 to 7.03 metric tons per hectare (72-112 bu/a), with a mean of 5.76 (92). For the matched conventional farms, the range was 4.58 to 6.96 metric tons per hectare (73-111 bu/a), with a mean of 5.63 (90). Thus, the average productivity potential of the soils was within 2 percent.

As another measure of relative land quality, we asked at least two county agricultural officials to estimate the rental value of the cropland on each farm in 1975. The averages were $168 and $163 per hectare for the organic and conventional groups, respectively, a difference of 3 percent.

Table 2. Mean yields on 14 organic and 14 conventional farms and all farms in the same counties, 1974-1976[a] (number of crop-years of data shown in parentheses).

	Mean Yield			
	Organic		*Conventional*	
Crop	*Sample*	*All Farms[b]*	*Sample*	*All Farms[b]*
	Mt/ha			
Corn	4.83 (n=37)	5.08	5.20 (n=41)	4.89
Soybeans	2.02 (n=36)	1.81	2.15 (n=35)	1.81
Wheat	1.95 (n=24)	2.28	2.53 (n=17)	2.28
Oats	2.18 (n=26)	1.97	2.22 (n=30)	2.08

[a]1 metric t/ha = 15.9 bu/a for corn, 14.9 bu/a for soybeans and wheat, and 27.9 bu/a for oats.

[b]For each sample, this column shows the average of county yields for the county-year combination in which there was a farmer in that sample who raised the indicated crop.

Soil Organic Carbon

The different production practices on the two groups of farms may affect soil properties, especially soil organic matter. To examine this we took soil samples from 35 pairs of farms in the same five-state region (not necessarily the same farms included in our economic study). The organic farms had been managed organically for nine years (median) prior to sampling. The median distance between the sampled areas in a pair was .4 kilometer (.25 mi.). We took five soil samples from the same soil type and following the same crop on both fields within a given pair. We analyzed these samples from each field for organic carbon content by wet oxidation with $K_2Cr_2O_7$ (*6*). Each sample consisted of 20 or 30 cores, each 15 x 2 centimeters (6 x .8 in.).

Organic carbon content in organic fields averaged 2.35 percent versus 2.21 percent in conventional fields. By the Wilcoxon one-sample test on the within-pair differences (used because these differences were not normally distributed), this average difference proved statistically significant at the 95 percent level of probability. In 23 of the 35 pairs the organic field

had the higher organic carbon content. Seventeen of these 23 differences were significant at the 98 percent level of probability. Of the 12 cases in which the organic carbon content was higher in the conventional field, only 5 were statistically significant at the 98 percent level. In some of these cases differences could arise from the intrinsic variability of a soil type rather than differences in management. However, this random variation cannot account for the overall difference between the two groups, which was statistically significant. There was a high correlation ($r = .89$; $P > 99\%$) between the organic and conventional fields in a pair. We expected this because the fields in a pair had the same soil type and were near each other.

Corn Yield Measurements

We measured corn yields on 22 of the 33 pairs of fields involved in the organic carbon test—4, 7, and 11 pairs in 1975, 1976, and 1977, respectively. The median distance between fields within a pair was .2 kilometer (.13 mi.). The two farmers in each pair used the same corn variety and planted as close to the same date as possible. (Organic farmers planted two days later on the average.) In all respects the farmers followed their ordinary practices, including their usual crop rotations. On the organic fields the distribution of previous crops was soybeans, 10; corn, 6; forage legumes, 5; and wheat, 1. On the conventional fields, the distribution was soybeans, 7; corn, 14; forage legumes, 0; and wheat, 1. Average fertilization rate on the conventional fields was 131, 29, and 52 kilograms per hectare (116, 26, and 46 lb/a) of N, P, and K, respectively. All conventional fields were treated with herbicides, and half received an insecticide application. We hand-harvested 6 plots (4.6 row-meters each) per field in 1975 and 15 plots (3.0 row-meters) per field in 1976 and 1977. Within a given pair, all plots on both fields had the same soil type.

The mean measured yield was 6.41 metric tons per hectare (102 bu/a) on the organic fields (range: 3.45-7.78 t/ha), which was 3 percent lower than the mean of 6.62 metric tons per hectare (106 bu/a) on the conventional fields (range: 0.50-11.32 t/ha). This difference was not statistically significant. The correlation between the yields on the conventional and organic fields ($r = .80$; $P > 99\%$) reflected the fact that fields within a pair were matched by soil type, location, variety, and planting date.

Table 3. Mean proportion of cropland in various crops on 14 organic and 14 conventional farms, 1974-1976.

	Percentage of Cropland in Crop	
Crop[a]	*Organic*	*Conventional*
Corn for grain	24	37
Corn for silage	8	6
Soybeans	19	29
Wheat	8	6
Oats	11	5
Rotation hay and rotation pasture[b]	28	15
Sorghum	1	3

[a]Crops not shown are rye, buckwheat, and barley, which account for less than 1 percent each.

[b]Established stands only. New seedings with nurse crop counted under the nurse crop (usually oats).

These data were consistent with the conclusion we reached earlier (Table 2) using farmers' reported yields. From the farmers' reports, the organic yields were 7 percent lower on the average. From our own measurements they were 3 percent lower. Obviously, we would not expect perfect agreement because different farms were involved, except for five organic farms that were in both the field experiments and the economic study. On those five fields the mean measured yield was 5.08 metric tons per hectare (81 bu/a) after being adjusted downward by an assumed 5 percent harvest loss to convert from hand-picked to machine-harvested yield. By comparison, for all their corn fields, these five organic farmers reported a mean yield of 4.94 metric tons per hectare (79 bu/a), which tends to support the validity of relying on farmers' reported yields.

Limitations of the Work

There are several possible sources of error in our work. The samples in the economic and resource study were relatively small and only roughly matched. To the extent that we have measures of comparative land quality (corn yield potential and estimated rental value) the two groups are about equal, but these measures are very incomplete. We have no measure of the managerial competence of the organic farmers. About the conventional farmers in the economic study we can say only that they were recommended as top management operators by county agricultural officials and that their yields, on the average, were higher than those of other farmers in the same counties.

We selected the organic farm sample in an ad hoc way, essentially by word of mouth, because no listing of the organic farm population was available when the study began. We relied on farmers' reports of yields, although our own measurements tended to support the validity of this approach.

Our study compared only the crop production enterprises on each farm. A complete analysis would cover all the land on a farm, including permanent pasture. Therefore, our data on production and income per hectare of cropland constitute only a partial measure of the productivity and profitability of these farms.

The limits of the data's applicability should be stressed. The data cannot be used to compare organic and conventional practices on Midwest cash grain farms or on any farms in other parts of the country. We obtained our results during three years of relatively unfavorable conditions. They will not necessarily be applicable under more favorable conditions. Also, organic farms constitute a small minority of midwestern farms. Our results are not intended to predict what might be expected if the proportion of organic farms increased. Pesticide-using neighbors may be helping organic farmers control pests, although they may also be reducing the populations of beneficial species that control pests. Also, except for nitrogen, which can be provided through nitrogen-fixing crops, not all farms could supply their requirements for plant nutrients entirely through livestock manure and other farm-generated materials because nutrients must leave the farm either as livestock or as crops for human consumption.

Some Concluding Thoughts

Recognizing these limitations and possible errors in our work, we still can state that in comparison to conventional farms the organic farms we studied performed surprisingly well in terms of income and production costs. Moreover, organic methods ap-

peared to offer considerable benefits in the form of reduced dependence on purchased inputs and external energy sup s, reduced soil loss, and increased soil organic matter. From the national viewpoint, the lower corn production on organic farms may be advantageous or disadvantageous, depending on whether the surplus of corn that led to the feed grain set-aside program in 1977 continues in the future.

A major conversion to organic methods hardly seems realistic for American agriculture. However, the likelihood of aggravated energy problems and stricter environmental regulations for agriculture in the future will make it increasingly desirable to have available practical alternatives that depend less on intensive chemical use. Organic farming is just one such possibility. There are many other farming systems that represent compromises between organic farming and prevailing practices. The fact that elimination of conventional fertilizers and pesticides from some farms does not automatically result in drastic consequences suggests that a considerable reduction in mical use on more farms may be realistically possible.

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Dr. LOCKERETZ. First, a bit of background on the organic farmers we studied.

Although this may come as something of a surprise, we have found that about 85 percent of the operators of commercial grain-livestock farms in the Corn Belt once used conventional chemicals. They chose to give them up for various reasons, such as concern over their own health and that of their families, concern over the effects of toxic chemicals on their livestock, and concern over effects on soil quality.

But when they gave up these materials, they did not abandon modern, scientific agriculture. They still use up-to-date machinery for tillage, planting, and harvesting. Moreover, they still sell most of their production through conventional channels, and receive only the prevailing market price.

In short, the organic farmers we studied have little in common with the stereotype of a "back to the land" homesteader who is motivated primarily by some far out metaphysical vision, and who sells at rip off prices whatever surplus he manages to produce with a couple of horses on a few acres.

What about corn yields?

Corn is the crop that recieves the heaviest applications of chemicals in the Corn Belt. About 96 percent is treated with herbicides, and about 98 percent with inorganic fertilizers.

In fact, a greater quantity of nitrogen fertilizer is used on corn than on any other crop in the country. Nevertheless, we found that organic farmers had corn yields that averaged only about 9 percent below those of their conventional neighbors. Under highly favorable growing conditions, when corn can benefit from fertilizer applications, the conventional farmers did considerably better. But under drought, which was a serious problem in parts of the region during the mid-1970's, organic farmers seemed to do about as well as, if not better than, their conventional counterparts.

As to crop production economics, our study found that organic farms produced about 10 percent less gross market value per acre of cropland. However, their expenses also were lower, and in terms of net returns, the two groups appeared to be roughly comparable.

From the viewpoint of the overall agricultural economy, it is relevant that part of the reason that gross production is lower on organic farms is that they have less of their land in corn, which has had a set-aside program for the last 2 years to reduce the surplus. In contrast, more of their land is in rotation hay, which is much more soil-conserving than corn or other row crops. In fact, we estimate that soil erosion is reduced by about one-third under the rotations used on organic farms.

Now a word about energy requirements. Most modern agricultural chemicals, including nitrogen and other fertilizers, as well as insecticides and herbicides, are made from natural gas or petroleum. We estimate that to produce $1's worth of crop on an organic farm takes only about 40 percent as much fossil energy as on a conventional farm.

These, then, are some of the major findings. Before I attempt to summarize their significance, let me insert a note of caution. A study such as this does not definitely and conclusively analyze such a complex subject. There are a great many sources of variability and possible errors in the data we have collected, and one must be very cautious lest

too much be inferred from our findings. We certainly do not agree with some organic farming supporters who claim that our study shows that farmers can confidently switch to organic methods without losing production or profit.

Things are very different when just a few farmers are using a particular practice—as is the case today with organic farming—compared to when everybody tries to do it.

But while we cannot say what the lessons of our study are for an individual farmer who may be thinking about converting to organic methods, we do believe that our study has interesting lessons of a more general kind. Our findings—however limited in their applicability—are in clear contrast to the frequently made assertion that productive and profitable agriculture simply is not possible without heavy use of agricultural chemicals.

Leaving aside the question "Could everybody do it?" which we have not attempted to answer, just the fact that even some commercial farmers appear to be doing quite well with organic methods is, to us, a surprising and remarkable phenomenon, one that certainly contradicts a lot of conventional wisdom.

But the more important question does not have to do with organic farming, as such. The two groups of farmers we studied represent just two approaches out of many. For most of the 3½ decades since agricultural chemicals began to become so important, there was little reason to doubt the desirability of the trend toward increasing use of these materials, a trend that has culminated in the widespread adoption of the practices we refer to as "conventional" in our study.

But more recent developments, especially the increased awareness of the potential environmental and health hazards of agricultural chemicals, and the recognition of how vulnerable our food system is to energy-related disruptions, have raised serious questions about these trends. This is not to say that therefore we should go back to practices of 35 years ago, as some extreme critics of fertilizers and pesticides would wish. It does suggest that we may have given up something by accepting without much supporting data the often dogmatically asserted pronouncements about how a major reduction in fertilizer or pesticide use would doom us to wildly increased food costs, if not outright starvation and famine. Such assertions have narrowed our vision concerning the full range of new approaches that agriculture could take.

If even a few farmers can succeed reasonably well with such a wild and extreme method as organic farming, then maybe there are many others who could profitably reduce their use of chemicals by considerably more than has generally been thought possible. Unfortunately, most of the research that would enable them to do so is yet to be done. But if American farmers are to have the flexibility that they will need to adjust to constantly changing conditions, our research programs must also be flexible enough to look at ideas that once were dismissed out of hand, but that may deserve reexamination when conditions have changed. Data, not dogma, is the only basis for deciding what role chemicals should play in our agricultural system.

Thank you, Mr. Chairman.

Mr. JONES. Thank you, Dr. Lockeretz. We appreciate your presence and your testimony. If you will remain we will call you back at a later time for questioning.

Our next witness, whose subject is energy usage, is Prof. David Pimentel, College of Agriculture and Life Sciences, Cornell University.

Welcome. If you have someone with you, you may invite them to join you.

STATEMENT OF PROF. DAVID PIMENTEL, COLLEGE OF AGRICULTURE AND LIFE SCIENCES, CORNELL UNIVERSITY

Professor PIMENTEL. All alone.

Mr. JONES. You may proceed.

Professor PIMENTEL. Very good.

"Eating Oil" was the title of a recent editorial in the Wall Street Journal. It appeared and was prompted by a scientific paper that I published in Science magazine in 1973 and there is a good deal of truth in the title. In fact, in the United States each year to feed each and every person in the United States we utilize the equivalent of 400 gallons of oil. About 17 percent of our total energy goes into supplying us with food. This includes production, processing, distribution, and preparation. About 5 to 6 percent of our total energy economy goes into production. Fossil energy has become as vital to agriculture as land and water.

In the production of an acre of corn we utilize about 90 gallons of gasoline equivalents. It takes about a gallon of gasoline to produce one bushel of corn.

Roughly, for each calorie of energy that we invest in corn production, we get about two corn calories in return. Corn is a favorable crop as far as the conversion of fossil energy into food energy.

If you talk about apples, oranges, or vegetables, we roughly have to invest about two calories to get one back in these food products.

As far as livestock production goes, the energy inputs are significant. These animals consume large quantities of grain. In fact, about 90 percent of U.S. grains are consumed by livestock and we humans only consume 10 percent. It takes about 25 calories of energy for example, to produce 1 calorie of steak.

On an average the food that we consume on our table requires that 10 calories for each 1 that we consume. This includes all the energy inputs for production, processing, distribution, and preparation.

The use of energy, land and water resources are interdependent and, in fact, can be substituted one for the other within limits. Suppose, for example, we had 2 acres and wanted to reduce our use of that land to 1 acre. Roughly we would have to require a threefold increase in energy to accomplish this.

This has a relationship to our loss of agricultural land in the United States. From 1945 to 1975 we have blacktopped over, with highways and urbanization, the equivalent of the total State of Nebraska and this is just agricultural land. Of course, as we reduce the quantity of agricultural land that is available for crop production, we must use more energy to produce our crops.

Soil erosion also has an impact on crop production. The average loss of soil per crop acre in the United States, according to the USDA is 9 to 10 tons of soil per acre per year. Since we have been farming here in the United States it is calculated we have lost approximately a third of all of our top soil due to erosion.

This has implications relative to energy as well as to our environment broadly. For each inch of top soil that is eroded from our cropland this reduces the productivity of the land.

To offset the loss of our top soil we have to use more fertilizers, pesticides, and other energy inputs. The best estimate is that we are now required to invest an additional 5 gallons of gasoline equivalents per acre per year in crop production to offset the soil erosion problem.

This totals then about 50 million barrels of oil per year due to this soil erosion and environmental degradation. Soil erosion continues today at a very rapid rate as well as the construction of highways on agricultural land and the covering of agricultural land with urbanization.

Water use in irrigation, is another aspect of the environmental energy. We can produce crops in arid lands, but to irrigate requires large quantities of energy. In fact, energy inputs run between 2 to 5 times more energy to produce a crop on arid land with irrigation than inputs to produce the same crop on rain-fed land.

Pesticides have also been mentioned several times this morning. To produce and apply 1 pound of pesticide requires about 1 gallon of gasoline equivalents. We utilize in agriculture today about 1 billion pounds of pesticides. Thus, we use about 1 billion gallons of gasoline equivalents annually in pest control in agriculture.

Interestingly enough, since 1945 there has been about a tenfold increase in the quantity of pesticides being used in agriculture and yet, our crop losses since 1945 have remained at about 33 percent. Now, there are some explanations for that, but I do not have time to go into detail. There are also some environmental and health costs associated with this. A recent estimate suggested that the environmental and social costs of using pesticides is about $900 million annually. I should point out, however, that pesticide use is giving us about a $3 return for every dollar invested in pest control.

Agriculture depends upon large quantities of energy as I indicated. Clearly, the current energy crisis and high prices are affecting agriculture and will continue to affect agriculture. We in agriculture will have to improve the use of energy resources in crop and livestock production. We will have to improve the use of land and water; we will have to improve our pest control practices. Through more efficient and more effective use of our resources we should continue to have a productive agriculture and at the same time protect our environment. Thank you.

[The full statement of Professor Pimentel follows:]

STATEMENT OF PROF. DAVID PIMENTEL

AGRICULTURAL PRODUCTION, ENERGY AND THE ENVIRONMENT

"Eating oil"—Each year every American consumes about 400 gallons of oil equivalents for the food he eats. This amount of oil represents about 17% of the total energy used in the United States. Agricultural production itself uses 5–6% of our total energy.

Fossil energy has become as vital a resource for crop and livestock production as land and water. The major uses of energy in agriculture are fuel for mechanized equipment and the production of nitrogen fertilizer and pesticides.

For example, approximately 90 gallons of gasoline equivalents are required to raise an acre of corn. This amounts to an expenditure of about 1 gallon of gasoline per bushel of corn produced and yields about 2 calories of corn for each calorie of fossil energy.

Producing other types of food products, however, is not as energy-efficient as corn. For example, in producing apples, about 2 calories of fossil energy are expended per calorie of apple harvested. With beef, about 25 calories of fossil energy must be utilized to obtain one calorie of beef protein.

If the corn is converted into alcohol, then we are investing 2 to 3 calories of fossil energy, cycled through corn, to obtain 1 calorie of alcohol. Thus, at least twice as much fossil energy must be used to obtain one equivalent in alcohol. At present this does not appear to be a realistic way to save energy.

Energy, land, and water use in crop production are interdependent and, within limits, can be substituted for one another. For example, if we attempt to produce an equal amount of food from one acre instead of two, increased energy in the form of fertilizers and pesticides is required. In fact, under such production conditions, energy use increases more than 3 times to obtain the required 2-fold increase in yield on one acre.

This also relates to the amounts of agricultural land we have and the current trend in the United States to "blacktop" over fertile land with highways and urbanization. Just from 1945 to 1975, we in the United States "blacktopped" agricultural land equivalent in area to the state of Nebraska. The result of this is increased energy expenditure to maintain current high production levels on less land.

Land degradation in the form of soil erosion acts in a similar manner. With each inch of topsoil that is lost, crop yields decline 5 to 10%. The estimate is that the U.S. already has lost about one-third of its topsoil because of the erosion caused by cultivating the land. We calculated that currently about 5 gallons of gasoline equivalents per acre per year are being used to offset this degradation. Unfortunately, soil erosion both from farming in general and poor cultural practices continue at extremely high rates and thus we continue to lose valuable agricultural soils in the United States.

In dry areas where water has to be pumped to irrigate land for crop production, energy inputs may increase from 2- to 5-fold that of normal rain-fed production. Already in some of the arid regions of the United States, low value crops such as alfalfa can not be economically produced with irrigation because of high energy costs.

U.S. agriculture is a heavy user of pesticides and these are made from petroleum. About 1 gallon of gasoline equivalent is required per pound of pesticide applied. With more than 1 billion pounds of pesticides used annually in agriculture, this amounts to over 1 billion gallons of fuel per year expended just for pesticides.

Since about 1945, pesticide use in the United States has increased more than 10 times. According to the USDA, crop losses due to pests during this 34 year period have not declined. Yearly, we average a loss of about one-third of all crops despite pesticides. Some changes in agricultural practices have increased our pest control problems, necessitating the use of even more pesticide to offset these problems. In addiiton, the pesticides themselves are causing such environmental problem as human poisonings and fish kills.

Because our agricultural production requires large fossil energy inputs, the current energy crisis is affecting our food/fiber production as well as other segments of our society. Improved agricultural production practices could help us reduce our expenditures of fossil fuel. Such strategies include soil conservation and the use of integrated pest management to reduce our heavy reliance on pesticides. We in agriculture need to seek ways to improve our management of energy, land, and water resources to meet food and fiber needs of our people.

Mr. JONES. Thank you very much, Professor. We appreciate the opportunity of hearing from you and if you will remain, we will call you back in a little bit.

Our next witness is Dr. Edward H. Glass, head, Department of Entomology, New York State Agricultural Experimental Station.

Welcome, doctor. We are glad to have you.

STATEMENT OF DR. EDWARD H. GLASS, HEAD, DEPARTMENT OF ENTOMOLOGY, NEW YORK STATE AGRICULTURAL EXPERIMENT STATION, GENEVA, N.Y.

Dr. GLASS. Thank you, Mr. Chairman, other distinguished members of these subcommittees, I am most pleased to have the honor and

privilege to discuss with you the subject of crop protection and integrated pest management, or IPM. This is a very important topic for the world. Its importance has been recognized by Congress several times in recent years, by requesting a study by the Office of Technology, by scheduling committee hearings, and by the support it has provided for research and implementation.

The subject has also received considerable attention from the executive branch and several Federal and State agencies. Crop protection activities impinge on technology, productivity and the environment. It is, therefore, most appropriate that you include this topic in your consideration of the general topic under consideration this morning.

In spite of all this attention during the past decade, IPM is not universally accepted. Part of the problem results from a lack of understanding of the concept. Also, the term is being used by different groups for different ends. The result has been considerable disagreement over goals, priorities, and jurisdictions.

Because each person seems to bring his or her bias to IPM, it may be worthwhile for me to provide a brief account of my background.

I grew up and worked many summers on a vegetable farm near Boston. A large percentage of my effort was devoted to one aspect of crop protection—weeding and hoeing. As a boy, I was very interested in ornithology and considered making it my career. However, I eventually became an economic entomologist and have worked 5 years for a pesticide manufacturing firm and 32 years for State experiment stations. For the past 6 years I have been project leader of the New York State tree fruit pest management extension project. My training, experience, and interests span the period for before the organic pesticide era to the present.

What I say this morning of course reflects my past, my employment as a professor of Cornell University and my recent experience as technical consultant to the OTA study on pest management strategies in crop protection. However, the opinions and conclusions expressed are my own. I am not representing any organization or interest.

I have divided my testimony into three sections according to the title of this hearing:

One: Technology of crop protection;

Two: Crop protection and agricultural productivity; and,

Three: Environmental considerations in crop protection.

Now, as to technology of crop protection. The control tactics most commonly used in U.S. agricultural production are chemical, cultural, plant resistance, and biological. New and promising measures such as genetic, behavior modifying substances, hormones, sterile male release, eradication and others are still unproven or have limited applicability.

Some of the problems associated with presently used control measures are:

One. Limited range of effective control tacts such as the range of effective pesticides and resistant varieties;

Two. Development of resistance to available pesticides, especially insecticides and acaricides;

Three. Outbreaks of secondary pests caused by applications of pesticides or changes in cultural practices;

Four. And excessive soil erosion and water loss resulting from tillage practices to control weed, plant pathogens, insect or other pests.

A major concern is the recent reduced effort to research and implement improved control measures. For example, there has been a reduction in many land grant universities and in some USDA research units in breeding programs for pest resistant crops. This reduction was based, in part, on the assumption that commerical seed companies would incorporate resistance without support from the public sector. However, experience with wheat and corn in certain sections of the country shows the fallacy of this assumption.

In Kansas and Nebraska alone, the acreage of Hessian fly-resistant wheats has decreased from about 66 percent in 1973 to about 42 percent in 1977. Hessian fly losses have increased concurrently. The reduction in Federal support for crop protection research in terms of real dollars over the past three decades has also necessitated cuts in these research efforts.

The rate at which new pesticides—with the exception of herbicides—are developed and introduced has dropped very significantly during the past 15 years. As a result of this and the rapid rate that pesticides are being lost to resistance and regulation emergencies have developed on several crops. For example, Cornell University requested 12 emergency 24C registrations for New York in 1979 because all registered pesticides were no longer effective and no effective alternatives were available.

I am very pessimistic about the future of crop protection in this country unless more emphasis is given to it and there are some new technological breakthroughs. There are some promising new developments but nothing, in my opinion, that will make major impacts on crop losses during the next 10 to 15 years.

There is much optimism about integrated pest management, IPM, and I share in this optimism. However, IPM is a concept and does nothing in terms of reducing pest losses, saving the environment or reducing health hazards until IPM systems are demonstrated and put into practice. At present, developed IPM systems are in place on relatively small proportions of U.S. agriculture.

It is likely that expansion will be modest with present efforts. These systems are relatively sophisticated and require much research and demonstration before they can be implemented on a large scale. Very little of the much needed integrating type of research is now funded or being done at present.

In the OTA study I have been adviser to, we estimated that IPM can be implemented widely in the United States provided present efforts can be expanded and properly coordinated. We estimated that pesticide use can be reduced in a range from zero up to 75 percent, depending on conditions, crop losses can be reduced by as much as 50 percent, and control costs maintained or reduced.

I suspect it is no surprise to you gentlemen to hear that all people involved in crop protection do not agree with these estimates, especially those persons most heavily involved with chemical pesticides. But whether these estimates are accurate or not, I am convinced that the IPM concept is superior to present approaches and will produce much needed relief from the significant deficiencies and problems of present crop protection efforts.

Now, as to crop protection and agricultural productivity. If current pest loss estimates for the United States are correct and if all such

losses could be eliminated, we could retire 123 million acres of crop land, that is one-third of the present crop acreage, without any reduction in total production. Obviously, complete reduction of losses from pests is an impractical and impossible goal. But we could get a more realistic goal of reducing losses by one-half to about 16.5 percent. Such a reduction could free 61 million acres, or more than the amount required to produce the estimated biomass needed for the United States to convert to gasohol.

The development and use of synthetic chemical pesticides has been one of the most significant contributions to the high yield of American agriculture. There is every reason to believe that a concerted effort to further reduce crop losses by developing the full potential of the array of control tactics, especially plant resistance, biological, cultural, and chemical, and integrating them into optimized production systems could result in a 50-percent reduction in crop losses caused by pests within the next 20 to 30 years.

Let me turn now to environmental considerations in crop protection.

Much agricultural practice has been dictated by the need to avoid pest damage. Plowing, and most cultivating and row spacing practices were developed to manage weed problems. Crops are often transplanted rather than direct seeded to avoid weed competition. Certain crops are planted early or late to avoid heavy losses from diseases or insects.

Crop rotations since the days of the Incas have been used to reduce losses by pests, especially nematodes. And, of course, the development and widespread use of pesticides in agricultural production has been a response to crop losses caused by pests.

Unfortunately, some of these practices have real or potentially adverse impacts on the environment. For example, wheat production in the drier areas of the Great Plains States requires a fallow period between crops to conserve moisture. Weeds must be controlled during this period. Several shallow cultivations destroy the weeds but loosen the soil, eliminate ground cover, and increase soil erosion by wind and rain.

Chemical herbicides are now being substituted for cultivation with significant reductions in soil water losses and erosion but with increases in rodents and rattlesnake populations. Comparable soil erosion reductions are obtained with minimum tillage practices on corn, but there has been some escalation of some insects and pathogens from minor to major pest status. Fall plowing to control insects and diseases may lead to unacceptable soil erosion during winter and early spring.

The problems resulting from the widescale use of pesticides, especially the chlorinated hydrocarbon insecticides and certain mercury fungicides, has been widely publicized to the point where much of the U.S. population is paranoid about any pesticide.

While I see nothing intrinsically good about pesticides beyond their effectiveness in reducing losses of good and fibre and reducing human disease, there appears to be no long-term deleterious effects on the environment from the pesticides now in use in agriculture. However, there is no reason to use more than necessary and it behooves the Nation and the world to be alert to potential problems that may not now be recognized. Surveillance should be particularly strict for the most widely used materials.

Any agricultural practice will have some impact on the local agroecosystem and often beyond. These impacts must be measured and evaluated against the benefits gained by a particular practice. In the final analysis, this is what IPM is all about in terms of crop protection. IPM is simply crop protection with the balanced use of such measures as cultural, host plant resistance, biological, and chemical that are most appropriate after careful consideration of all factors involved. These latter considerations include economics, feasibility, the environment, and health.

The IPM approach to crop protection benefits the small as well as the large farmer. Also, there should be considerable spin-off for those producers who wish to practice organic farming. And finally, IPM ultimately benefits the consumers of agricultural products which means everyone in this country.

Thank you, Mr. Chairman.

Mr. JONES. Thank you very much, Dr. Glass. We appreciate your presence and we hope you can wait to return to the witness table later.

Our next witness is Mr. G. Ray Sawyer, cotton and sorghum producer from Texas and his subject will be using IPM.

Mr. Sawyer, we are delighted to have you here with us. Mr. Hance, is he a constituent of yours?

Mr. HANCE. No, I wish he were.

STATEMENT OF G. RAY SAWYER, COTTON AND GRAIN SORGHUM PRODUCER FROM THE STATE OF TEXAS

Mr. SAWYER. My name is G. Ray Sawyer. I am a cotton, grain sorghum, and wheat producer or farmer from Hill County, Tex. Hill County is located between Dallas and Waco. I graduated from Texas A&M University in 1949 and have been farming since that time. This year I have 400 acres of cotton, 950 acres of milo, and 100 acres of wheat.

I first became involved in pest management in 1972 when our county was designated as a pilot county in the cotton pest management program. Prior to this time, most farmers in our area used a set program of spraying their cotton every week until June 15. This usually was from five to seven times, and if we got bollworm trouble, four to five times more.

In 1962 I was following this pattern and had to spray for bollworms. After applying 3 applications of the recommended insecticide I found the bollworms were not dying, so I gathered a quart fruit jar full and took them to Texas A&M. Upon examination by Dr. Perry Adkisson, they were determined to be tobacco budworms. At that time, the tobacco budworm was almost impossible to kill with the available chemicals. This experience was repeated by many of my neighbors, so we began looking for some answers to our problem.

For the next several years, we tried increased amounts of chemicals, we tried using less water in our mixture until we were using low volume straight insecticide. None of these methods seemed to be the answer. So in 1972 when the cotton pest management program was offered to us, we were ready to try it. The first 2 years, most farmers involved learned their cotton could tolerate more insects without

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economic loss than we had believed possible. Then in 1974, my area of the county suffered a bad hailstorm during the last of May, destroying the cotton and delaying the grain sorghum 3 to 4 weeks. The cotton was replanted and the milo had to be sprayed for midge. The insecticide sprayed on the grain sorghum drifted on the cotton, killing all the beneficial insects, so the bollworm and tobacco budworm got another cotton crop. This experiment told us we needed an integrated pest management program with all crops on the farm involved. The farmers participated on a voluntary basis, paying the cost of the scouts who regularly visit the field and make a count of insects, including beneficial insects present. The reports by them are given to the farmer and county entomologist. The entomologist then makes recommendations, and the producer makes the decision to spray or not to spray. The integrated pest management program is based on the use of natural environment beneficial insects to control the pest harmful to the crop.

I do not want you to believe that the producers can produce the food and fiber necessary to feed the world with beneficial insects alone. The use of chemical is absolutely necessary. IPM has convinced me that I can no longer spray indiscriminately. We must know what insect pest is causing the problem and use the least amount of insecticide at the proper time to obtain control.

The producers in the integrated pest management program have reduced the number of applications of pesticides by more than 50 percent and amounts of chemicals by 75 percent.

The increased cost of production of crops, machinery, fuel, chemical pesticides, et cetera, have placed a heavy economic burden on the farmers of this county. IPM is one tool we must use to survive.

Thank you, very much.

Mr. JONES. Thank you very much, Mr. Sawyer. We appreciate your being here. We will call you back following the next witness.

Our next witness is Mr. Lee Cunningham of the Wonderlife Corp., Des Moines, Iowa. The subject is organic farming.

We are delighted to have you.

STATEMENT OF LEE CUNNINGHAM, WONDERLIFE CORP., DES MOINES, IOWA

Mr. CUNNINGHAM. Thank you, Mr. Chairman. I am associated with the Wonderlife Corp. of Des Moines, Iowa. I am not a scientist. I did my undergraduate work at the college of agriculture.

I am here today as a farmer representing a sizable group of farmers who use the biohumic agricultural production system. This is a system of farming which maximizes the natural biological processes in soils by increasing the life and health of the soil. It is a production system based upon accepted conservation practices, the need to conserve energy, the need for consistent results on fullsize farms, and the need to protect our great productive land resource from massive infusions of toxic pesticides and superplant stimulants.

I was asked to come here by persons preparing for these hearings who felt more input would be desirable on organic farming. Organic farming generally conjures up the concept of a little old lady in tennis shoes out in her composted garden or a small weed infested farm with a few chickens and sheep, a one-row tractor and a rusting cultivator.

While I do not discredit these pictures I do not represent any such persons. Rather, we are an organization of full-scale farmers who at first glance may appear and in many respects are quite similar to their conventional farming neighbors. The difference lies in the fact that bio-humic farmers have elected to discontinue use of chemical pesticides and fertilizers and in the alternative have begun using a program or system of farming that utilizes the living soil's inherent ability to produce. This program has been developed and tested in actual use over a substantial period of time.

About 20 years ago a small handful of farmers from northern Iowa and southern Minnesota got together over their common concerns about some of the then newer approaches to agriculture. Some had been having increasing problems with their livestock, others had been put on alert by unexplainable sickness in their own families, and some had real questions about the effect that the approach being recommended by their county agents and fertilizer and pesticide companies. These farmers did some individual and collective research on their own. They found that not all agricultural scientists agreed with the recommended conventional farming approach.

The late Dr. William A. Albrecht, who for 25 years was chairman of the University of Missouri's department of soils, gave them some enlightenment. He told them that we are exhausting the quality of our soils and with it the quality of our production. He indicated that chemical salt fertilizers are upsetting plant nutrition and that this nutritional imbalance is the cause of insects, disease, and weeds. The use of pesticides to stop these natural effects is, in his words, an "act of desperation in a dying agriculture. It is not the overpowering invader we must fear but the weakened condition of the victim." His view was that there are two distinct philosophies in agriculture. One concentrates on producing more bulk—more bushels, more tons, more bales per acre. The other is concerned with producing crops, livestock, and livestock products of better quality.

Dr. Albrecht was convinced that natural soil fertility is diminishing to the point of where it is barely able to support us; that this declining fertility is already manifest in the poor health and lowered vitality of plants, animals, and man.

Most disease can be considered as degeneration. Health does not result from isolation from germs but from repelling successive attacks by the invader. These invaders are merely nature's way of ridding the environment of sick or imbalanced organisms. Today, with the massive growth of admittedly degenerative disease this analysis seems to be confirmed.

These farmers went to other places in their effort to find an alternative. They found that Dr. Albrecht's position was borne out by the work they observed at Rothamsted Soil Research Center in England, the oldest agricultural experiment station in the world. There the same healthy living soil story was being told.

Also, they observed the Hunza people in northern Pakistan. These people are remarkably healthy, often living to be over 100 years, still blessed with a full mouthful of teeth and a full head of hair. Even today these people are virtually free of cancer and heart disease. This radiant health seems to be largely attributable to the way they treat the soil. The Hunzas simply treat their soil as a living, creative process.

They nurture the life in their soil and never apply any toxic substance to it.

After looking to these and a number of other sources of such a philosophy of the soil these few farmers were inspired to look for ways to maximize these biological processes in the soil and to do so as a complete, viable, and cost effective alternative to the conventional approach to farming.

Over a period of the past 2 decades this effort grew and evolved into the bio-humic system. With a good deal of on-the-farm testing as well as help from agricultural colleges a system involving four key steps was developed that could be shared with other farmers in a way that would allow them to convert to the bio-humic program.

While improved soil fertility begins the first year under this system, restoration of low fertility soils or soils heavily damaged by pesticides or highly acidic fertilizers may require additional time to restore optimum fertility. Nonetheless, it is generally done without significant economic loss. An example of the responses we get from newly converted bio-humic farmers is that of Norman Sudbeck, of Wynot, Neb. He indicated that since going on the system his crops are "just as good as they always were and we have a lot less trouble with our livestock'. William Brenner, of Onarga, Ill. said that "every year I can tell that my soil is improving on the bio-humic program. It is softer, it smells better, it is like virgin soil. I would not go any other way."

Mr. Paul Billberg, a 2,000-acre farmer at Wannaska, Minn. indicated that when "you consider our whole operation we now have better average yields and higher test weights than before when we used chemicals".

These four key steps I refer to are:

One. Preserve all living soil organisms by eliminating life-destroying practices such as deep moldboard plowing, use of pesticides, ammonium nitrate, sugar phosphate, anhydrous ammonia and highly acidic fertilizers;

Two: To replace humus lost each year and minerals removed in crops by addition of Wonder Life bio-humic fertilizers which are made up of humates from a leonardite source, natural trace elements, and several strains of like bacteria normally found in healthy soil;

Three: To use crop rotations, cultivations, timed plantings and rest of land to reduce pest problems such as weeds, insects, diseases, to fix nitrogen, to solubilize minerals and to encourage beneficial organisms for biological control; and,

Four: To conserve nutrients in crop residues and manures near the soil surface for use by soil organisms and plant roots. Mix organic matter in the top 4 to 6 inches of the soil by use of chisel plowing or minimum tillage.

Mr. JONES. Excuse me, Mr. Cunningham. Those bells indicate another vote and we will have to recess for about 10 minutes at this point.

[Brief recess.]

Mr. JONES. Sorry to delay you, sir.

Mr. CUNNINGHAM. In the interest of time, Mr. Chairman, I will submit the balance of my statement together with a publication entitled Motivations and Practices of Organic Farmers.

Mr. JONES. Very well.

[The full statement of Mr. Cunningham together with attachment follows:]

STATEMENT OF MR. LEE CUNNINGHAM

Mr. Chairman, My name is Lee Cunningham. I am associated with the Wonder Life Corporation of Des Moines, Iowa. I am here today as a farmer representing a sizable group of farmers who use the BIO–HUMIC Agricultural Production System. This is a system of farming which maximizes the natural biological processes in soils by increasing the life and health of the soil. It is a production system based upon accepted conservation practices, the need to conserve energy, the need for consistent results on full size farms, and the need to protect our great productive land resource from massive infusions of toxic pesticides and super plant stimulants.

I was asked to come here by persons preparing for these hearings who felt more input would be desirable on "organic farming". Organic farming generally conjures up the concept of a little old lady in tennis shoes out in her composted garden or a small weed infested farm with a few chickens and sheep, a one row tractor and a rusting cultivator. While I don't discredit these pictures I do not represent any such persons. Rather we are an organization of full scale farmers who at first glance may appear and in many respects are quite similar to their conventional farming neighbors. The difference lies in the fact that BIO–HUMIC farmers have elected to discontinue use of chemical pesticides and fertilizers and in the alternative have begun using a program or system of farming that utilizes the living soils' inherent ability to produce. This program has been developed and tested in actual use over a substantial period of time. About twenty years ago a small handful of farmers from northern Iowa and southern Minnesota got together over their common concerns about some of the then newer approaches to agriculture. Some had been having increasing problems with their livestock, others had been put on alert by unexplainable sickness in their own families, and some had real questions about the effect of the approach being recommended by their county agents and fertilizer and pesticide companies. So these farmers did some individual and collective research on their own. They found that not all agricultural scientists agreed with the recommended conventional farming approach.

The late Dr. William A. Albrecht, who for 25 years was chairman of the University of Missouri's department of soils, gave them enlightenment. He told them that we are exhausting the quality of our soils and with it the quality of our production. He indicated that chemical salt fertilizers are upsetting plant nutrition and that this nutritional imbalance is the cause of insects, disease, and weeds. The use of pesticides to stop these natural effects is, in his words, an "act of desperation in a dying agriculture. It is not the overpowering invader we must fear but the weakened condition of the victim." His view was that there are two distinct philosophies in agriculture. One concentrates on producing more bulk—more bushels, more tons, more bales per acre. The other is concerned with producing crops, livestock, and livestock products of better quality. Dr. Albrecht was convinced that natural soil fertility is diminishing to the point where it is barely able to support us; that this declining fertility is already manifest in the poor health and lowered vitality of plants, animals, and man. Most disease can be considered as degeneration. Health doesn't result from isolation from germs but from repelling successive attacks by the invader. These invaders are merely nature's way of ridding the environment of sick or imbalanced organisms. Today with the massive growth of admittedly degenerative disease this analysis seems to be confirmed.

These farmers went to other places in their effort to find an alternative. They found that Dr. Albrecht's position was born out by the work they observed at Rothamsted Soil Research Center in England, the oldest agricultural experiment station in the world. There the same healthy living soil story was being told. Also they observed the Hunza people in northern Pakistan. These people are remarkably healthy, often living to be over 100 years, still blessed with a full mouthful teeth and a full head of hair. Even today these people are virtually free of cancer and heart disease. This radiant health seems to be largely attributable to the way they treat the soil. The Hunzas simply treat their soil as a living, creative process. They nurture the life in their soil and never apply any toxic substance to it.

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biological processes in the soil and to do so as a complete, viable, and cost effective alternative to the conventional approach to farming. Over a period of the past two decades this effort grew and evoked into the BIO–HUMIC system. With a good deal of on the farm testing as well as help from agricultural colleges a system involving four key steps was developed that could be shared with other farmers in a way that would allow them to convert to the BIO-HUMIC program. While improved soil fertility begins the first year under this system, restoration of low fertility soils or soils heavily damaged by pesticides or highly acidic fertilizers may require additional time to restore optimum fertility. Nonetheless, it is generally done without significant economic loss. An example of the responses we get from newly converted BIO-HUMIC farmers is that of Norman Sudbeck of Wynot, Nebraska. He indicated that since going on the system his crops are "just as good as they always were and we have a lot less trouble with our livestock". William Brenner of Onarga, Illinois said that "every year I can tell that my soil is improving on the BIO-HUMIC program. It's softer, it smells better, its like virgin soil. I wouldn't go any other way." Paul Billberg, a 2,000 acre farmer at Wannaska, Minnesota indicated that when "you consider our whole operation we now have better average yields and higher test weights than before when we used chemicals."

These four key steps are to (1) preserve all living soil organisms by eliminating life-destroying practices such as deep moldboard plowing, use of pesticides, ammonium nitrate, super phosphate, anhydrous ammonia and highly acidic fertilizers, (2) to replace humus lost each year and minerals removed in crops by addition of Wonder Life BIO-HUMIC fertilizers which are made up of humates from a leonardite source, natural trace elements, and several strains of like bacteria normally found in healthy soil, (3) to use crop rotations, cultivations, timed plantings and rest of land to reduce pest problems (weeds, insects, diseases), to fix nitrogen, to solubilize minerals and to encourage beneficial organisms for biological control, and (4) to conserve nutrients in crop residues and manures near the soil surface for use by soil organisms and plant roots. Mix organic matter in the top 4 to 6 inches of the soil by use of chisel plowing or minimum tillage.

It has been found to be important that all the steps be followed since it is the conditions that result from the aggregate of these steps that creates a healthy, e.g., competitive production system. Merely applying humus or merely rotating crops without the other steps and a proper understanding of the underlying concept being employed is the reason that some have not had the desired success. Clearly the farmer must realize he is dealing with living things and get involved in the husbandry of them.

The best proof of the effectiveness of the system are the growing hundreds of such full scale farmers currently using this approach to farming. This organization has spawned others with varying degrees of similarity so that the numbers of farmers involved today is well into the thousands. The BIO–HUMIC farmers seem to average very close in acreage size to the conventional farmers in their respective areas. This, of course, ranges from several sections in grain plains to as small as 180 acres in dairy or other livestock intensive areas.

The reasons farmers elect to go onto this system once they understand it are numerous. One significant virtue of the BIO-HUMIC system is that energy inputs are significantly reduced. In independent studies done at Washington University in St. Louis and the University of Missouri researchers found that energy consumption of conventional farming is roughly three times that required with the BIO-HUMIC approach. A majority of the natural or "organic" farms included in the study were BIO-HUMIC farms. The reasons energy is so drastically reduced are that (1) pesticide and fertilizer manufacture squanders large amounts of energy, (2) less tractor power is required to till healthy soil on this type of system. The cited University of Missouri study found that plowing could be performed in at least one higher tractor gear than when farming conventionally. And (3) irrigation needs are substantially reduced. In fact even where irrigation is not used it is found that due to the improved soil structure and soil water holding capacity on this system that droughth stress is less severe than on conventional systems and plants can endure longer droughth periods.

A second major advantage is that superior quality foods and feeds are produced on this system. Crops harvested generally contain higher levels of total digestible nutrients and have a reduced incidence of nitrates, pesticides, and mycotoxins including the rapidly growing incidence of carcinogenic aflatoxins and T–2 toxins in several areas. Many BIO-HUMIC farmers receive premium

prices for their commodities due to its integrity particularly in feed grains, cereal grains and red meats. As Owen Langle of Mankato, Minnesota, put it, "I am selling corn to hog farmers who find it so much better than what they buy from an elevator that I get a substantial premium for it. Boyd Boyer of Kent, Illinois, says his philosophy is to "raise healthier grain so you will have healthier livestock. Then you have healthier food for people."

A third beneficial result is that the natural fertility of the soil is improved. Improved tilth and health with greater water holding capacity and an improved cation exchange capacity means less erosion and less nutrients lost through leaching. Walt and Paul Zander of Waverly, Iowa, indicate that when farming conventionally they "hard hard, lumpy, heavy soil. Now it's always loose and easy to work." BIO-HUMIC farmers also report massively increased earthworm activity and faster breakdown of organic residue in the soil.

Fourthly, increased economic returns are experienced by these farmers. The comparative studies show that yields are generally maintained so with production costs reduced the farmer nets more profit with less risk. Cyril Venner of Carroll, Iowa, who together with his brothers farms over 2,000 acres and has been on this system over 7 years says that "I get more soybeans, more alfalfa hay, more oats, and equal corn yields, all with higher feed value and lower production cost on the BIO-HUMIC program." Melvin Sicheneder who has a substantial hog confinement operation at Easton, Minnesota, says that from farrowing to market he saves an average of two bushels of corn per pig. Glenn and Rex Spray at Mt. Vernon, Ohio, who farm 800 acres ask "After experiencing the best yields ever of quality crops with below normal cost, why should we even consider returning to the chemical approach?"

Many other benefits are realized but one which is voiced by many of the BIO–HUMIC farmers is that once you have eliminated poisonous pesticides and highly acidic fertilizers with their dangerous side effects on animals and man, a new peace of mind arises from working more closely with the biological processes of nature. As Noah Yoder of Lewisburg, Pennsylvania says, I have the satisfaction of producing food as I believe God intended, without destroying life. Bernard Karvan of Linwood, Nebraska, states that if he had to go back to chemicals he would quit farming.

It is sometimes suggested that certain problems arise with this type of program that leave it an impossible or uneconomic alternative to full scale production. Perhaps the most frequent is that yields and profits are too low under this system. Several years ago. Lockeretz engaged in a research survey involving hundreds of "organic" farmers. His findings show that of these farmers less than 5% saw this as a problem. It would seem that given the heavy overhead, high debt: equity ratios, and weather and market risks of the American farmer today that such percentages would suggest that with the proper implementation and administration of this farming system that this concern or limitation simply is not real. Earl Cunningham of Sleepy Eye, Minnesota, a seed producer for the Minnesota Crop Improvement Association who has been on the BIO–HUMIC program for 15 years says that this program "has convinced us and has facilitated the burning of the mortgage". Neil Pashley of Williamsfield, Ohio, says that "Life is so much simpler farming without chemicals, so much more profitable, so much more enjoyable". Even during the above described conversion process our farmers generally do not experience a net decrease in profits.

Another concern with this system is that the weeds and pests can't be controlled without the use of herbicides and other pesticides. Our first response is that to use such poisons is to treat the effects of a problem rather than the cause. We find that weeds and pests are merely natures response to a skewed or stressed environment. This is a natural effort to clean out and restore balance to the eco-system involved. In the above mentioned Lockeretz survey only a small minority or organic farmers indicated that weeds and pests were a problem. BIO–HUMIC farmers have developed a broad range of techniques and management procedures to reduce this problem. Timed planting, proper rotation, varied kinds of cultivation, and other approaches are used. Wayne Kraft, a 600 acre farmers at Decatur, Illinois, indicated that it was only after getting on this program that they were able to control weeds. David Schroeder of Columbus Grove, Ohio, says that "the farther away we get from chemicals the easier it is to control weeds."

Another charge made of this system of agriculture is that it is too labor intensive. Here again few organic farmers have found this to be true. Perhaps the fact that most such farmers do not require the larger tractors used by conventional farms accounts for this misconception. Also the stereotypical organic gardener image probably suggests it.

For the past twenty years the Wonder Life organization has from time to time asked that agricultural colleges and governmental agencies take a look at this system of farming to assist us in its development. For most of that time such requests have either been ignored or additional resistance to it was brought into play by means of adverse publicity or attempts at regulation. This has been done on the premise that no one can do what these hundreds of farmers are doing. In 1971 then Secretary of Agriculture, Earl Butts, indicated that without the now traditional chemical approach "fifty million Americans would starve" to say nothing of the effect on our balance of payments.

However, in the past few years several major agricultural institutions such as Texas A & M University have begun to research the program and the products used. Their findings tend to support the basis for such a system. Earlier this year Secretary Bergland began to look at this alternative and has initiated a preliminary investigation of it and now the Agriculture Department has allocated some $70 million dollars to a full scale organic farming study.

We welcome your review and study assessment of what we are doing. Hundreds of BIO–HUMIC farmers would be most happy to open up their farms and operations to anyone who is interested. We are having dozens of tours across the Midwest throughout the summer. Let us know of any way we can be of help.

AGRICULTURE AND WASTE RECYCLING

MOTIVATIONS AND PRACTICES OF ORGANIC FARMERS

Based upon this research survey, the decision to use organic methods does not necessarily imply an overall approach to farming that sets midwestern organic farmers apart in a fundamental way from the conventional farmers who comprise most of midwestern agriculture.

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PURPOSE

MODERN AGRICULTURAL PRACTICES developed at a time when energy and other natural resources were abundant and inexpensive. But since the energy crisis of 1973, there has been growing interest in ways to make agriculture less dependent on energy-intensive chemicals like nitrogen fertilizer and synthetic pesticides. Also, in recent years, adverse environmental effects of pesticide and fertilizer use have become matters of increasing concern. Consequently, in 1974 the Center for the Biology of Natural Systems began a study of organic farming to assess its potential as a resource-conserving and less environmentally damaging alternative to conventional agricultural practices.

The results of this study have been reported in detail elsewhere.[1, 2] In brief, the performance of a selected group of commercial scale crop-livestock Corn Belt organic farms was compared with that of a matched sample of conventional farms. The organic farms studied had somewhat lower yields than the conventional farms but these were offset by lower input costs. On balance, the organic group appeared to do about as well in terms of net income per acre, with a considerably lower use of fossil fuel.

This study confined itself to micro-level questions, i.e., the performance of individual farm enterprises. We cannot draw inferences concerning total production or food prices. Even so, the fact that individual large-scale organic farms can be economically competitive challenges the belief that present day organic farmers can perform no better than farmers of forty years ago, and that they have no relevance to modern day agriculture.* Organic farmers therefore present an interesting case of unconventional management. They have rejected modern fertilization and pest control methods, which are generally considered indispensable to modern agriculture. Yet at the same time they try—with reasonable success, apparently—to attain a level of production and profitability that enables them to survive in competition with farmers who are using all the modern farm inputs. But the differences between organic and conventional management are of more than just academic interest. Environmental and energy factors may cause more farmers to make greater use of some techniques that organic farmers (as well as many conventional farmers) are already using, such as rotating forage legumes like alfalfa with row crops, and recycling of livestock manures to cropland. In a sense, then, these "old-fashioned" techniques are becoming fashionably modern. It is therefore interesting to consider why organic farmers—who now are making considerable use of certain methods that many other farmers eventually might adopt to a more limited degree—have chosen this system, and how this decision was related to other aspects of their approach to farming. To explore this topic we have made a survey of operators of midwestern commercial-scale organic farms.

Perhaps the best-known statement of this view was made by former Secretary of Agriculture Earl Butz: "Before we go back to an organic agriculture in this country, somebody must decide which 50 million Americans we are going to let starve or go hungry." [Emphasis added]

METHODS

Since there is no census of organic farmers, it was not possible to construct a random sample of the population. Instead, we attempted to locate as many organic farmers as possible within a five-state (Missouri, Iowa, Illinois, Minnesota, and Nebraska) area.

One problem in selecting farms to study is that the term "organic farming" has no standard meaning. Therefore we generally relied upon farmers' self-definitions. However, we eliminated farmers who used inorganic nitrogen fertilizer, acidulated phosphate, or insecticides. We did not exclude farmers who use muriate of potash or who selectively use herbicides, although many organic farmers find these inputs unacceptable. Although our criteria were all negative (i.e., materials that a farmer may not use if we are to consider him organic) we know from other studies[1] that organic farmers, as defined here, tend to use certain positive practices to a greater degree than do conventional farmers. For example, they have a greater proportion of their cropland in rotation meadow, and less in row crops, compared to con-

ventional farms. Manuring practices are similar on organic and conventional crop-livestock farms, but a larger proportion of organic farms have livestock.*

We mailed a brief survey to organic farmers already known to us and asked that they send us the names of others they knew. We sent the same survey and request to the farmers whose names we received in the first and later waves of responses. In all, 1135 brief surveys were mailed: 685 responses were received (60 percent).

A total of 302 farmers (44 percent of respondents) met the following criteria for inclusion in this study: they had to raise field crops primarily, farm at least 100 acres, and use organic methods on more than half of the land they managed. Most of the respondents who did not meet these criteria were not organic, or only partly so. Others had retired, or ran vegetable and fruit farms. A longer, more detailed questionnaire about attitudes and practices was sent to 250 of these respondents, excluding 37 who indicated that they did not wish participate in further studies, plus 13 who were used in other components of the project.

We got responses to the longer questionnaire from 174 farmers (70 percent). Because 40 percent of the farmers did not respond to the brief questionnaire, and 30 percent didn't respond to the longer one, we can't be confident that our respondents represent a cross-section of midwestern organic farmers.* Moreover, our method for finding farmers—which relies on their being known to other organic farmers—probably biases our sample in favor of those who belong to organic farming organizations or attend meetings of organic farmers. This issue is discussed later.

Respondents managed a median of 244 acres. Five-sixths managed all their land organically. Twenty-three of the respondents had always farmed organically. For the remainder, the median year of conversion to organic methods was 1970. About three-fifths of the farmers were between forty and sixty years of age, with approximately equal numbers above and below that range.

The questionnaire was designed to answer the following:

1) What were the motives and decision-making processes of the farmers who had converted to organic management?
2) What inputs did they use and which did they avoid?
3) Apart from their non-use of certain chemicals, to what extent were their equipment and practices modern?
4) What contact did they have with other farmers and with agricultural institutions, both conventional and organic?

FINDINGS

The Decison to Farm Organically

One hundred fifty-one respondents had converted from conventional to organic management. We questioned them about their motives for this change, the advisors they had consulted, and the time frame in which the decision had been made. All respondents, including the 23 who had always been organic, were asked to indicate advantages and disadvantages of organic farming.

Motives for conversion to organic methods

Motives for changing to organic management varied considerably, although the reasons given generally fell into three categories: specific problems with conventional farming, ideological misgivings about conventional farming, and contact with an individual or organization suggesting organic farming as an alternative. Table 1 summarizes the answers most frequently given.

TABLE 1. Reasons for Converting to Organic Farming

	% of Respondents Mentioning Reason
Specific Problems or Concerns	
Livestock health	32
Soil problems	30
Cost of chemicals	25
Chemicals not effective	23
Human health	22
At least one specific problem or concern	75
Ideological Concerns	
Dislike chemicals	24
Environmental concern	8
Religious concern	2
At least one ideological concern	34
Contact with Proponents	
Dealer for organic fertilizers and soil amendments	30
Farmer	14
Organization	8
At least one contact	48

Problems with conventional farming were mentioned by three-quarters of the farmers who formerly used conventional methods. About a third had been concerned about livestock health. Nearly as many were persuaded to convert by deteriorating soil quality. Several respondents wrote "The soil was dead."

A third of the farmers expressed some ideological criticism of chemicals; less than one-tenth cited environmental or religious objections. For example:

> "I feel that I would be violating the Fifth Commandment 'Thou shalt not kill' if I would continue to use chemical fertilizers and chemical pesticides. It would be an indirect method . . . of killing my fellow man by means of undernourishment and disease from poor quality food and chemical residues . . ."

Contact with a proponent of organic farming motivated half the respondents to consider a switch, with about one-third mentioning organic farming product salesmen. As will be discussed later, these salesmen play an important role in supporting organic farming. For the most part, the farmers were predisposed to consider organic farming before contact with salesmen.

The typical scenario included all three elements. A generally critical attitude towards chemical inputs was galvanized by some specific problem with their performance. Subsequent contact with organic farming enthusiasts further convinced the farmer of these drawbacks and suggested an alternative.

Advisors on adopting organic methods

Once seriously considering or-

92 percent of the 302 organic farmers identified through the brief survey described later have livestock. The corresponding figure for conventional farms in the same five states was 82 percent in 1969. The 1977 figure is lower if the trend from 1964 to 1969 has continued.*

However, among farmers who were eligible for receiving the second questionnaire, the response rate for the brief survey was well above the overall rate of 60%. As needed, we sent the brief survey a second or third time to those who didn't respond. Of those responding to first, second, and third mailings, the proportion meeting our eligibility criteria were 52%, 36%, and 16% respectively. (This declining proportion is to be expected, since persons for whom the survey was not appropriate—e.g., non-organic farmers—could be expected to be less willing to reply.) We can assume that of the 450 people who didn't respond even after three mailings, less than 16% would meet our criteria. Under this assumption, we conclude at most 72 otherwise eligible farmers failed to respond to the first survey, so that our actual response rate among the eligible group was at least 81% (302/373).

ganic farming, all those who formerly farmed conventionally sought some outside advice and assistance. As Table 2 shows, the organic farming product salesman was the most significant change agent. In contrast, few of these farmers had gone to more conventional sources of information: only five farmers had consulted the Soil Conservation Service (SCS) and just two talked with Extension agents. Marginal comments indicated that at least some of the respondents believe that the Extension Service and even the SCS are hostile towards organic farming and are inaccurate sources of information about it. (For example, one respondent wrote in, "They don't want to know about it.")

TABLE 2. Sources of Advice on Decision to Adopt Organic Methods

	% Who Consulted Indicated Source
Salesman for organic farming products	84
Organic farmer	72
Books or articles	61
Soil Conservation Service	3
Extension Service	1

Timing of conversion to organic methods

Of organic farmers who formerly used chemicals, four-fifths converted to organic methods within the past decade, with the median date being 1970. Virtually all of these farmers began using organic methods the same year that they first considered the change, and most converted all their land by the first or second year.

Eighteen percent indicated that their net income dropped temporarily after they began farming organically. Sixty percent reported no drop, while the remaining 22 percent were uncertain, either because their records were incomplete, or because losses appeared to have been caused by drought or other adverse farming conditions unrelated to the conversion.

Perceived advantages and disadvantages of organic farming

The farmers studied were highly committed to organic farming. Of the 32 who had not converted all their land, 16 planned to do so, while 10 of the remaining 16 could not convert rented land because of the owners' objections. Obviously, a decision to become organic can be readily reversed. Twelve percent had considered (then decided against) returning to conventional methods, most frequently because of low yields or weed problems.

The fact that most of these farmers have never even considered giving up organic methods and that most are or will be managing all of their land organically indicates a strong commitment to this way of farming. Therefore, it is not surprising that these respondents reported considerably more advantages than disadvantages to organic farming. When presented with lists of both, a mean of 13.3 advantages were checked, but only 2.8 disadvantages. Tables 3 and 4 show the advantages and disadvantages they considered most important.

TABLE 3. Perceived Advantages of Organic Farming

	% Indicating That This Was One of the Three Most Important Advantages
Healthier for the farmer and his family	54
Healthier for livestock	48
More wholesome in harmony with nature	28
Better for the soil	26
Better for the environment	25
Closer to the way of farming in the Bible	20
Lower production costs	18
Higher net income	12
Higher quality product	11
Tillage easier	10
Yields suffer less under adverse conditions	9
Consumes less energy	8
Less dependence on outside suppliers	7
Fewer insects	6
Crop dries better	4
Fewer weeds	4
Total hours of labor less	1
Yields higher	1
Organic products command a premium price	1
Work more evenly spread through the crop year	0

The safety of organic farming, for both livestock and farmer, is its most significant advantage in the opinion of these respondents. Of the four most frequently mentioned disadvantages, only one—weed problems—is agricultural. The other three problems—finding suitable markets and up-to-date information, and the negative attitudes of others—reflect the social context of organic farming. These difficulties suggest some of the reasons they have turned to organic farming institutions, a subject considered later in the paper.

TABLE 4. Perceived Disadvantages of Organic Farming

	% Indicating That This Was One of the Three Most Important Disadvantages
Difficult to find a market for organic products	22
Weed problems worse	16
Fewer up-to-date sources of information	16
People look down on organic farmers	14
Difficult to get enough manure	10
Greater expertise needed	9
More labor required	8
Can't have all land in cash crops	5
Harder to get loans	5
Lower yields	4
Lower profits	2
Pests worse	2
Organic farming requires livestock	1
No time to take vacation	0
No disadvantages	13

Check Acceptability of Inputs Used

Although small-scale certification programs do exist, there is no universally recognized standard of organic farming. Therefore, we sought to determine the degree of consensus about the acceptability of certain inputs in organic crop and livestock operations.

We asked respondents whether they had used, might use, or would not use certain inputs on their organic cropland. The results are presented in Table 5.

TABLE 5. Acceptability of Selected Inputs for Organic Cropland

Substance	% of Respondents Who Would Never Use Indicated Substance*
Anhydrous ammonia	93
Insecticides	85
Herbicides	75
Urea	70
Super phosphate	60
Grain silage preservative	45
Sewage sludge	37
Potash	27
Rock phosphate	21
Trace minerals	8

*It is possible that some farmers did not understand the question and included inputs on non-organic land they manage, or referred to their practices before conversion to organic methods. When it was clear from marginal notes that such misunderstandings had occurred, the respondent was eliminated from the tally unless the answer could be extracted from the comments.

Chemical fertilizers, insecticides, and herbicides—substances used by the vast majority of conventional farmers—are, of course, unacceptable to most organic farmers we surveyed. Farmers who had more contact with organic farming institutions—dealers, organizations, or publications—more frequently in-

dicated that they would never use these inputs.

One hundred fifty-four (89 percent) the farmers raised livestock for sale. All but 10 farmers considered their livestock organic, but only 27 percent of the livestock producers marketed any of their livestock through organic channels. However, there are few clear differences between the substances that farmers feed to livestock marketed through organic and conventional channels, as shown in Table 6.

TABLE 6. Substances Fed to Livestock by Organic Farmers (N = 131)*

Substance	% Feeding Indicated Material: Not Considered Organic by Producer (N = 10)	Organic, Marketed through Conventional Channels (N = 87)	Organic, Marketed as Organic (N = 34)
Own chemically grown crops or feeds	30	7	0
Purchased chemically grown crops or feeds	30	43	21
Mineral supplements	90	87	91
Vitamins	90	68	59
Hormones	30	2	0
Antibiotics	3	11	0

*20 farmers don't market livestock. 23 did not provide adequate answers to questions about either markets or substances

contrast to the situation for organic crops, there appears to be no generally agreed-upon definition of organic practices for livestock. This is consistent with our finding that, unlike with crops, for livestock there was no relationship between management practices and contact with organic farming institutions.

Modern Equipment and Practices

This study focused on farmers who had decided, for a variety of reasons, to reject certain modern farming inputs. It is of interest to see if this decision was general or selective. Data on their use of other practices and equipment are summarized in Table 7.

TABLE 7. Equipment and Practices

	% Who Have Adopted Practice or Who Have Indicated Equipment
Practice	
Soil testing	73
Nutritional analysis of crop	42
Plant test plots to compare materials or practices	40
Keep records of yields	
For at least some of farm	41
For entire farm	12
Have [illegible] registered livestock	10
Equipment	
Silo	
Glass steel	11
Bunker or trench	15
Upright concrete	33
Hay handling system used	
Big bales	12
Small bales	71
Tractors	
At least one 60 hp or more	82
At least one 100 hp or more	33

While there was considerable variation in this regard, the majority of the farmers had adopted at least some modern equipment and practices.

RELATIONSHIP WITH FARMERS AND AGRICULTURAL INSTITUTIONS

Relations with conventional farmers

Two-fifths of the farmers reported as a disadvantage of organic farming that others tend to look down upon this management system. As mentioned earlier, 14 percent considered this one of the three leading disadvantages. Nevertheless, over four-fifths said that they did discuss organic methods with conventional neighbors. According to the respondents, most neighbors were indifferent or skeptically interested in organic methods; only 14 percent said that most of their neighbors were hostile.

tween organic and conventional farmers can be strained by problems arising from differences in management. On the one hand, organic farmers can be plagued by drifting chemical sprays or chemicals in runoff water. On the other hand, organic farmers may be viewed as sources of weed or insect pests. We asked respondents to tell us (in a necessarily one-sided report) if they had experienced such difficulties. Nearly half (46 percent) said that they had had some problem from a conventional neighbor, usually drifting spray. Those who marketed crops through organic channels were more likely to report this. Only 5 percent reported complaints against themselves, mostly about weeds.

The landlord's attitude is important to farmers who wish to manage rented land organically. Fifty-nine farmers rented land, about half of them from relatives. As reported above, 10 respondents who rented land were unable to complete conversion to organic methods because of the insistence of the owner that they farm conventionally. However, nearly half of the owners, most often relatives, actually favored organic farming.

Contact with conventional farming institutions

Almost half (47 percent) of the respondents had had some formal conventional agricultural training, usually through high school courses (33 percent), GI farm training (16 percent), or college courses (9 percent). Moreover, they reported about as much contact with conventional as with organic farming institutions: these farmers are not isolated as individuals or as a group. Table 8 gives data on three different kinds of contact with farming institutions: magazines, organizations and meetings. The more institutional contact a farmer had, the more likely he was to be using modern equipment and practices. A few of the farmers stated in marginal comments that they read conventional magazines for an unconventional reason: "to see what the enemy is up to."

TABLE 8. Contact with Agricultural Institutions

Form of Contact	Organically Oriented	Conventionally Oriented
Mean number of magazines read	1.7	2.4
Mean number of memberships in organizations	8	8
Mean number of meetings attended in 1976	1.1	1.0

Relationship with organic farming institutions

Although contact with organic agricultural institutions did not preclude contact with conventional farming institutions, it clearly played an important role in supporting these farmers' activities. Table 8 has already shown the degree of contact that respondents had with other organic farmers through magazines, organizations and meetings. Four-fifths read at least one organic farming magazine; half belonged to at least one organic farming organization; and three-fourths had attended at least one meeting related to organic farming in 1976.*

**Since our method of finding respondents depended on their being known to other organic farmers, our sample may have an unrepresentatively large proportion of farmers who are highly involved with organic farming institutions. To explore this point, we tallied the number of times that each respondent's name was referred to us by other respondents to the first questionnaire. This was significantly related to degree of contact with organic institutions. Since we can assume that the organic farmers who were never referred at all are likely to be similar to those referred only one or two times, we conclude that the data are indeed biased in the anticipated direction. Comparable calculations showed that our sample is also biased towards farmers who follow commercial organic programs and who have changed to organic methods relatively recently.*

We have already seen that commercial dealers for organic products, ···ch as fertilizers and soil amendnts, are a particularly significant change agent. After a farmer adopts organic methods, a dealer plays an important role as a source of inputs, advice, and encouragement. Just over half of the respondents had attended a farmer-dealer meeting sponsored by an organic product, and about one-third belonged to a particular organization of farmers who use one of these products. As Table 9 shows, nine-tenths of the farmers were using some purchased organic materials in their farming. Many companies supply not only their product, but also a complete management program, including suggested crop rotations, tillage methods, etc. About half of the respondents were following such a program without modification.

TABLE 9. Use of Commercial Organic Products and Programs

Use of Commercial Organic Product	% of Respondents
No use	11
Some use	89
Product only	19
·uct and modified ·rson of program	19
··oduct and full program	51

There was a significant relationship between the year a farmer adopted organic methods and his involvement with a commercial product: those who changed recently are more likely to follow a complete commercial program. Farmers who have always farmed organically are more likely to use no product at all, or simply to use a product without the rest of the program. Moreover, these farmers had significantly fewer contacts of any kind with organic farming institutions compared to farmers who converted.

It was stated earlier that the disadvantage of organic farming most cited by respondents was difficulty in finding an organic market for their products. Indeed, only a minority (33 percent) use special organic marketing channels at all, and just a third of these (12 percent of the sample) are able to sell at least half of their prod· ··· this way. Of those who use spec· channels at all, five-sixths receive a premium price.

Because organic products command a premium on the retail market, it is sometimes assumed that organic farmers routinely receive higher-than-market prices for their goods, which is considered essential for them to survive economically. Actually, only 10 percent of the farmers were receiving premium prices on at least half of their crops or half of their livestock, and 18 percent were getting premiums on occasional sales (usually to individuals). It was clear that many more farmers would have used special channels had they been available.

Farmers who charged a premium stated that the higher price was not the result of higher production costs or extra expenses in marketing the product, such as special bagging. Rather, about four-fifths of these farmers said that the higher price was charged because of the superior quality of the product, and because customers were willing to pay more for organic merchandise. Given the farmers' readiness to charge higher prices, and the customers' willingness to pay them, it is reasonable to expect further development of special marketing channels, possibly through existing organic organizations. Although few of these organizations presently offer such a service directly, contact with organic farming institutions was significantly associated with a farmer's ability to locate an organic market for his output.

Organic farming institutions also compensate for two other difficulties reported by the respondents: lack of up-to-date information and the negative attitudes of others. These institutions offer technical advice and interpersonal support to the farmer whose use of organic methods precludes his seeking such help elsewhere.

DISCUSSION

Many people apparently have an image of organic farmers that is very different from what emerges from this study, judging by the correspondence we have received and the questions we have been asking in connection with our larger study of organic farming. It is sometimes assumed that organic farmers usually use animal power for tillage, that they mainly raise fruits, vegetables and specialty crops specifically for the organic or natural foods market, and that they tend to operate marginal, subsistence enterprises. It is also thought by some people that organic farmers represent a "back-to-the-land" movement that is an alternative to prevailing life styles and economic institutions.

While some organic farmers do fit this image, the overall picture of those we surveyed is very different. They raise field crops and livestock on a commercial scale, using mechanized methods. Most of their output is sold through conventional channels. Most farmed by conventional methods before changing to organic methods. Besides being involved with organic farming institutions, they tend also to maintain contact with conventional agricultural institutions, such as magazines and organizations. Their reasons for choosing organic methods generally were practical, that is, related to specific problems with conventional farming, such as possible adverse health effects of pesticides. Ideological or philosophical considerations also played a role, but to a lesser degree. In summary, it appears that for the type of organic farmer covered by our survey, choosing to use organic methods does not necessarily imply an overall approach to farming that sets organic farmers apart in a fundamental way from the conventional farmers who comprise most of midwestern agriculture.

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Mr. JONES. Thank you very much, Mr. Cunningham. You can remain where you are if you like and we will call the other witnesses to the table for questioning. I notice it is now 17 minutes to 12 so maybe we can get the questions asked and answered by then.

Dr. Wittwer, Dr. Aldrich, Dr. Lockeretz, Pofessor Pimentel, Dr. Glass, and Mr. Sawyer, will you come forward? I think we can hear you if you cannot get to a microphone.

Mr. AMBRO. I wonder if we can ask the panel to consider themselves in a seminar mode which is a fancy phrase for that which might be a debate format and so if a question is asked and the panelists disagree, they volunteer to respond or rebut. Is that possible?

Mr. JONES. If there is no objection we surely can. I am sure it is agreeable with everyone. We have an agreeable group of people here today. I yield to you, George Brown, for the first question. Move right on.

Mr. BROWN. Let me say first I found all the testimony extremely interesting and informative and I want to express my thanks to all the witnesses.

I want to ask one question of Dr. Pimentel. There has been a great deal of discussion here in the Congress with regard to the energy shortage and that this general problem of gasohol production and the energy efficiency with regard to the production of gasohol. I am led to believe from what you say, Dr. Pimentel, that you do not look on this as an energy efficient transaction; that the energy input required is greater than the output obtained.

I would like to have you discuss that just briefly because I would like to have some perspective before we authorize a few billion dollars for gasohol conversion.

Professor PIMENTEL. First of all this can be checked. The energy that goes to raise an acre of corn is 90 gallons of gasoline equivalents. From that you get about 90 bushels of corn on an average assuming that weather is satisfactory.

When we convert the corn into alcohol, we get about 2.5 gallons of alcohol per bushel of corn. This would mean from about 90 bushels of corn per acre, we can get about 230 gallons of alcohol.

In addition to the 90 gallons of gasoline to produce the corn, the grain must be processed into alcohol. This process of fermentation and distillation requires about 140 gallons of gasoline equivalent. Thus, adding the 140 gallons to process to that of producing the corn gives us a total investment of about 230 gallons of gasoline equivalent to produce approximately 230 gallons of alcohol.

The only gain one can see here is that some coal was used to produce the corn. Therefore, producing alcohol from corn allows to convert coal into a liquid fuel.

Mr. MARLENEE. If the gentleman would yield, I would like to pursue that just a little bit.

Mr. BROWN. Before I do, let me finish this thought.

Mr. MARLENEE. I certainly do not want to impinge upon your time. You said 140 gallons to process, or approximately 140 gallons.

Professor PIMENTEL. That is right.

Mr. MARLENEE. Suppose we used the corn stalks or the byproducts or some of the stubble that is there, pelletized it and used that for fuel. Would that decrease it?

Professor PIMENTEL. It certainly would, and I could make those calculations but you would gain on that.

Mr. BROWN. Have you also considered the energy value of the by-products; the mash that can be reused for food?

Professor PIMENTEL. Yes.

Mr. BROWN. And the reduced inputs that might go to corn if you knew you were going to convert that into gasohol instead of using it for human consumption.

Professor PIMENTEL. We also gain if we feed the corn mash after alcohol production to cattle. The mash cannot be stored but has to be fed to the cattle or other livestock soon.

This is a very complex question and there are some benefits that we can get, Mr. Brown. I do not think, however, that we are going to gain a lot from this effort, but it is not all negative.

Mr. MARLENEE. If the gentleman would yield again, we hear a lot of talking about the big plants. Everybody is gungho for big in producing and solving our gasoline shortage. Stopping and thinking about this, I would like to run this theory by you.

When we have these big plants we have transportation problems. We have to bring the grain in. We have to market the byproducts; take those byproducts out; the storage of the grain itself on the site to be used and utilized and we have the problem of the 140 gallons of energy that is used to process this thing.

Now, suppose big was not best and I am sure this has been explored by some of you before and I consider your testimony very excellent and this is why I wanted to run this by you. Suppose big is not best. Suppose we want the small plants on the farm at each individual farm where the farmer raised the product. He had it in storage already on the farm, no transportation problem where we have utilization of the byproducts, where we do not lose that much as far as the nutrients in the conversion. They are there yet and he utilizes them for livestock feed on the farm, so, therefore, no transportation problem, no marketing problem with that.

Have we, in fact, increased the efficiency significantly where he is producing enough for his own use for two or three farms or together producing enough for collective use of two or three farms and maybe some of the excess to be sold off?

Professor PIMENTEL. Well I would, of course, like to really examine this question carefully, but my own rough calculations suggest that we should favor the decentralization and small units. I think we would be in a better position to make use of the corn mash for livestock feeding in small decentralized systems.

Mr. MARLENEE. I thank the gentleman.

Mr. JONES. Gentlemen, we are going to have to necessarily adjourn this meeting because we have to be back at 2. We have two votes on the floor of the House right now. We have to be there in about 7 minutes. I hope that some of you gentlemen will be here this afternoon. We would like to talk to you over in a corner somewhere if we cannot talk to you before the witness table.

Mr. AMBRO. I would like to say that the caliber of the testimony is just excellent, but it stimulated an awful lot of questions and if the panelists would not mind maybe we could hold the record open for written questions and ask them to round it out with their responses later on.

Mr. JONES. I think that is a splendid idea and if you gentlemen are here this afternoon maybe some of us can have the privilege of talking to you. There are several questions I have and need the answers to.

I want to repeat what Mr. Ambro has said. This has been excellent testimony this morning. I wish we had more time to get into it a little deeper but without objection, we will hold the record open for some written questions to be placed in your hand and we hope you are here this afternoon so we can talk to you.

We will recess until 2 o'clock when Mr. Ambro, the chairman of the Subcommittee on Natural Resources and Environment will chair the hearing.

AFTERNOON SESSION

The subcommittees met at 2 p.m., in room 2325, Rayburn House Office Building, Hon. Jerome Ambro (chairman of the Subcommittee on Natural Resources and Environment) presiding.

Present: Representatives Ambro, Jones, Brown, Harkin, Walker, and Hance.

Staff present: [From the Subcommittee on Natural Resources and Environment] Ian Marceau, staff director, and David Clement, technical consultant.

Mr. AMBRO [presiding]. I would reopen these hearings and ask those of this morning's panel who were kind enough to come back and accede to the wishes of this chairman to reassemble at the witness table and we might continue with the questions until the next set of bells.

I would like to turn now to my friend and colleague, George Brown.

Mr. BROWN. May I thank you also for being generous to return this afternoon. I know it is an imposition on you, but we are fighting some difficult problems today.

Dr. Wittwer, I have been deeply concerned about this problem of a new generation of agricultural research and, of course, was interested in the development of the new program of competitive grants which I thought would help move us in that direction.

I was very interested in your analysis of the impact of the new competitive grants program, that is the fact that there is far more research proposals and qualified personnel available than there are funds.

Do you have any suggestion as to how we can change that situation without crippling the present system which was never our intention—how we can move ahead to get more support for this very important type of research that you have indicated here?

Dr. WITTWER. Congressman Brown, I recently sat with the advisory group for the competitive grant program in the Department of Agriculture and made the comment at the meeting that the competitive grant program for basic research in the support of agricultural research would never fly by eroding Hatch formulae funding or by a slow attrition of Hatch resources that has been precisely the strategy that has been followed for the past 2 years.

Mr. Brown, all you have to do is check the White House and the Congressional Records to substantiate this point.

Mr. BROWN. Where do I put my finger on the cause of this? It did not originate with the authorizing legislation, the members of the Agriculture Committee who were instrumental in trying to make this shift in the research program. We wanted a program which would open up

targeted research of importance to agriculture, to a broader range of research performance. We did not want to cut back on the formula grant program.

I have the impression there may be some, either in the Congress or in the Department who are trying to create the impression that we have to cut back on the formula grants if we are going to have a competitive grants program. I am not quite sure where to point the finger. Maybe it is OMB. We like to blame them for almost everything and it is conceivable that they are saying we have fixed limits on agricultural research. If you want competitive grants you have to take it out of the formula grants.

Well, if that is the case, I would like to pinpoint it and see if we can do something about it.

Dr. WITTWER. Let me clarify my position as I understand it which is what you have asked for. The problem does not reside in the Congress. The problem resides with OMB and the White House and with the agencies themselves.

Mr. BROWN. You mean the Department of Agriculture?

Dr. WITTWER. Yes. You want me to be frank, and I am being frank.

Mr. BROWN. Well, the Department of Agriculture I think can be faulted for trying to protect their existing programs if that is a fault, and I think sometimes they change too slowly but it is a very natural thing for them to do.

Dr. WITTWER. I understand. You did not want further comment?

Mr. BROWN. If anyone else has any comment on this matter I would appreciate hearing it because we are having the same problem in some other areas.

I am trying to encourage joint research with Mexico right now in accordance with the agreements entered into by the two Presidents and I do find there is a little problem in getting the enthusiastic support of the Department of Agriculture perhaps for the same reason that they are being told that if they do anything of this sort it comes out of some other program they do not want to cut back on.

I am frankly disturbed by that and you know it is not easy to control large organizations. The President has found that out and the Congress has known it for a long time, but if we have any suggestions for initiatives that we can take I would be very interested in hearing them from any of the panel.

Dr. WITTWER. I should say some of the very best minds in the country put the competitive grants package together and also that for sustained funding formula, I would hope that sufficient vision could be manifested in this area and we could move ahead. We need both, but not one at the sacrifice of the other.

Mr. BROWN. I was interested in one of the speakers and I am not sure who it was that commented some of the research being done on the economics of farming was being funded by NSF which is rather strange. I would think the Department of Agriculture would have a heavy vested interest in finding out whether it is cost effective to follow any particular mode of farming, whether it is organic, semiorganic or nonorganic or whatever it might be and yet, the department did not seem to be interested in funding that.

Mr. Chairman, recognizing the situation and the bells I would not want to prevent you from having your questions.

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Mr. AMBRO. This is a vote on the rule on standby gasoline rationing authority. I would suspect, since we have about 10 minutes, we will probably cross with other Members of the subcommittees and if you would like I will recess or turn it over to you. I am going down to vote. It will take 6 or 7 minutes to go down and vote and we will recess for that amount of time at which time I suspect Mr. Jones will be back. He and I both asked that you return and I am sure he has some questions and I would appreciate it if you could stick around for 5 or 6 minutes.

[Brief recess.]

Mr. AMBRO. Ed, I will turn it over to you.

Mr. JONES. If the panel would reassemble I have a question or two I would like to direct to you and we will try to let you go.

Dr. Lockertz and Dr. Cunningham, the Congressional Research Service report and the USDA project a 30-percent increase in agricultural productivity by the year 2000.

If the Nation adopts widespread organic practices, what impact will this have on productivity by the year 2000 and what impact would there be on farm income and consumer prices?

Dr. LOCKERTZ. That is a very difficult question to answer.

Mr. JONES. I am sure it is.

Dr. LOCKERTZ. I do not think we have the answer to that. Some people have put forth answers to that question but my view, and my ex-colleagues at Washington University, we know so very little about the subject of organic farming and in particular what we do know is about the current situation in which a tiny fraction of the farm population farms that way and it is virtually impossible to have any kind of reliable project from this current situation to a hypothetical future situation so I have to say that we just do not know and I do not think we have the data base and research base on which to answer that question, much as I would like to see it answered.

Mr. JONES. Thank you, sir.

Mr. Cunningham, how about you?

Mr. CUNNINGHAM. I think I would certainly agree. Certainly, any time that you have a group of farmers coming up with a system that is so substantially different than a conventional type of system as we have here and have those farmers actually develop that system, certainly the ability to project based on what they are doing would be limited.

I think that in terms of production, I can only speak again to what our farmers are doing and that is they do seem very competitive with their conventional farming neighbors, and in many instances getting premium prices for their production and in the area of human food.

Mr. JONES. I was very interested in what you had to say in your paper about premium payment being made for the products from organic farming. I was not aware of this fact.

I wonder if you could tell me how widespread the premium receipts actually are for organic farm products?

Mr. CUNNINGHAM. There are a number of channels that have been established for some time in that area. The natural foods industry is one that has now become, and I have heard many figures, one that I heard was in excess of $1 billion a year industry.

Mr. JONES. But that is for human consumption. I am talking about that which you alluded to in your statement about a farmer would pay a premium for feed grains.

Mr. CUNNINGHAM. Yes. The other area is feed grains and, in fact, that has been going on for some time in this form of agriculture in many instances by neighbors or large hog, dairy, or beef operations recognizing the value of that farmer's grain and buying it from him locally.

Our organization within the last year has instituted a program and we just started moving on it and I believe we moved about 3 to 4 million pounds of our farmers' grains to other operations for feed purposes during the last 6 to 9 months.

Mr. JONES. I suppose that if the situation prevails that there is probably not any substantial evidence but the universities or what-not, or your organization either proves that there is some advantage in the feeding of organic grains to livestock. Is there substantial evidence of that?

Mr. CUNNINGHAM. I do not think there is substantial evidence. I do not think there has been research on that.

At the University of Georgia I know there is a Dr. Roger Wyatt that is beginning to do some testing in the area of poultry feeds. There are a number of other loose studies where farmers who are producers of meats have done tests of the grain coming from their respective elevators, their local sources of supply and comparing it to those sources I have referred to here and they have found substantial differences in vitamin content, differences of protein levels as well as amino acid mixes and other nutritional factors that are testable.

Most of the people who are paying substantial premiums feel there are life support and health giving factors in the grains we have but we have not been able to determine that and put our finger on that point. Perhaps some research would show what those factors are.

Mr. JONES. Well, I see that the two subcommittee chairmen are back, George and Jerry and I have another question or two but I will withhold and I may ask you personally for an answer.

Thank you, very much.

Well, let me ask this. Mr. Sawyer, could you give us more details briefly on the cost and benefits of incorporating the IPM system on your farm?

Mr. SAWYER. Yes, sir. I pay $1—no, it is $1.80 an acre to the scouts to scout my cotton. If enough of us farmers got together and we have enough acreage it only costs us $1.80 to have it scouted by them and along with the county entomologist I have cut my spraying by the number of percent I have testified to and one spraying will pay for the scouting program. It will more than pay.

Mr. JONES. Normally, how many scout trips have to be made?

Mr. SAWYER. Well, they make at least one trip each week in the early stage of the cotton and in the latter stage they make two trips out there but it does not last but about 2 months and the number of acres we have involved in our program we take the cost of the scouts and divide the acreage into it and get a per-acre cost and each farmer pays his share of it.

Mr. JONES. Are the scouts college students?

Mr. SAWYER. Yes, sir; normally out for the summer that are trained in this field.

Mr. JONES. You do not grow tobacco?

Mr. SAWYER. No, sir.

Mr. JONES. How did you get that tobacco budworm?

Mr. SAWYER. He somehow migrated to our county but he is a tough bugger.

Mr. JONES. No tobacco near you, is it?

Mr. SAWYER. No, sir.

Mr. JONES. Thank you, gentlemen, very much. Jerry, I appreciate your allowing me to ask a question or two.

Mr. AMBRO. George, did you finish your line of questioning?

Mr. BROWN. Yes.

Mr. AMBRO. I wonder then, Dr. Wittwer, if we can talk a minute about nitrogen fixation.

Do you think yields could be maintained if biological nitrogen fixation is used?

Dr. WITTWER. If the transition is a gradual one. We have essentially the same input from biological nitrogen fixation now that we had 40 years ago. Meanwhile, there has been a tremendous increase globally from almost zero input up to nearly 50 million metric tons of chemically fixed nitrogen. Ten million to 12 million tons of this are consumed by the United States. A transition from chemically fixed to biologically fixed nitrogen is inevitable. Either we learn to fix nitrogen chemically in different ways than we do now and hopefully using renewable resources to do it, or we mount a massive effort of research in the biological nitrogen fixation area.

There are several routes to go. The legumes are commonly thought of as the most efficient biological fixers, but another very important potential input is with the blue-green algae in symbiotic relationship with the miniature fern agolla which exists in many cultural conditions throughout the world.

Mr. AMBRO. How about the Australian clover? Has anyone in the agricultural community say if they have looked at the subterranean clover in Australia?

Dr. WITTWER. Yes. Clovers and alfalfa are very different nitrogen fixers. Because of the very high intensity of the plant populations, they are the most productive in biological nitrogen fixation. Estimates range up to 400 to 500 pounds per acre per year.

Up until recently, nitrogen fertilizer and fossil energy have been very cheap and we have not mounted any major effort in this Nation or the world in moving toward alternatives. I am saying it is time that we did so. The options are many, the opportunities are great, and the research investment is extremely low.

Mr. AMBRO. Do you think from your own research, and again, any one else who would like to answer can, that this nitrogen fixation with respect to plant species use would require dramatic changes in agricultural practices in the United States?

Dr. WITTWER. Not necessarily. Looking at research opportunities there are at least three possibilities with biologically fixed nitrogen. They now exist with all legumes, the agalla-anabaena relationship in rice paddies, and with many forest tree species. Nitrogen fixing capabilities through research could be established for some additional major food crops in the future.

Mr. AMBRO. Anyone else want to respond? If not, as I said at the morning session I have questions for Doctors Aldrich and Pimentel. I see they have left but out of courtesy to our afternoon panel I would

prefer to ask those in writing though I do prefer this format, that is to get a kind of crossbreeding of attitudes, if you will.

Having said that I want to thank you on behalf of the other subcommittee chairmen and the entire committee for coming back this afternoon and spending so much time with us and for your excellent testimony.

While the panel is leaving I would like to say that we will continue the afternoon session in the same mode or format that we did this morning. We have some six witnesses who will be welcomed by me individually after which we will convene a panel of all six and proceed with the questioning.

The first witness with respect to overview is Dr. Leo M. Eisel, Director, U.S. Water Resources Council.

As Chairman Jones did, I will tell you that your entire testimony will be included in the record and you may proceed either extemporaneously or read it, or in any way you think is compatible with our time constraints.

STATEMENT OF DR. LEO EISEL, DIRECTOR, U.S. WATER RESOURCES COUNCIL

Dr. EISEL. Thank you, Mr. Chairman.

I am pleased to appear before the joint subcommittees hearing, and provide an overview on water and use requirements for the United States.

As you know, the Water Resources Council is in the final stages of publication of the Second National Water Assessment. The summary report is available, and I will be glad to provide copies to members of the subcommittees.

This national assessment presents current and projected water use and supply information for the entire Nation, for its 21 water resource regions, exhibit 1 to my statement, and for its 106 subregions, exhibit 2. Specific overview information is highlighted below.

WATER SUPPLY

Nationally, the United States has an ample supply of water from both surface and ground water sources. However, regional and local shortages exist because of uneven distribution of precipitation and associated runoff. Approximately 1,200 billion gallons per day flow into the oceans and lakes from the conterminous United States, exhibit 3 to my statement. Surface supplies are augmented by approximately 81 billion gallons of ground water withdrawn each day, exhibit 4. Ground water provides for about 25 percent of the total fresh water withdrawn for all off-stream uses.

GROUND WATER

In this report on water adequacy, special mention needs to be made of ground water.

In the United States, use of ground water for fresh water supplies has been increasing gradually. During the last 25 years total fresh water withdrawals—surface and ground water—increased at an annual rate of 2 percent whereas fresh ground water withdrawals increased 3.8 percent each year, on the average.

In 1975, ground water provided more than 40 percent of the total fresh water withdrawn in 23 of the 106 subregions. California extracted more ground water than all of the eastern regions combined.

For example, 48 percent of the total fresh water used in California in 1975 was obtained from wells; this accounted for 23 percent of the total national ground water withdrawal.

The principal use of ground water is for irrigation. In 1975, 82 billion gallons per day of fresh ground water were withdrawn for use. Of this quantity, 56 billion gallons per day were used for irrigation, which is about 68 percent of all ground water withdrawn and about 35 percent of all the water used for irrigation.

Serious ground water overdraft—that part of ground water withdrawal which exceeds recharge—is occurring in the High Plains from Nebraska to Texas, south-central Arizona, and parts of California. In the Texas-Oklahoma High Plains area, the ground water overdraft is about equal to the natural flow of the Colorado River.

More specifically, the Texas-Gulf region is experiencing a ground water overdraft of approximately 77 percent while the Arkansas-White-Red has an overdraft of about 62 percent.

Land subsidence resulting from ground water overdraft has also been a long-term problem. In California's central valley, for example, the land surface has already subsided several feet over a fairly large area. Analysis of the assessment data shows that 8 of the 106 subregions have critical overdraft problems, 30 have moderate overdraft, and 22 have only minor overdraft.

WATER USE

In 1975, the United States withdrew approximately 339 billion gallons per day of fresh water—surface and ground—for such offstream uses as agriculture, manufacturing, minerals production, domestic and commercial use, and steam electric generation. See exhibit 5.

By the year 2000, this amount is projected to decrease to 306 billion gallons per day, a 9-percent reduction. This decrease will be due to more efficient use of water as a result of conservation efforts, better technology and recycling and similar procedures.

Consumptive use of fresh water was 107 billion gallons per day in 1975. By the year 2000, consumptive use is expected to increase to 135 billion gallons per day, an increase of over 26 percent. Consumption use is more critical than the total quantity withdrawn for use because the water consumed is not available for downstream uses. The projected increase is a result of growth in manufacturing and mineral industries, steam electric generation, and agriculture, and also as a result of increased evaporation due to higher water temperatures resulting from increased recycling.

Exhibits 6 and 7 illustrate the uses of water by functional category. As is evident from these illustrations, agriculture is by far the largest user of water.

In 1975, agriculture claimed 48 percent of the total fresh water withdrawn and in terms of consumption, agriculture used 83 percent of the total consumption. By contrast, the second largest consumptive use of water was manufacturing and mining of our minerals. It accounted for only 8 percent of the net water consumed.

The third largest use of water was for domestic and commercial use of the cities and municipalities at 7 percent. Steam electric generation and public lands accounted for the remaining use of water.

Water in agriculture is used for irrigation and livestock. Livestock watering is only 1 percent of the total water withdrawn for agricultural use. However, the water consumed by livestock watering amounts to nearly two-fifths of the water consumed by municipal domestic needs. See exhibit 5.

In 1975, irrigation water withdrawal was about 157 billion gallons per day for the conterminous United States and consumptive use was 86 billion gallons per day. See exhibit 8.

In 1975, irrigation accounted for 81 percent of the total water consumed in the United States, and the California region used almost one-third of the total water consumed by irrigation.

Projections indicate that by the year 2000, water withdrawn for irrigation will decline to approximately 153 billion gallons per day and the water consumed will increase slightly to 92 billion gallons per day. Overall, agriculture will demand about 70 percent of the total water consumed in 2000.

Currently, the United States has about 2 billion acres used in agriculture and forestry of which about 422 million acres are croplands and 46 million acres are irrigated farmland.

We all know that efficient use of water is a goal of water conservation. If better management and technology can reduce water demand while producing the same level of service, the overall efficiency of water can be increased.

Irrigation is one candidate for water conservation because of the large quantities of water used and its concentrated practice in the relatively water short Western States. Recent reports indicate that the potential for savings in irrigation withdrawals is from 20 to 30 percent. These savings can be achieved by implementing such improvements as lined or covered canals, computer monitoring and scheduling of irrigation water releases, automated weirs and gates, irrigation at night instead of during the day, better land preparation, and improved sprinkler and drip systems.

In closing, I hope this brief presentation has provided the subcommittees with a general insight into the present and future availability and requirements for water in the Nation.

The Water Resources Council has also analyzed the adequacy of the Nation's water resources both in terms of quality and quantity considerations by regions and subregions. Such information is available and can be provided to your subcommittees, if so desired.

We are indeed pleased that this joint subcommittee is giving attention to what we consider a very important consideration for the well being of our Nation.

Thank you, Mr. Chairman.

Mr. AMBRO. Thank you, Dr. Eisel.

Let me compliment you on providing us with eye opening facts and would like to ask you if you will provide us with the detailed breakdown that you mentioned when you were going over page 3 of your testimony.

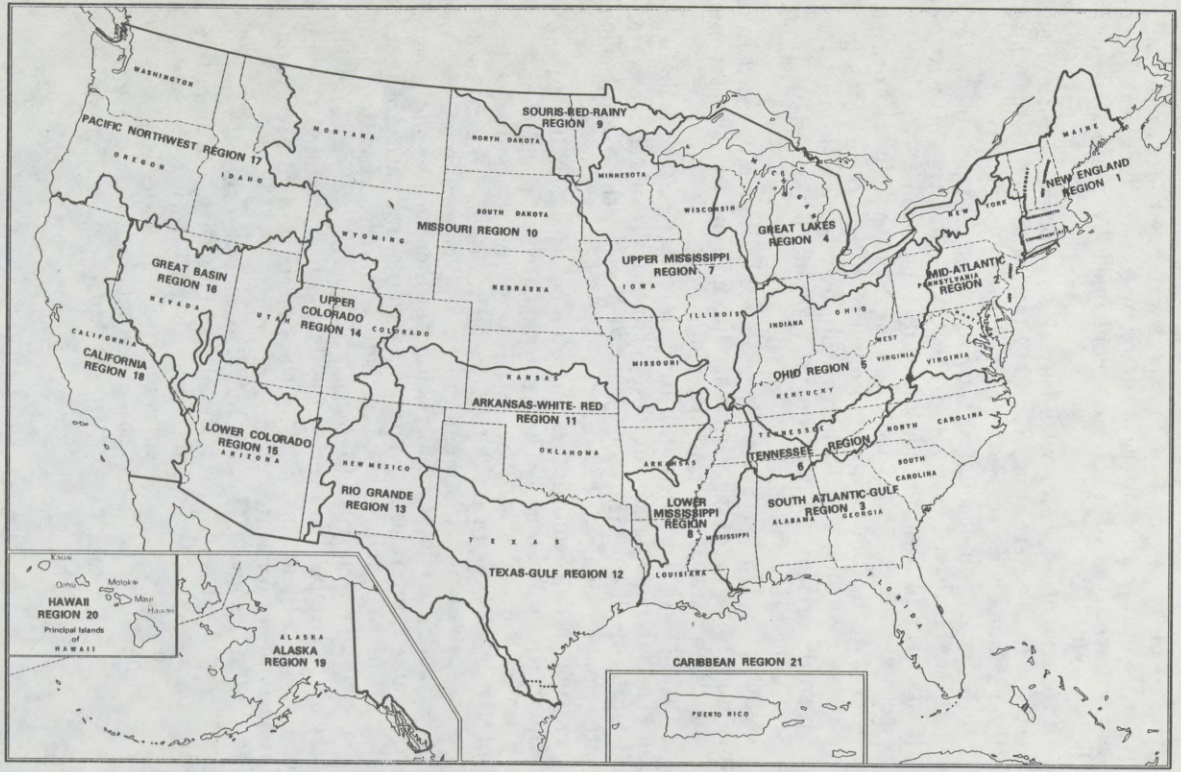
Dr. EISEL. Certainly. This basically is for the 106 subregions concerning the serious ground water overdrafts.

Mr. AMBRO. I thought you said 109.

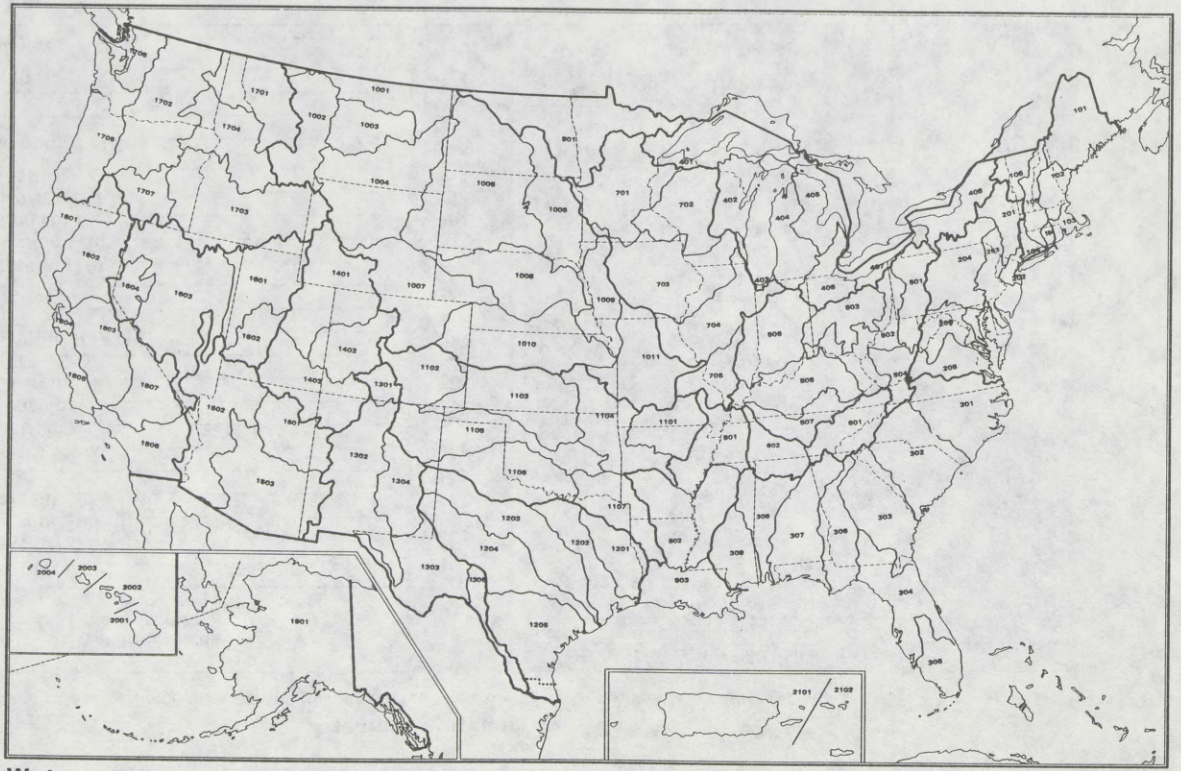
Dr. EISEL. I meant 106.

Mr. AMBRO. We will place the various exhibits attached to your statement in the record at this point.

[The exhibits referred to follow:]



Water Resources Regions



Water resources subregions used in the Second National Water Assessment

Streamflow frequency—"1975"

[Italic numbers not included in total because these are inflows to another region]

Water resources region and No.	Mean	Streamflow, in billion gallons per day			
		Percent exceedance			
		5	50	80	95
New England (1)	78.2	107.7	77.4	62.7	48.3
Mid-Atlantic (2)	79.2	115.1	77.8	61.2	48.4
South Atlantic-Gulf (3)	228.0	356.6	219.3	164.1	121.8
Great Lakes (4)	72.7	103.9	71.7	57.3	44.9
Ohio (5)	*178.0*	*254.0*	*178.0*	*141.0*	*105.0*
Tennessee (6)	*40.8*	*57.9*	*40.8*	*35.9*	*31.4*
Upper Mississippi (7)	*121.0*	*189.0*	*121.0*	*91.8*	*65.3*
Lower Mississippi (8)	433.0	757.0	433.0	282.0	202.0
Souris-Red-Rainy (9)	6.0	11.4	5.8	3.4	1.8
Missouri (10)	*44.1*	*74.3*	*43.2*	*29.9*	*17.6*
Arkansas-White-Red (11)	*62.6*	*120.7*	*59.1*	*37.4*	*21.6*
Texas-Gulf (12)	28.3	62.4	22.9	12.3	6.3
Rio Grande (13)	1.2	4.4	.6	.3	.2
Upper Colorado (14)	*10.0*	*15.6*	*10.0*	*7.0*	*3.9*
Lower Colorado (15)	1.6	1.7	1.6	1.4	1.2
Great Basin (16)	2.6	4.7	2.4	1.6	1.2
Pacific Northwest (17)	255.3	344.7	254.3	213.3	179.7
California (18)	47.4	87.4	44.3	29.8	19.5
Total, Regions 1–18	1,233.4	1,956.9	1,210.9	869.4	675.3
Alaska (19)	905.0	1,030.0	898.0	795.0	705.0
Hawaii (20)	6.7	10.3	6.3	4.9	3.8
Caribbean (21)	4.9	7.1	4.5	3.3	1.6
Total, Regions 1–21	2,150.0	3,004.3	2,119.7	1,692.6	1,385.7

Ground-water withdrawals and percentage of overdraft—"1975"

Water resources region and No.	Total withdrawal (mgd)	Overdraft		Subregions		
		Total (mgd)	Percent	Number in region	Number with overdraft	Range in overdraft (percent)
New England (1)	635	0	0	6	0	...
Mid-Atlantic (2)	2,661	32	1.2	6	3	1- 9
South Atlantic-Gulf (3)	5,449	339	6.2	9	8	2-13
Great Lakes (4)	1,215	27	2.2	8	1	30
Ohio (5)	1,843	0	0	7	0	...
Tennessee (6)	271	0	0	2	0	...
Upper Mississippi (7)	2,366	0	0	5	0	...
Lower Mississippi (8)	4,838	412	8.5	3	3	7-13
Souris-Red-Rainy (9)	66	0	0	1	0	...
Missouri (10)	10,407	2,557	24.6	11	10	4-36
Arkansas-White-Red (11)	8,846	5,457	61.7	7	7	2-76
Texas-Gulf (12)	7,222	5,578	77.2	5	5	24-95
Rio Grande (13)	2,335	657	28.1	5	4	22-43
Upper Colorado (14)	126	0	0	3	0	...
Lower Colorado (15)	5,008	2,415	48.2	3	3	7-53
Great Basin (16)	1,424	591	41.5	4	4	7-75
Pacific Northwest (17)	7,348	627	8.5	7	5	4-45
California (18)	19,160	2,197	11.5	7	5	7-31
Regions 1-18	81,240	20,889	25.7	99	69	1-95
Alaska (19)	44	0	0	1	0	...
Hawaii (20)	790	0	0	4	0	...
Caribbean (21)	254	13	5.1	2	1	5
Regions 1-21	82,328	20,902	25.4	106	60	1-95

Total withdrawals and consumption, by functional use, for the 21 water resources regions—"1975," 1985, 2000

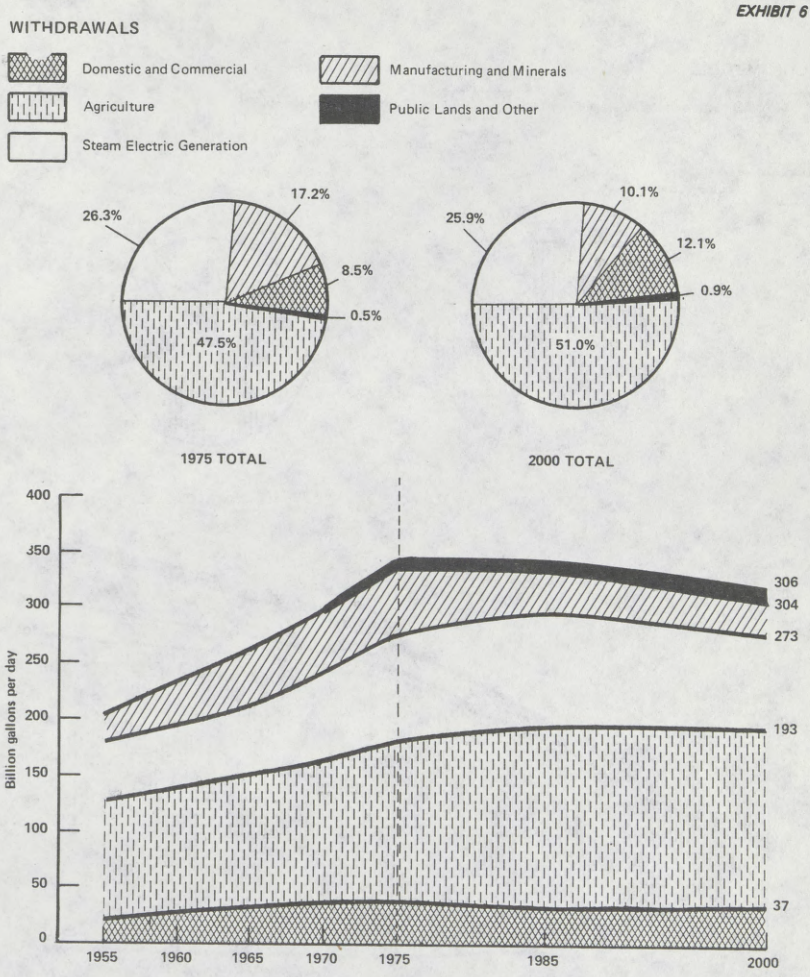
[million gallons per day]

Functional use	Total withdrawals			Total consumption		
	"1975"	1985	2000	"1975"	1985	2000
Fresh water:						
Domestic:						
Central (municipal)	21,164	23,983	27,918	4,976	5,665	6,638
Noncentral (rural)	2,092	2,320	2,400	1,292	1,408	1,436
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Manufacturing	51,222	23,687	19,669	6,059	8,903	14,699
Agriculture:						
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506
Livestock	1,912	2,233	2,551	1,912	2,233	2,551
Steam electric generation	88,916	94,858	79,492	1,419	4,062	10,541
Minerals industry	7,055	8,832	11,328	2,196	2,777	3,609
Public lands and others[1]	1,866	2,162	2,461	1,236	1,461	1,731
Total fresh water	338,500	330,375	306,397	106,590	120,545	135,080
Saline water,[2] total	59,737	91,236	118,815			
Total withdrawals	398,237	421,611	425,212			

[1] Includes water for fish hatcheries and miscellaneous uses.

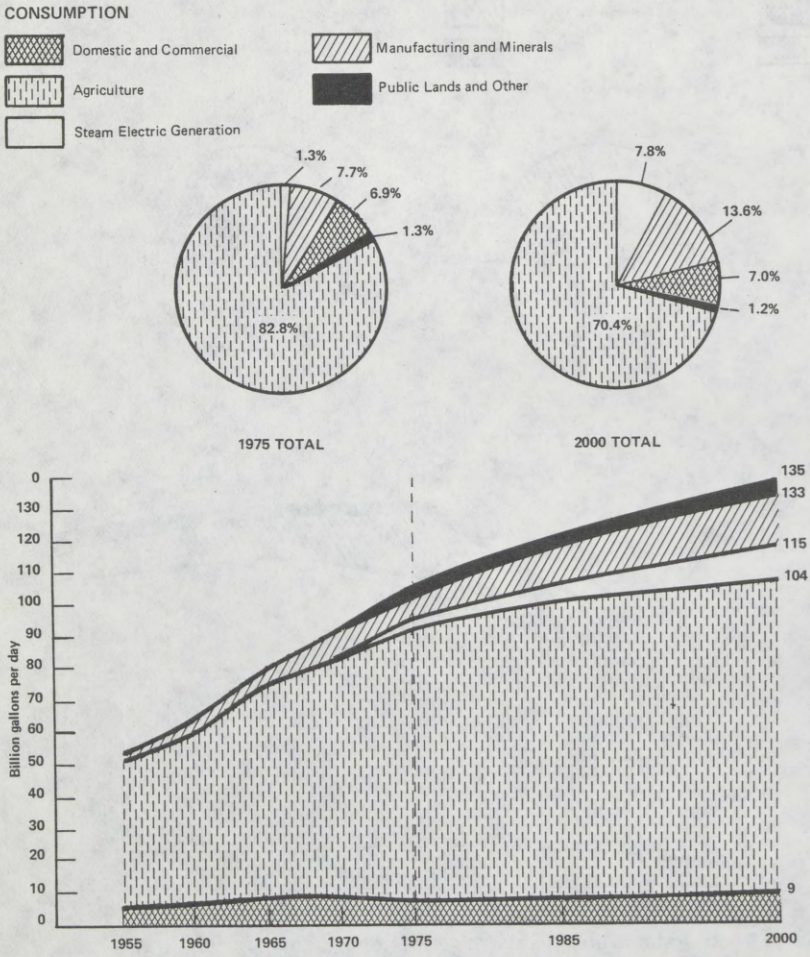
[2] Saline water is used mainly in manufacturing and steam electric generation.

EXHIBIT 6



Total fresh-water withdrawals, by functional use

EXHIBIT 7



Total fresh-water consumption, by functional use

Irrigation fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	35	41	46	25	29	33
Mid-Atlantic (2)	265	366	481	196	269	354
South Atlantic-Gulf (3)	3,464	4,008	4,509	2,752	3,184	3,597
Great Lakes (4)	145	211	282	114	169	232
Ohio (5)	47	68	91	37	53	74
Tennessee (6)	14	18	21	11	14	17
Upper Mississippi (7)	192	283	387	153	230	323
Lower Mississippi (8)	4,580	4,559	4,444	3,065	3,204	3,272
Souris-Red-Rainy (9)	46	144	434	37	116	350
Missouri (10)	31,636	39,376	36,236	14,214	17,597	17,607
Arkansas-White-Red (11)	9,980	10,483	9,776	7,048	7,468	7,125
Texas-Gulf (12)	11,538	9,333	7,427	9,347	7,597	6,100
Rio Grande (13)	5,684	5,498	4,873	3,886	3,920	3,570
Upper Colorado (14)	6,400	7,223	6,672	2,194	2,657	2,741
Lower Colorado (15)	7,989	7,299	6,343	4,026	3,962	3,720
Great Basin (16)	6,969	6,120	5,825	3,225	3,082	3,196
Pacific Northwest (17)	33,181	34,639	29,961	11,026	13,362	13,213
California (18)	34,611	34,863	34,764	24,282	25,134	26,311
Total, Regions 1–18	156,776	164,532	152,572	85,638	92,047	91,835
Alaska (19)	4	4	4	3	3	3
Hawaii (20)	1,447	1,226	951	474	481	473
Caribbean (21)	516	490	319	276	289	195
Total, Regions 1–21	158,743	166,252	153,846	86,391	92,820	92,506

Mr. AMBRO. Dr. Eisel, if you would withdraw now but remain in the room for the later panel session I would appreciate it.

At this time I would like to call on Mr. Victor Koelzer, consultant and civil engineer, of Fort Collins, Colo.

I would like to welcome you, sir, and I hope I pronounced your name correctly.

STATEMENT OF VICTOR A. KOELZER, CONSULTANT AND CIVIL ENGINEER, FORT COLLINS, COLO.

Mr. KOELZER. Thank you. I would like to compliment you on pronouncing it correctly, but I do not get disturbed if it is not.

My statement will focus on development of water supplies for irrigation in the 10 major river basins of the States west of the Mississippi. This is not a total picture of irrigation of agriculture in the U.S., since supplemental irrigation is currently being practiced to some degree in most other States, particularly in the South Atlantic-Gulf and Lower Mississippi basins, as well as in Hawaii. However, consumptive use of water for irrigation in the 10 western basins represents 91 percent of the total estimated consumptive use for irrigation in the United States in the year 2000.

My statement also is concerned primarily with available water quantity, although certainly water quality is equally important—if the available supply is not of adequate quality, it is almost equivalent to no supply at all. However, my expertise with regard to water quality is quite limited and I am assuming that others will speak to that important subject.

My remarks deal with six major aspects of supplies for development of irrigated agriculture: (1) available supplies; (2) analysis of potential water uses; (3) efficiency of water use; (4) competing water uses; (5) loss of "prime" agricultural land; and (6) integration of management of surface water and ground water.

AVAILABLE SUPPLIES

The Water Resources Council has presented extensive information on the availability of supplies in different major river basins of the country. I am sure that Dr. Walker will present details of this information. However, I would like to point out three things:

First, the data in the Council's assessments are for total supplies within a basin and thus, do not show areas within basins which are heavy or small contributors to the basin total;

Second, the supplies do not show the degree to which reuse water is available, from return flows of cities, industries or irrigation; and,

Three: The data represent something near the average supplies. Thus, in comparing supplies with projected uses, local problems within basins can exist which are not revealed by basin totals and periods of drought can cause serious problems which are not reflected in long-term averages.

ANALYSIS OF POTENTIAL WATER USES

One of the problems of the presentation in the Water Resources Council's Assessment is that very little identification is given to the relative importance of the different projected uses. This is understand-

able in an organization such as the Council, which takes action by consensus and would be hard pressed in many cases to take positions with respect to relative importance. A person in my position need have no such inhibitions.

The result is that the assessment consists of relatively simple tabulations or charts, depicting the uses for irrigation, municipal water, manufacturing, et cetera.

Without any qualifications as to how important it would be to meet each of the various segments of water use, the mere presentation of such projections tends to make the reader view them as a "requirement". There is a strong implication that each segment of use must be met, which tends to make the forecast of self-fulfilling prophecy.

Several years ago the National Water Commission attempted to meet this objection by analyzing the need for irrigated agriculture by considering 11 so-called "alternative futures." Each "alternative future" was a scenario representing a possible combination of farm policy, U.S. population, water price, exports and level of technology.

By this process, the reader could select the scenario he considers to be most likely. The Commission's conclusion, that the then existing 35 million irrigated acres could be reduced by the year 2000 by amounts varying from 5.5 to 22 million acres, and still meet all requirements of the various scenarios was widely criticized as being unrealistic.

The most severe criticisms of the Commission's studies were:

One: Most of the farm policy scenarios assumed a free market, which has existed only in a very few years out of the last 40;

Two: The assumptions about prices that would be placed on irrigation water—$15 to $30 per-acre-foot—were neither representative of contracts negotiated for payout of projects nor values that were institutionally possible to implement; and,

Three: That the range of possible exports was too low in view of definite trends toward higher amounts.

This latter assumption was particularly one-sided in that the only assumption of exports exceeding the 1967–1969 years was double that average by the year 2000, whereas exports that were double the 1967–1969 average were reached in the 1972–1973 export year, the year the Commission's report was released, and the exports have exceeded double the 1967–1969 average in each of the last 5 export years.

I have found it helpful to use another approach prepared by the Planning Panel of the National Water Commission, in comparing developed water supplies to the Water Resources Council's tabulations of water uses. The meeting of some segments of water use is obviously of more importance than others. Drinking water for people, obviously, is more important than supplying water to irrigate corn, since corn is a surplus commodity which can be grown easily in non-irrigated areas and which must be exported to handle surpluses. One is an imperative which must be met, the other represents an opportunity for economic exploitation, but is far from being essential.

It is helpful, therefore, to view competing uses as fitting into a spectrum of importance, ranging from "needs" to "opportunities". Although few uses can be absolutely categorized as occupying a specific position, most will trend toward some particular position in the spectrum.

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EFFICIENCY OF WATER USE

An understanding of the concept of withdrawals versus consumptive use is highly important when comparing the available water resources to various uses in the spectrum of needs and opportunities. In some uses, particularly the domestic uses of drinking water, bathing, toilet flushing, et cetera, virtually 100 percent of water withdrawn is returned to some water body after use. Water quality may be degraded, but the water can be used for most purposes if the point of return is physically located in a stream system so it can be economically exploited. If used water is discharged into a sink, such as the Great Salt Lake, or to the ocean, it is not reusable.

Other uses, that is agricultural irrigation or lawn sprinkling, typically consume about 70 percent of water withdrawn. Industrial uses will vary widely as to the amount consumed, but the percentage of water returned is often quite high. The ability to reuse is again dependent on quality and the point of return to the system.

Some uses are totally instream and may involve no consumptive use. Environmental uses for fishery flows and scenic attractions, navigation, and hydropower are in this category, the requirement being expressed in terms of providing given rates of flow.

Some such instream uses also may involve evaporation from reservoirs or by use of phreatophytes and thus do involve direct consumptive use of water.

Efficiency of use is often viewed as having a direct relationship to the amount of water conserved. However, it is obvious that conservation efforts will have varying degrees of impact if viewed in the context of consumptive use, as opposed to withdrawals. For example, water conservation in the home, such as conserving water used in a plumbing fixture or appliance, or water saved at the point of application for irrigation, has a large local impact. That impact may represent a saving in withdrawal of 100 percent of the water conserved.

This saving in diversion can be highly important in the savings in storage and diversion facilities, in municipal water treatment facilities or in waste treatment facilities, the cost of which often bear a close correlation to the amount of water diverted. Thus, significant economic savings, as well as some beneficial environmental impacts can result.

This is not, however, the whole story. When considered on a consumptive use basis, so-called savings by conservation measures are often an illusion.

Water "saved" through more efficient plumbing is not a saving in the total stream system, since virtually all of the water used in plumbing systems is returned, through the sewer system and the waste treatment plant, to the stream systems. In eastern cities, return flow for all domestic uses is close to 100 percent of the water diverted, while in western cities it may fall as low as 70 percent, due to consumptive use of water through law irrigation.

Similarly, in many systems, much of the water "lost" in application of irrigation water eventually returns to the stream system. Such return flow is often on the order of 30 percent of the water diverted.

Thus, when we hear the assertion that, if we could only save that 30 percent, we would automatically increase our supplies by an equal

amount, it is a gross oversimplification, because in many cases that water is returned to the stream system and, if of good quality, can be reused.

Thus, to the extent that return flows can be reused, conservation does not represent a true saving. We fear that it often is viewed as such, creating an illusion of savings that are greater than can be realized. There is danger in promising too much.

Consideration of conservation is too complex to assume that it is, by definition, always justified. Since water is a resource that is renewed every year, water conservation should not be an end in itself, and is justified only if it serves an economic or environmental purpose.

For example, conservation of deliveries of water by an irrigation district whose wastewater is of good quality can be reused and is justified only if the costs of storage and diversion facilities that are saved justifies the costs of the conservation measures—it may well not be economically justified from the viewpoint of saving water in the total stream system. In fact, such savings in deliveries can have adverse environmental consequences, such as where elimination of seepage from canals eliminates or reduces areas for wildlife habitat.

Therefore, steps for water conservation should be analyzed on a case-by-case basis. Its economic justification should be analyzed in each case by economic comparison with other alternatives for storage and diversion, as well as for its environmental consequences. It could then be included in a plan when justified on these bases, rather than being a necessity in each plan that is developed, as is often visualized.

COMPETING WATER USES

I return now to the needs versus opportunities approach in comparing water supplies with potential water uses. I will give my concept of where various uses fit in the spectrum of needs and opportunities.

As to needs, the only water use that can be considered as an absolutely imperative in drinking water, assuming that people already live in an area to be served. Other components of domestic water—flushing of wastes, bathing, operation of appliances—while not absolute imperatives trend toward being in the "needs" categories, or at least in the high end of the spectrum of "opportunities."

Certain agricultural crops have to be grown under irrigation in order to meet consumer demands for a continuous supply of fresh fruits and vegetables. Such crops, which utilize only 11 percent of the western regions irrigated acres, represents a high priority use for water to meet consumer needs. Many will consider such uses to be in the "needs" category.

OPPORTUNITIES

Irrigation is the largest user of the Nation's water resources, representing almost 75 percent of forecasted consumptive use for all purposes in the Western United States in the year 2000. This agricultural use has come from both private and public investments. During the early years of development and in the past two decades, irrigation development has largely come from private investments. Of the 35 million acres irrigated in the 17 Western States, less than 10 million acres were developed under Federal projects.

Increased competition for historical irrigation water and depletable ground water supplies in the Great Plains are reasons for concern about the future of water for irrigation in the United States. While the total acres that will be retained in irrigation in the future may be unpredictable, it does seem clear that substantial shifts in irrigated crops will be made in the irrigation sector. Some recent evidence for this shift took place on the high plains of Texas when the high cost of energy resulted in a shift of irrigation from low value wheat production to higher value crops. Similar types of shifts in irrigated crops will undoubtedly be made in the future as the cost of irrigation water increases.

Where does irrigation rank in the spectrum of opportunities? In my opinion, its position will vary, largely dependent on the economic value of production. This will not necessarily agree with the perception of the role of many westerners of irrigation. To many, irrigation has developed almost a sacred position, expressed as "water for irrigation is the lifeblood of the West". This concept may have had validity in the early stages of opening of the West, but today, evaluation for new projects in the West can more closely rest on purely economic evaluations. Some will agree that exceptions to this will occur where equities between States, as reflected by interstate compacts, are involved.

Industrial uses are not imperatives, but most will fit high in the spectrum of opportunity uses because of their importance to the national economy.

Nationally, industrial activities—manufacturing, mineral processing, ordinance and construction—account for 37 percent of total income and 29 percent of civilian employment.

Without going into specifics, it is obvious that some industrial uses will have a higher opportunity value than others. Quality aspects of return flow will have an important bearing. Recycling to maintain stream quality probably will hold down future withdrawals.

Water uses for energy production will be rated high in the scale of opportunity uses by many, particularly in view of current needs for minimizing U.S. dependence on oil importations. Included are cooling water for steam electric powerplants, evaporation from reservoirs used for hydropower, and water needs for oil shale and synthetic fuel development.

Environmental objectives served by instream flows include maintenance of fish life for sports fishing, maintenance of rare and other needed aquatic species, maintenance of scenic attractions, and maintenance of wildlife habitats, refuges, bays and estuaries.

Estimates of instream flow requirements to meet opportunities for navigation purposes have not been estimated separately from other instream needs in the major river basins of the Western States. These opportunities are not mutually exclusive of opportunities for other instream purposes. In most cases, there can be, with some adjustments, a high degree of compatibility between releases for navigation and those for hydropower and for environmental uses.

Opinions will vary considerably on where instream uses will rank in the spectrum of values of usage. Most will agree that they are in the category of opportunities, rather than being absolute needs. Some environmental advocates may disagree, and certainly will argue that

instream environmental uses rank high in the spectrum of opportunities.

On the other hand, developmental advocates will argue for a lower position. Both will agree that allocation for such uses cannot be made totally on the basis of monetary evaluation of benefits.

The Water Resources Council has made the comparisons shown in table I for the 10 major river basins in the Western States. The comparisons indicate that the available water is insufficient to meet all potential uses plus in-stream flow desires in 3 of the 10 western basins.

Mr. AMBRO. We will insert table I in the record at this point.

[Table I referred to follows:]

TABLE I.—SUMMARY OF FRESH-WATER SUPPLY AND USE FOR THE YEAR 2000[1]

[Data are in million gallons per day]

Water resources region and number	Supply				Use				
	Stream inflow[2]	Natural outflow[3]	Net imports	Ground-water overdraft	Total consumption	Net evaporation[4]	Net export	Remaining stream outflow	Instream flow approximations[5]
Souris-Red-Rainy (9)	0	6,138	641	0	446	19	0	6,314	3,673
Missouri (10)	0	61,525	0	0	19,913	5,595	137	35,880	33,958
Arkansas-White-Red (11)	0	67,694	200	0	8,887	3,111	0	55,896	46,169
Texas-Gulf (12)	0	35,626	30	0	10,529	1,992	0	23,135	22,917
Rio Grande (13)	0	5,309	199	0	4,016	785	0	707	2,287
Upper Colorado (14)	0	13,956	0	0	3,232	728	1,095	8,901	7,947
Lower Colorado (15)	8,901	−605	0	0	4,708	1,236	3,896	[6]−1,544	6,864
Great Basin (16)	0	5,976	251	0	4,036	333	0	1,858	3,389
Pacific Northwest (17)	0	268,523	47	0	15,196	2,083	0	251,291	214,004
California (18)	0	68,050	3,881	0	29,699	686	0	41,546	32,607

[1] "The Nation's Water Resources, 1975–2000," Second National Water Assessment, by the U.S. Water Resources Council U.S. Government Printing Office, Washington, D.C. 20402, December 1978.

[2] Flow across international boundaries is not shown.

[3] Estimated water supply generated within each region. Negative values indicate that evaporation and plant transpiration are greater than rainfall in the region.

[4] From man-made reservoirs with storage capacities larger than 5,000 acre-feet and from farm ponds and lagoons. If precipitation exceeds evaporation value is zero.

[5] U.S. Fish and Wildlife Service estimates for optimal and wildlife habitat conditions.

[6] Negative values show the amount of excess water use without ground-water overdraft. Streamflow will be maintained to meet commitments to Mexico.

Mr. KOELZER. Mr. Chairman, this does not mean that economic or environmental disaster faces those regions. The available supply is far more than needed for drinking water, the one imperative that can be represented as an absolute need. It also is far more than needed for those aspects which rank very high on the opportunity scale, such as other domestic uses, certain manufacturing and energy uses, high cash crop agricultural uses and many environmental uses.

The major accommodations that will be required are in the lower portions of the spectrum of water use opportunities. Included will be many agricultural uses—particularly for crops that are surplus and are, or can be produced in nonirrigated areas—navigation, hydropower and some environmental uses. Most can be evaluated on the basis of dollar economics, but the final accommodations required between such uses and environmental uses must be made primarily in the political arena.

LOSS OF "PRIME" AGRICULTURAL LAND

The growing competition between agricultural uses and other potential uses can cause problems. Many economists will argue that such competition, both for presently developed water and potential future

developments, should be settled by allowing the free market to operate to decide how water shall be used. Such market forces currently operate in some areas. One that I am familiar with is the northeast Colorado area, where an open market is presently causing currently irrigated land to be transferred to urban and industrial purposes through purchase of irrigation water. Undoubtedly, potential energy uses also will be able to outbid agriculture for water in the future.

Many view this transfer of use by the market process as a major problem. I have been asked, on occasion, for suggestions as to how to strengthen and preserve the ability of agriculture to prevent such transfers.

I do not accept the view that transfer of water from agriculture to energy is to be deplored in all cases. In view of the large surpluses we have today in farm production in some major commodities, which require exports of over 50 percent of our wheat and 30 percent of our corn, it is difficult for me to accept a view that loss of any agricultural land is a tragedy.

Future growth in crop yields, coupled with some offsetting increases in agricultural land—such as development of timbered lands in the South and ground water irrigation in areas of good ground water in the Northern High Plains—should more than meet future U.S. food needs, as well as continuing high exports.

One would have to develop a total global view of food needs before the loss of some of our agricultural lands could become a problem. I am not certain it represents a problem even then, in view of the undeveloped land presently existing in the world and the vast potential for increased yields that exists in developing countries.

Further, I ask the question "Is it the responsibility of the United States to adopt a total worldwide concern, irrespective of our own interests, in the world food picture"?

Second, in irrigated areas the loss of presently irrigated land in the west to burgeoning urban growth is far from being a total loss. This is contrasted with losses of land in unirrigated areas, such as where the prime farm lands around Chicago are totally lost when such lands are urbanized.

In the West, aside from the fact that water taken from most irrigated agriculture to serve urban needs results in a higher valued use of water and almost certainly a higher level of economic activity, is the fact that most of the water thus "taken" is not lost to the total agricultural picture. At least 70 percent—and as high as 90–100 percent if lawn watering is eliminated—of water used for municipal uses is returned to the hydrologic system for usage downstream by other agricultural interests.

Since availability of irrigable land in most of the West is not short—only water is—this means that other agricultural land can be brought under irrigation as irrigated land near urban centers is phased out to accommodate urban growth. This can result in higher irrigation development costs, but this is one of the tradeoffs that need to be evaluated.

Also, in some areas—but not in Colorado—State laws may preclude the transfer of point of use of the water. The Northern Colorado Water Conservancy District has accumulated statistical information which demonstrates that this transfer of location of irrigated lands

has actually taken place within the district, without significant loss of total irrigated land, while urban areas in the district are rapidly expanding into irrigated areas.

There can be environmental losses involved in the transfer of agricultural water use to urban use, such as the loss of greenery or open space. The entire question is one of tradeoffs, economic as well as environmental.

In my view, this precludes overall, simplistic decisions as to whether lands and waters should be retained for agricultural uses instead of being used for urban or energy purposes, or vice versa.

The situation calls for a framework in which these tradeoffs can be analyzed and presented for decision, on a case-by-case basis. In my opinion, the evaluation procedures espoused by the Water Resources Council in its "Principles and Standards," while by no means perfect in their present stage of usage, offers such a framework. They would allow the evaluation of economic tradeoffs involved in transfer of water use from agriculture to "energy," and provide a means whereby the consequences of such transfers on environmental quality, regional development and quality of life can be displayed in a manner that would allow decisionmakers to make informed judgments.

INTEGRATION OF MANAGEMENT OF SURFACE AND GROUND WATER

The following statement on this subject is taken largely from a position paper developed by the Water Policy Committee of the American Society of Civil Engineers, a paper in which both Dr. Ackermann and I had a leadership role.

It is well known that surface water and ground water cannot always be viewed in isolation, since at various times in the hydrologic cycle, there is physical interchange between the two.

There is justification for this separation, in many cases, of supplies for small communities—for example, in many areas of Illinois—where the municipal supply is rather distinctly from either ground or surface water and there is little interchange between the two that is of practical significance from a supply viewpoint.

Yet, they are often treated as separate entities in many instances of larger supplies, such as for irrigation, where such separate consideration is inappropriate.

In these cases, the separate consideration relates to the laws pertaining to their use, to the institution which deals with them and, sometimes, to scientific or engineering procedures which are inadequate for planning their use.

Many of the problems of ground water use result from an inadequate understanding of the physical principles of aquifer systems. Generally speaking, there are less data available for ground water systems than for surface water. The ability to model ground water systems is not as well developed for surface water, and data cannot be transferred between areas of hydrologic similarity as easily, if at all, as they can for surface water. This, in turn, results in an inadequate understanding of the economics and principles of interaction between ground and surface water systems.

Only a few States have water rights laws which recognize the interaction of surface and ground water. Many have laws governing

surface water rights but in most the laws pertaining to use of ground water are either indefinite or overly permissive in pumping. A few States have encountered difficulty in protecting surface water rights because of excessive ground-water pumping and have had to move toward conjunctive use laws.

Improved laws are needed in many areas, and since water rights are a matter of State primacy, more States should move in that direction, where needed.

Efficient integration of surface and ground water would, ideally, permit drawdown of the aquifer during low flow periods and the use of the aquifer for storage of excess surface flows at times of high surface runoff.

Difficulties in understanding or in obtaining data on response time or capacity of aquifers may prevent efficient use of an aquifer as a storage vehicle for such surplus surface water. In some instances, the transmissability limits movement in an aquifer and inhibits its use for storage. In other cases, State laws are restrictive, preventing pumping of the aquifer in a manner to create storage. The situation is too complex and site-specific to allow generalization, but it may be possible to allow use of some aquifers as a storage vehicle to achieve better integration of surface and ground water use. However, it should be approached cautiously, on a case-by-case basis, to avoid injudicious mining.

Another problem is the degradation of ground water, which may not be restricted to the large user, but may occur in supplies for small communities as well.

Since degradation is not visible, and often remains undetected until there is a crisis, it is often neglected. However, continuing a "hands off" policy on ground water quality will only encourage continued procrastination. To limit interest to regulating point pollution sources leaves much of the problem unsolved.

On the other hand, the arbitrary "standards" approach of the Federal Water Pollution Control Act, with no regard to cost should be avoided.

The problems that have been discussed will not be easy to solve. However, effective planning and management of conjunctive use of aquifers and surface water sources will contribute to their solution in many instances.

That concludes my statement.

Mr. AMBRO. Mr. Koelzer, I ask that you be available for the panel later on.

I now call up Professor William E. Martin of the University of Arizona. You may proceed in any way you wish, Professor.

STATEMENT OF PROF. WILLIAM E. MARTIN, DEPARTMENT OF AGRICULTURAL ECONOMICS, UNIVERSITY OF ARIZONA

Professor MARTIN. Thank you, sir.

I have been studying the supply of water in agriculture for the past 20 years and its relationship to economic development in the West.

I have provided two separate statements, both focusing on the adequacy, cost and benefit of public investment of water supply in the West and I will just briefly summarize both of them without going into them in detail.

The first statement, "The Need for Additional Water in the Arid Southwest" summarizes a good deal of our research in the area and takes the traditional economic efficiency point of view. Its general conclusion is that while public irrigation development was a cornerstone in the development of the West, it is no longer necessary or even advantageous to try to maintain a high level of irrigated agriculture in this area. Acreage is bound to decline in future years as higher valued uses bid away water from agriculture.

The marginal crops, that is hay and grains, will decline in the West and move towards the East. Vegetables and fruit crops, the high value crops, will remain.

Also, net income in agriculture will decline much less rapidly than will agricultural acreage itself. Such a process should not be cause for general alarm. It will not slow economic growth and in fact, will be necessary for further economic development.

In my second statement, "Returns to Public Irrigation Development and the Concomitant Costs of Commodity Programs," I take a little bit different view and try to present the argument for public investment and irrigation.

Now, to do so one must value the distribution effect of a cheap food policy more than the value of being economically efficient; that is, you have to value a cheap food policy more than having the project having a positive benefit cost ratio.

You can make a case for net consumer benefits from public development in the past, especially in providing fruits and vegetables, even while at the same time irrigation contributes to our commodity surpluses and the cost of agricultural commodity support programs.

For example, since World War II total payments under commodity support programs have varied from about one-sixth of 1 percent in 1974 to almost 8 percent of total farmers' cash receipts from marketings on a national basis.

In 1969, a per capita consumer contribution of $19 is implied. In 1974, the contribution was only about $2.50. In 1977, the per capita contribution rose again to about $8.50.

The problem for consumers is they are paying for the privilege of not having higher quantities and lower prices on cereals and field crops, thus any benefits from public irrigation must be absorbed by vegetables, fruit crops, and nuts.

What might be the total incremental benefits to these crops? In 1977 per capita food expenditure was about $1,100. Ten percent of this expenditure was on fruits and vegetables and given the estimated elasticity of demand and assuming an increment in U.S. production of fruits and vegetables of 26 percent, the incremental consumer benefits attributable to public irrigation would be about $34 per capita.

If we compare that $34 per capita with the cost of our agricultural commodity programs, the Bureau of Reclamation projects have been worth the associated commodity costs in the past. Of course, those data summarize the past and current situation and I cannot help believing that in the future we will find that the less expensive project sites have already been developed and future development will be slight.

People are slowly beginning to believe that water runs downhill and to reverse that phenomenon requires energy. Arizona's Salt River

project, the first construction activity of the Bureau of Reclamation beginning in 1902 is a major producer of electricity, as well as agriculture. Currently, the central Arizona project is under construction. It will require a quarter of the output from three 750 megawatt generating units to lift that water more than 2,000 feet uphill. I cannot see that this trend can last very long. Thus, the growing scarcity of reasonably inexpensive water development opportunities along with growing competing needs for water lead to the same basic conclusions as in my efficiency argument.

Acreage of irrigated agricultural land will slowly decline in coming years as water is transferred to domestic municipal and industrial uses, especially to mining and electric generation. Agriculture production will tend to shift eastward again as western irrigation declines. This will be a slow process, probably not too much will be noticed in our lifetime, but the trend really is inevitable.

Thank you, Mr. Chairman.

Mr. AMBRO. Thank you, very much.

We will have both of your statements printed in the record at this point.

[The statements of Professor Martin are as follows:]

STATEMENT OF WILLIAM E. MARTIN, PROFESSOR OF AGRICULTURAL ECONOMICS, UNIVERSITY OF ARIZONA, TUCSON

SUPPLY AND QUALITY OF WATER FOR AGRICULTURE

Two separate statements, both focusing on the adequacy, costs, and benefits of public investment in agricultural water supply in the West follow.

The first, "The Need for Additional Water in the Arid Southwest," takes the traditional economic efficiency point of view. Its general conclusion is that while public irrigation development was a cornerstone in the development of the West, it is no longer necessary or even advantageous to try to maintain a high level of irrigated agriculture in this arid region. Irrigated agricultural acreage is bound to decline in future years as higher valued uses bid water away from agriculture. Such a process should not be cause for general alarm, and will not slow economic development.

The second statement, "Returns to Public Irrigation Development and the Concomitant Costs of Commodity Programs," presents the argument for public investment in irrigation. To do so, one must value the distributional effects of a cheap food policy more than the value of being economically efficient. A case is made for net consumer benefits from public development in the past. However, the growing scarcity of reasonably inexpensive water development opportunities, along with growing competing needs for water, lead to the same basic conclusions as before. Acreage of irrigated agriculture will slowly decline in coming years.

THE NEED FOR ADDITIONAL WATER IN THE ARID SOUTHWEST: AN ECONOMIST'S DISSENT

(By William E. Martin)

The framers of water policy in the arid western United States have generally been committed to providing a full and plentiful supply of water, on the assumption that water was the "limiting resource" and that rapid expansion of the local and regional economies depends directly upon a liberal water supply. This proposition has been accepted by the public largely on the grounds that it was and is self evidently true. With the stark vistas of our desert surroundings serving as sufficient proof that water is a crucial resource, numerous schemes are presently being considered throughout the Southwest for obtaining additional supplies.

I, and several of my colleagues, on the basis of several years of investigation of the empirical evidence, have reached the conclusion that although economic

growth in the West may originally have been based on a liberal water supply, additional water is no longer necessary (at least in the foreseeable future) and may in fact be "detrimental to our health." In this statement, I review the evidence in support of this conclusion. My specific evidence is related only to the State of Arizona. However, I believe our findings have implications for the whole Southwest.

THE ARGUMENTS FOR ADDITIONAL WATER

The necessity for water importation into Arizona (and elsewhere in the West) has been justified on several grounds. It has been argued, first, that such a plan is a necessary condition to insure the continued growth of the economy. Second, it has been asserted that such a project would rescue agricultural communities dependent upon a dwindling supply of groundwater. Third, it is argued that additional water is desirable from the economic viewpoint, in that the benefits of such an investment will exceed the costs. In the following sections we turn to the evidence from Arizona relative to each of these three assertions, while arguing for the wider applicability of our conclusions.

WATER AND ECONOMIC GROWTH

Sufficient time has elapsed since the late 1940's to provide an adequate test of the hypothesis that continued economic growth in Arizona was dependent upon supplemental supplies of water. Population, employment, production, income and other measures have all registered growth rates that are among the highest in the nation, ranging from 200 to 600 percent and higher over a 20 year period.[1] By any measure, the hypothesis can hardly account for the data. Let us examine a model which does explain the data, and thus can be used as a basis for a prognosis for the future.

Over 90 percent of the 6 to 7 million acre feet of water utilized each year currently goes for crop irrigation. All other uses, household consumption, mining, manufacturing, etc., account for less than 10 percent of total water use.[2] Personal income (wages, salaries, rents, profits and interest) amounts to about $16 per acre foot of water used in the grain and forage sectors accounted for less than eight percent of personal income and grains and forages less than two percent of personal income as long ago as 1958. In contrast, returns per unit of water intake are relatively high in the nonagricultural sectors. In the manufacturing sector, the equivalent figure is greater than $80,000 per acre foot. A case in point: one of the large electronic plants in the Phoenix area provides more man-years of employment than do all the crop farms in Maricopa County, on an annual water consumption equivalent to that on about 1,000 acres of crops. Maricopa County has about 41 percent of all cropland in Arizona.

The manufacturing, tourist and associated service industries have been the most rapidly growing sectors since World War II. Manufacturing volume has increased more than ten-fold and tourist spending nearly as much.[3]

The market for land and water resources has been responsive to changing demands. This responsiveness, taken together with abundant and inexpensive groundwater supplies, has permitted water to be readily available to the most rapidly growing sectors of the economy at relatively low cost. Many firms need only small supplies and have obtained them through the municipal distribution systems who in turn have been absorbing water from agricultural land taken over by urban expansion. Others have taken advantage of the availability in much of Central Arizona of good quality supplies of groundwater at costs of about three to five cents per thousand gallons. Groundwater supplies have been such that physical exhaustion or deteriorating quality have occurred in only scattered instances. Thus economic forces, rather than physical limits, have been the major influences on water utilization.

What of the irrigated crop sectors themselves who use the great majority of the water? Have they experienced the declines in production, income, and employment that had been forecast for them in the absence of supplemental water? The volume of crop sales in Arizona expanded some threefold in the first twenty postwar years. Some of this was price inflation, but even when inflation is taken into consideration, irrigated farming emerges as a rather robust corpse. There

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[1] Valley National Bank, Arizona Statistical Review, Phoenix, September, 1966.
[2] Martin, William E. and Leonard G. Bower, "Patterns of Water Use in the Arizona Economy," Arizona Review, vol. 15, No. 12, 1966.
[3] U. S. Department of the Interior, Bureau of Reclamation, Pacific Southwest Water Plan, Boulder City, Nevada, 1964, p. 9.

is, in fact, considerable evidence of increased activity even in the areas completely dependent upon pumped water, in spite of falling groundwater tables. How is this unexpected result explained? We can look at two factors, the impact of technological improvement and the fact that water using firms can usually adjust their operations to cope with increasingly costly water.

Technological advance is a potent force in the modern economy, and has had a major influence in the adjustment of the Arizona economy to water scarcity. Improved efficiency of pumping plants, more productive crop varieties and better techniques of water application are examples.

The modern Arizona farmer has shown that he does adjust to water scarcity in a manner consistent with production economics theory. Producers substitute other productive resources for water when water becomes more scarce and expensive. An example of such a substitution is the investments made in water saving conveyances (pipelines or concrete ditches). Another adjustment is the shifting of resources from marginally profitable crops into more productive activities exemplified by the recent introduction of pecans into the Central Arizona area. In addition, today's larger farms make more efficient use of all resources. Thus, scale economies have helped to offset higher water costs.

In sum, then, a dynamic economy, relying on a free market for land and water resources, technological improvements, and the great adaptability of water users, coupled with the fact that the most rapidly growing sectors of the economy demand relatively minor amounts of water, serves to explain the present prosperous state of the economy and the consequent failure of earlier dire predictions to materialize. We conclude from the evidence that water has not been the limiting factor on growth in Arizona up to the present time and has, in fact, been inexpensive and ample in supply.

(Since a lead time of a decade or more is required for planning and constructing major water conveyance systems, we must inquire into what conditions are most likely in future periods before judging the desirability of water transfer investments. It is convenient to postpone that inquiry to a later point in this paper.)

THE CASE FOR A RESCUE OPERATION

Underlying some arguments for additional water in Arizona is the belief that conditions are such that the agricultural lands dependent upon pumped water are presently being abandoned at a rapid rate, and that the communities supported by these farms are thereby feeling economic stresses. It is felt that in the absence of additional water to rescue the agricultural economy, major deflations in the value of capital assets are likely.

I have already commented on the validity of the land abandonment thesis in the past and present, but what of the future? Will the need arise for water imports to rescue Central Arizona agriculture? A recent study of Pinal County by Stults[4] throws some light on this question. Assuming no new water supplies, no new restrictions on groundwater use, that water withdrawals will have the same impact on the declining water table as has been recorded in the past, and that growers can and will adjust cropping and water use patterns in response to changing prices and costs, Stults projected cropping patterns, net incomes and water uses for forty years into the future (to 2006). On the further condition that federal agricultural programs remain unchanged, his projections indicated that irrigated acreage cropped would in fact drop nearly by half. But, the reduction would be entirely at the expense of low-valued crops which are at present contributing little to net return. Farm size would continue to increase, as small farms unable to cope with technical change and higher water costs would be consolidated into larger units. Acreage of cotton, specialty vegetable crops and citrus would not be sensitive to water costs even that far into the future. Water use was projected to decline some 45 percent as crop acreage decreased. The average pumping lift of the areas currently with deepest wells would increase another 300 feet, to about 810 feet, but most areas would have water available at much lesser depths than this. Most significantly, while crop acreage and water use fall to nearly half of their current levels, net returns in excess of variable costs decline by only twenty percent. Two-thirds of this impact is associated with

[4] Stults, Harold M., "Predicting Farmer Response to a Falling Water Table: An Arizona Case Study." Rept. No. 15, Proceedings of the Committee on the Economics of Water Resources Development of the Western Agricultural Economics Research Council, December 1966.

changes in production of low-valued crops, the balance in increased water costs in the high-valued sectors. None of these effects are because of a physical lack of water. They are merely profit maximizing response to increasing water cost associated with increasing pumping depths.

These analyses, together with the earlier discussion on economic growth, seem to cast doubt on the need for a rescue operation in the form of a major water importation scheme. The impacts of increasing water costs are likely to be registered slowly over a period of several decades since they can be partly ameliorated by new technologies and adjustment of crop production patterns.

We observe that the agricultural communities in Central Arizona are undergoing significant changes. Economic activity in many of these towns, for example, has drastically declined in comparison to their heydey in the early 1950's, when a cotton boom brought thousands of workers in to develop land and irrigation systems and to tend and harvest the cotton. However, it would be mistaken to associate these changes more than slightly with the water supply. More crucial has been the effect of improved agricultural technologies which have largely made hand workers obsolete in cultivating and harvesting cotton, and the interstate expressway systems which route traffic around the town, depriving it of income from serving travelers. These sorts of outside forces can be expected to continue to shape the future of Southwestern communities.

ADDITIONAL WATER AND ECONOMIC EFFICIENCY

"Cost-benefit analysis" has been developed to insure that the signals of the price system that reflect the preferences of consumers and relative scarcities of resources are brought to bear in public investment evaluation as they would be in the calculations of private firms. If the economic benefits genuinely exceed the economic costs, projects are "economically efficient," that is, they can make a contribution to rising standards of living. If, however, the costs exceed the benefits, the project will result in some reduction of the national income, and is in this sense, undesirable.

The canons of benefit-cost analysis require, among other things, that the value of the gains incremental to the project must exceed the incremental costs. Incremental (marginal) is the crucial word. If benefit-cost analysts would rigorously observe the implications of this word, I believe much of the controversy over water projects would disappear. I return to my Arizona example to illustrate this principle.

First, municipalities and industry (who account for less than ten percent of total water use) can always obtain adequate quantities of inexpensive water by purchasing water from agriculture (who uses the other 90 plus percent). I have already shown how regional growth has been achieved through this process. Thus, any additional water must be evaluated at its incremental value in agriculture where declining activity would occur.

Secondly, within agriculture particular crops are marginal. As the Stults analysis showed, any change in net income occurs at a much slower rate than does the decrease in either acreage or water use. One of the myths associated with the declining water table in the Southwest is that a loss in acreage because of increasing water cost implies a proportionate loss of income. Obviously, such a phenomenon will not occur so long as adjustments in cropping patterns are made at the margin of crop profitability and acreage continues to transfer to the larger, more efficient farms. Some crops typically yield very high net returns per acre while other crops have low net returns. Naturally, acreage of low-valued crops will drop out before acreage of high-valued crops and shifting production to the larger farms will help maintain income levels.

Since adjustments to the falling water table take place with the marginal crops, any new imported water supplies must also be valued at the margin. Given the present cropping opportunities in the Southwest, additional supplies of water could be expected to be used to expand or maintain the acreage of hay and feed grains. High-valued crops will continue to be grown up to the limit of their allotment (for cotton) or market (for fruits and vegetables) for many decades without additional water supplies. Farmers would benefit from imported water only to the extent that the additional supply of water contributed to their net income by reducing their water cost or by allowing additional profitable acreage of low-valued crops.

This conclusion presents the area with an apparently insolvable difficulty. It is quite true that the water table is falling, water costs are rising, and acreage and net farm income will soon begin to decline. But low-valued crops can be grown only if water costs are also low. That low-valued crops are currently being grown shows that water costs still are relatively low. In fact, as we have shown elsewhere,[5] introduction of supplemental water into the Central Arizona area at any price much above $3 or $4 per acre-foot at the main canal, would actually hasten the net income decline and land devaluation. Since the least expensive additional supply suggested would be sold to farmers at $17 per acre-foot at main canal side (subsidized by municipalities and industries from an average cost of about $60), the chance of reversing the net income decline looks very bleak. When the water table falls to the point that imported water becomes the least expensive source, both pumped and imported surface water will be too expensive to support the low-valued crops if the low-valued crops must pay for their own water.

Because opportunities for obtaining additional surface supplies anywhere in the arid Southwest at a lower cost than suggested above seem to be quite limited, implications of the Arizona case should be quite widespread.

Note that if additional water would actually hasten acreage abandonment, not only are the direct benefits less than the costs (in fact are negative) but also any indirect benefits would be negative. However, where additional water would preserve farm acreage the indirect economic activity generated in other sectors is estimated at about $10 per acre-foot[5 6]. Clearly direct and indirect benefits are less than the $60 average cost.

It is clear that recent patterns of water use cannot be extended indefinitely into the future, so that one cannot reasonably assert that water importation will never be economically desirable. On the other hand, the huge investments required to import supplemental water, if made prematurely, could result in substantial economic losses in terms of productive opportunities foregone by the taxpayers who were required to support the project. I have only to review the arguments presented so far to state that little need will exist at least until after the turn of the century.

First, I have faith that the role of technological progress and dynamic adjustments to change which have carried us successfully thus far will continue to partially offset increasing scarcity of water.

Second, we believe that the agricultural sectors presently at the margin in their demand for water, will continue to be the marginal sectors. Projected demands for food and fiber from U.S. agriculture do not show that large increases in acreage now devoted to high valued crops will be necessary.[7]

Finally, a number of forecasts to the contrary, vast demands for water for municipal and industrial use appear unlikely to materialize soon. Even in Pima and Maricopa Counties of Arizona (containing Tucson and Phoenix, the main population centers of the State) municipal and industrial use projections in the year 2000 represent only a small fraction of current total consumption, and only about half the annually recurring supplies in the region.

MY GENERAL CONCLUSIONS

I cannot see how costs could be much lower or benefits much higher than in Arizona for large water transfer schemes elsewhere in the Southwest. Thus I am led to the general conclusion that while irrigated agriculture was a cornerstone in the development of most of the Southwest it is no longer necessary or even advantageous to try to maintain a high level of irrigated agriculture on the desert in order to maintain or further the continued development of the already developed economies.

My view is that irrigation development, its maturation and its ultimate decline are natural phenomena in an economically developing arid region and irrigation decline should not in itself be a subject for general alarm. Our economies do have real problems, but we must search for prescriptions that fit the particular disease.

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[5] Young, Robert A. and William E. Martin, "The Economics of Arizona's Water Problem," Arizona Review, vol. 16, No. 3, 1967.

[6] Kelso, M. M. and James J. Jacobs, "Economic Analysis of Transfer of Water from Irrigation to Municipal Use: A Case Study of Tucson," Proceedings of the Western Agricultural Economics Research Council Committee on Economics of Water Resources Development, December 1976.

[7] Heady, Earl O. and Leo V. Mayer, Food Needs and U.S. Agriculture in 1980, National Advisory Commission on Food and Fiber, Tech. Paper vol. 1, Washington, D.C., 1967.

Returns to Public Irrigation Development and the Concomitant Costs of Commodity Programs

(By William E. Martin)

Development of agriculture, and associated agricultural problems, have had a prominent place in congressional deliberations virtually throughout the history of the United States (Benedict). Early policy stressed land development, and the Reclamation Act of 1902 was in such spirit. It was "An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands." With later modifications of policy to provide greater sources of income for works construction, Congress continues to support the Bureau of Reclamation's water development, output increasing activities.

Yet, since 1929, with time out for war, the federal government also has effected commodity programs designed to reduce the supply of major agricultural commodities so as to maintain product prices "at levels that would be above the market price in a free and reasonably normal market situation" (Benedict, p. 517). Such a situation would tend to strike most economists as peculiar (inefficient). Some of the "facts" generated by these apparently contradictory policies are the subject of this statement.

In the past two decades resource economists, including myself, have severely criticized Bureau of Reclamation project evaluation procedures. Young summarized these criticisms and concluded that if we explicitly adopt a national accounting stance such that benefits and costs are evaluated from the point of view of the whole nation ("to whomsoever they may accrue . . . "), and if we assign a dominant role to economic efficiency in our assessment, "there would have been only a very few, if any, projects initiated in the past two decades which would have met the B–C criterion" (p. 9).

I will not dwell on all the criticisms, but there is one issue that is of particular importance to returns to irrigation development and associated costs of commodity programs. Water development projects traditionally are evaluated outside of a general equilibrium context, and it is assumed that each single project will have no effect on commodity prices. While the elasticity of demand for agricultural output may be close to infinite for the Bureau's smallest, 221 acre project, it could not be infinite over all of its 9.3 million irrigated acres. It is because of the existence of downward sloping demand curves that there could be a rational economic reason for simultaneous irrigation development and agricultural income support programs if questions of welfare and distribution are considered.

There may be a case for a consumer subsidy to producers where an irrigation project lowers the prices of agricultural products. While we may be sacrificing national economic efficiency, the consumer should be willing to pay to gain the distributional effects of increased quantities at lower prices. This amount will be larger where the project produces products for which there is an inelastic rather than an elastic demand. The subsidy could be in the form of zero interest on irrigation project repayment charges—past and current practice under reclamation law or through direct support payments on the commodities. ("Current projects are subsidized to over 80 percent of costs, if the interest on a normal repayment period is factored in" (Young, p. 131)). However, it is important that output be allowed to increase and prices allowed to fall. If the original price is maintained through production controls there is no consumer gain to provide a subsidy.

PUBLIC INVESTMENT IN IRRIGATION DEVELOPMENT

Bureau of Reclamation facilities do not comprise the entire investment in U.S. irrigation. In fact, Bureau of Reclamation facilities serve only 9.3 million acres while "other project facilities" serve 13.3 million (USDA, 1979). ("Other" projects include BIA and Corps or Engineers projects as well as state and private development.) Private on-farm facilities serve another 22.7 million acres for a net farm irrigated acreage of 45.3 million out of 367 million acres in "planted crops and fallow" in the United States (pp. 28, 39). But the net value of the capital investment in Bureau projects in 1975 was $8.960 billion out of $9.005 net federal investment, with other group projects valued at only $2.370 billion. Private individual facilities were valued at $4.640 billion (p. 27). Thus, in terms of federal investment, Bureau projects comprise 99.5 percent of value. In the

context of the issue of federal commodity programs versus federal irrigation development, I will concentrate on the acreage in and output from Bureau projects.

U.S. AND BUREAU OF RECLAMATION ACREAGES

In Table 1 U.S. acreage and Bureau of Reclamation acreage are compared by crop. Of the cereals, barley and rice are the only crops with Bureau acreage exceeding 1 percent, with 6.1 percent of U.S. barley and rice acreage each. Total cereal acreage on Bureau lands is less than 1 percent of the U.S. total. Bureau lands are 6.6 percent of U.S. alfalfa acreage, but probably less than 1 or 2 percent of total forage acreage. Thus, we find that while forages and cereals are grown on 62 percent of all Bureau lands (37 percent and 25 percent, respectively) (USDI, 1978a), they are but a percent or two of U.S. forage and cereal lands.

TABLE 1.—TOTAL UNITED STATES AND BUREAU OF RECLAMATION CROPPED ACREAGE, BY MAJOR CROPS, 1977

Crop	Thousand acres		Bureau of Reclamation as a percent of United States
	United States [1]	Bureau of Reclamation [2]	
Cereals:			
Barley	10,586	647	6.1
Corn	82,680	646	.8
Oats	17,793	86	.5
Rice	2,261	139	6.1
Rye	2,652	1	0
Sorghum	15,994	96	.6
Wheat	74,804	595	.8
Other	(?)	116	----------
Total	>207,770	2,327	<1.1
Forage:			
Alfalfa	27,085	1,791	6.6
Other hay	33,408	242	.7
Irrigated pasture	(?)	987	----------
Other forage	(?)	432	----------
Total	>60,493	3,452	<3.4
Miscellaneous feed crops:			
Dry beans	1,395	335	24.0
Cotton	13,694	1,476	10.0
Hops and mint	116	83	71.5
Sugarbeets	1,277	379	29.7
Soybeans	59,080	8	0
Other	(?)	33	----------
Total	>75,562	1,784	<2.4
Vegetables:			
Potatoes	1,349	257	19.1
Melons	322	67	20.8
Other vegetables	>2,786	470	<16.9
Total	>4,457	794	<17.8
Fruit:			
Citrus	1,163	154	13.2
Major deciduous	1,657	427	25.8
Minor fruits	108	42	38.9
Berries	45	2	4.4
Total	2,973	625	21.0
Nuts	471	152	32.3
Seeds	>1,587	175	<11.0
Total cropland [3]	367,000	9,310	2.5

[1] USDA, Agricultural Statistics, 1978, various tables.
[2] USDI, 1977 Land and Water Resource Accomplishments, 1978a, table 4.
[3] ESCS staff, Natural Resource Capital in U.S. Agriculture, tables 6 and 17. These estimates are for 1975. Individual crop estimated do not add to total because of different sources and missing acreage estimates.

Field crops are a different matter. Twenty-four percent of the dry bean acreage is on Bureau lands, 30 percent of sugar beet acreage, 10 percent of cotton acreage and 74 percent of all hop acreage. But with soybean acreage negligible,

total miscellaneous field crop acres on Bureau lands are less than 2.4 percent of the U.S. total.

The speciality crops—vegetables, fruits, seeds and nuts—are the major crops on Bureau lands when compared to U.S. acreage. Vegetables are on only 9 percent of Bureau lands but account for close to 18 percent of U.S. acres. Fruits and nuts are on 8 percent of Bureau lands but account for 21 percent and 32 percent of U.S. fruit and nut acreage, respectively. Seeds are but 2 percent of Bureau lands but approximately 11 percent of U.S. seed acreage.

To summarize, lands currently irrigated by Bureau of Reclamation projects are only 2.5 percent of total U.S. cropland, but they contain a significant percent of vegetable, fruit, nut, seed and miscellaneous field crop acreage, as well as a significant acreage of barley, rice and alfalfa.

THE INCREMENTAL OUTPUT FROM FEDERAL INVESTMENT

More important than mere area is the productivity of the irrigated lands. In Table 2 is shown the 1977 production of major crops grown on Bureau lands, the index for yields from wholly irrigated lands as compared to unirrigated lands, and the implied increment in production due to irrigation on Bureau lands as a percent of 1977 total U.S. production. Also shown is total Bureau production as a percent of total U.S. production.

TABLE 2.—INCREMENTS IN PRODUCTION FROM IRRIGATING BUREAU OF RECLAMATION LANDS, 1977

Commodity	1977 bushels of Record production [1] (thousands)	Index for 17 Western States [2]	Implied dryland production (thousands)	Increment from irrigation as percent of 1977 U.S. production	Total bushels of record production as percent of 1977 U.S. production
Barley	49,914 bu	205	24,348 bu	6.1	12.0
Corn	59,346 bu	181	32,788 bu	.4	.9
Cotton	1,663 bales	256	[3]	11.6	11.6
Dry beans	6,374 cwt	309	[3]	39.1	39.1
Oats	5,908 bu	153	3,861 bu	.3	.8
Sorghum	6,259 bu	193	3,243 bu	.4	.8
Soybeans	263 bu	126	209 bu	Negligible	Negligible
Wheat	44,776 bu	187	23,944 bu	1.0	2.2
Rice	7,978 cwt	[4]	0	8.0	8.0
Alfalfa		230		[5] 5.8	10.2
Potatoes		179		[5] 9.9	22.5
Vegetables and melons		318	[3]	[5] 26.9	26.9
Orchards		214	[3]	[5] 25.6	25.6

[1] USDI, 1978a.
[2] USDC, 1974 Census of Agriculture. Compares irrigated with nonirrigated.
[3] Dryland acreage in the West is minimal.
[4] No dryland acreage.
[5] Based on index and relative acreage.

Two assumptions are crucial to the estimates of the increment from irrigation. First, it is assumed that cotton, dry beans, vegetables and melons, and orchards would not be grown in the absence of Bureau irrigation. Thus, for these crops total production is equal to incremental production. Second, for all crops it is assumed that no other irrigation water was available; that is, that the Bureau was required to develop full water service rather than merely supplemental water service. Both assumptions obviously cause an overestimate of the increment from irrigation, since 54 percent of all lands irrigated by the Bureau receive supplemental rather than full water service (USDI, 1978a).

Given these caveats, we see that the greatest increases in production caused by Bureau water are for vegetables, melons, orchards, and dry beans. Other significant increases are for cotton, rice, barley alfalfa and potatoes. The increments in corn, oats sorghum, wheat and soybeans are each 1 percent or less.

Now let us examine recent participation in the major commodity programs. In Table 3 are shown the quantities of commodities pledged to the commodity credit corporation under the commodity loan programs, as percents of total U.S. production for the years 1972 to 1977. (Flaxseed, honey, naval stores, peanuts, rye, and tobacco—not produced on Bureau lands—are excluded. These commodities, along with storage facility and equipment loans comprised 16 percent of the 1977 loan program.) If we take these quantities as a rough measure

of farmer and Congressional perception of excess agricultural production, we might compare them with production increments associated with public irrigation investment. These increments, developed in Table 2, are also presented as the last column of Table 3.

TABLE 3.—QUANTITY OF COMMODITY PLEDGED TO THE COMMODITY CREDIT CORPORATION[1] AND INCREMENT IN PRODUCTION FROM IRRIGATION ON BUREAU OF RECLAMATION LANDS

[Percents of total U.S. production]

Commodity	1972	1973	1974	1975	1976	1977	Increment from irrigation 1977[2]
Barley	10.1	3.7	2.3	2.5	4.9	10.8	6.3
Corn	7.5	4.6	1.6	2.5	4.4	.5	.4
Cotton	14.2	13.6	21.4	8.4	9.0	.3	11.6
Dry beans	5.3	.4	.5	0	0	0	39.1
Oats	4.6	1.6	.6	.6	.8	6.5	.3
Sorghum	3.7	2.0	.6	1.2	2.9	5.9	.4
Soybeans	7.1	8.0	2.9	0	1.7	.0	Negligible
Wheat	9.2	3.5	2.0	2.3	22.1	20.1	1.0
Rice	26.8	20.6	8.2	16.7	20.2	4.6	8.0

[1] USDA Agricultural Statistics 1978.
[2] Table 2.

A portion of all of the cereal grains have consistently gone under loan during this recent 6-year period. In 1977 10.8 percent of the barley crop was pledged while the public irrigation increment was 6.3 percent. Only 0.5 percent of corn production was pledged—but the irrigation increment was 80 percent of that amount. Oats and sorghum were each pledged at about 6 percent of production even though the irrigation increment was minor. Less rice was pledged in 1977 than the Bureau increment, but large quantities had been pledged in previous years. Wheat was heavily under loan (20 percent) even with only a 1 percent public irrigation increment.

The two commodities with the largest production increment from public irrigation investment, dry beans and cotton, while pledged in earlier years, apparently were clearing the market at "satisfactory" prices in 1977. No beans were pledged in 1977 although the irrigaiton increment was 39.1 percent. Only 0.3 percent of cotton was pledged while 11.6 percent of U.S. production was attributable to public irrigation investment.

COSTS AND BENEFITS

How might these data be interpreted? Clearly the grains have generally been and continue to be in "excess" supply relative to Congressional intent. But irrigation development seems not to be a major culprit, except perhaps with barley. The problem would exist even without public irrigation development. On the other hand, irrigation investment to grow these crops is obviously unnecessary. The problems with cotton, dry beans, and soybeans seem to be lessening. At least with dry beans, one might see a need for having developed production. Still, overall one could hardly argue the necessity of public water development from the point of view of the U.S. producers' of these commodities. That the commodity programs exist is enough evidence that water has not increased net income. Benefits, if there are any, must be on the consumers' side. A consumer should be willing to pay to have larger quantities with lower prices. Unfortunately the mechanism for subsidies generally have not allowed the consumer to receive full benefits.

Consumer benefits surely have been achieved with investment in water for fruits, nuts, vegetables and melons, potatoes and perhaps even alfalfa. While many of these crops with the exception of alfalfa have been under marketing orders, with the obvious intention to restrict output and raise prices, the very magnitude of their position in total U.S. production suggests a positive benefit. The problem is, of course, that even though demands for most fruits and vegetables are more elastic than for the basic commodities, they still are inelastic. Therefore, a downward shift in supply tends not to benefit consumers greatly—perhaps not enough for project and producer subsidy.

Let us work backwards to see what consumer benefits would have to be if the federal water projects were to be beneficial. The 1975 Bureau of Reclamation

gross real investment in irrigation project facilities was $9.1 billion (USDA, 1979). This value "represents the estimated cost of reproducing all existing irrigation * * * works at unit costs prevailing in [1975]" (p. 43). If consumers were to receive the full value of the irrigation investment, an annual total return of $910 million would be required if the investment were evaluated at an interest rate of 10 percent. With a 1975 estimate of "number of people eating from civilian food supplies" of 211 million (USDA, 1978a, p. 552), the required annual per capita consumer's surplus would need be only $4.31. Given the large amounts of vegetables, fruits and nuts that are incremental in Bureau of Reclamation Project acreages, I do not find a $4.31 consumer benefit unbelievable.

In fact, annual per capita subsidy costs of Bureau project construction have been at most about $3.50 in 1975 dollars. I make this estimate as follows. Given the 1975 estimate of $9.1 billion for reproducing all existing irrigation facilities, and assuming amortization at 10 percent for 50 years (the normal payback period), total principal and interest would equal $45.891 billion. North and Neely estimate that current projects are subsidized to about 80 percent of costs, when the interest in the normal repayment period is included. Eighty percent of the total is $36.713 billion or $734 million per year (of which only 20 percent is principal). With a 1975 population of 211 million, the annual per capital subsidy would be $3.47. Of course projects have been constructed over the past 75 years. In any given year only a portion of the 153 projects actually would be under repayment.

However, because of commodity programs for cereals and field crops, there is the additional cost of government payments to farmers. Since World War II, total payments have varied from 0.6 percent (1974) to 7.9 percent of total farmers' cash receipts from marketings on a national basis (USDA, 1978b). In 1969 a per capita consumer contribution of $19.06 is implied, in 1974 the contribution was only $2.52, and in 1977 the contribution rose again to $8.47. The problem here for consumers is that they are paying for the privilege of not having higher quantities and lower prices on cereals and field crops. Thus, the costs must also be absorbed by any benefits to vegetables, fruits and nuts.

What might be the total incremental benefits to these crops? Per capita food expenditure in 1977 was $1,136 (USDA, 1978c). Ten percent of this expenditure was on fruits and vegetables (USDL). Given a price elasticity of demand for fruits and vegetables of around −0.75 (George and King, p. 49), and assuming an increment in U.S. production of fruits and vegetables of 26 percent (Table 2), the incremental consumer's surplus attributable to public irrigation would be $34.26 per capita. Perhaps Bureau projects really have been worth the associated commodity program costs.

The data presented have summarized the past and presented the current status of public irrigation investment and commodity programs. What of the future? I cannot help believing that because the less expensive project sites have already been developed, future development will be slight. People slowly are beginning to realize that water naturally runs downhill and to reverse that phenomenon requires energy. For example, Arizona's Salt River Project, the first construction activity of the Bureau, is a major producer of electrical energy. Currently, the Central Arizona Project is under construction. It will require a quarter of the output from the three 750-megawatt coal-fired units of the Navajo Generating Station to lift the water more than 2,000 feet uphill (University of Arizona).

Let us examine the recent trends in construction activities and the crops grown on these new irrigated acres, as a possible clue to the future. The 20 years for which Young suggests negative benefit-cost ratios should serve. Since 1960, in the last 27 percent of the Bureau's history, 35 percent of its 153 projects have come on-line, but these projects irrigate only 10.6 percent of its land. Since 1970, 15 percent of Bureau projects began producing on only 3.4 percent of Bureau land. Apparently we are not running out of projects, only land on which to put them. Further, while between 1960 and 1968 acreage developed with full water service was 1.3 times that developed with supplemental service, since 1970, 4.4 times as much supplemental service has been developed than full service (USDI, 1978b). Supplemental service may well reduce fluctuations in crop yields, but surely develops a smaller production increment than full service development. I suspect many of the supplemental-water projects are so called "rescue" projects such as the Central Arizona Project, where the marginal cost of not having the "rescue" water is very small (Kelso, Martin and Mack).

Finally, we may ask what crops are being grown on these newer project acreages? Economists, including myself, have generally argued that projects should

be evaluated in terms of the value of the productivity of water on the lowest valued crops—the grains and forages, and that higher valued crops—fruits and vegetables—would be grown in any case if a market were available. From an efficiency point of view the correctness of this argument seems clear. However, the data show that since 1960, the total Bureau land increase of 10.6 percent was associated with a 10.9 increase in project vegetables. a 23.4 percent increase in project nuts, an 8.7 percent increase in project fruit and 9, 11.5 and 10.6 percent increase in project cereals, forages and miscellaneous field crops, respectively. In other words, all crops tended to increase proportionately to land in projects. In the years since 1970, the 3.4 increase in Bureau lands include a 21.7 increase in project nuts, a 5 percent increase in project fruits, a 4.6 percent increase in project vegetables, almost proportional increase in project forages and field crops, but only a 1.4 percent increase in cereals.

These data, however, could be misleading. An increase in project fruits or vegetables need not mean a net increase in fruit or vegetable acreage of the same size—especially on supplemental-water projects. As shown above, recent projects are mostly supplemental. Still, one might suspect a positive distributional effect toward consumers.

CONCLUSIONS

While it is clear that recent public irrigation development projects are economically inefficient from a national accounting stance, rational economic arguments can be made, at least for past projects, on the basis of distributional gains to consumers. Such gains are probable even in the face of the costs of our national commodity programs. The gains could be substantial if output were not restricted, and any farmer income support were handled through direct income payments.

Arguments for future development are much weaker. Low cost project sites no longer exist. Projects now use energy rather than develop it. Alternative uses for water in high MVP uses are growing. The increments from the development of supplemental water are not as large as from the full service projects that made the deserts bloom rather than merely "rescuing" marginal acreages. If the intent of Congress remains to provide inexpensive food to consumers while supporting producer incomes, new directions in both water development policy and farmer support policy are clearly necessary.

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Mr. AMBRO. I would now call on Dr. Jan Van Schilfgaarde, Director, U.S. Salinity Laboratory, U.S.D.A., California, and as with Mr. Koelzer, you may correct me on the pronunciation of your name.

STATEMENT OF DR. JAN VAN SCHILFGAARDE, DIRECTOR, U.S. SALINITY LABORATORY, USDA, CALIFORNIA

Dr. VAN SCHILFGAARDE. I am used to problems of that sort. You did very well, sir.

First of all, I intend to abstract the statement I gave you. As others have pointed out over 90 percent of the water consumed in the Western United States is consumed by irrigation in the Western United States and nationwide about 80 or 82 percent is consumed by irrigation.

We are fully aware, of course, that demand for water continues to increase to the extent that irrigation of agriculture can hardly maintain itself. In 1950, there were still substantial opportunities for adding new croplands to our agricultural base, especially by irrigation. On a worldwide basis the evidence shows that the newly added lands have lower productivities, suggesting that most of the productive cropland is already being farmed.

From 1950 to 1975, the increase in cultivated area fell far behind that of population accounting for only one-fourth of the gain in food output.

Irrigation is an age-old art that predates recorded history. Only about 12 percent of the world's farmland is irrigated, but a substantial portion of the population depends on it. The percentage of production is substantially higher than that based on area. Even with only adequate management, the unit production can be high; double or even triple cropping is often possible.

On the other hand, capital costs are generally high, and the energy inputs can be substantial. In the 17 Western States, irrigation accounts for nearly 90 percent of water withdrawn. Nationally, irrigation accounts for 80 percent of the water consumed. But in the absence of stored food reserves, irrigated agriculture helps insulate against the vagaries of weather. It also supplies most of our fruits, nuts, and vegetables.

Irrigation in arid and semiarid regions is always associated with salinity. About one-third of all irrigated land is affected by salinity. To sustain a continuing irrigated agriculture, we must maintain a soluble salt balance; that is, we cannot permit the soluble salts in the root zone of our soils to build up to a level where they depress crop growth. Salt balance has often been interpreted as requiring that the amount of salt removed in the drainage water must equal or exceed that brought in with the irrigation water. While this simple concept is conceptually sound, it requires refinement before it can be applied to field situations.

More specifically, when the concentration of salts in the soil water is low, primary minerals tend to dissolve, adding to the salts in the soil

solution; when the concentration of salts in the soil water increases, mineral dissolution stops and certain salts such as lime and gypsum tend to precipitate. As a consequence, the amount of salt that is discharged in the drainage water can be changed drastically, by as much as 50 percent, by changing the amount of water that is passed through the soil.

As a consequence, reducing leaching by reducing the amount of irrigation water applied will result in a reduced quantity of salt discharged. It will also change the composition of the discharged salt, increasing the amount of sodium relative to calcium and magnesium.

Furthermore, because the precipitated salt accumulating will be chemically inactive, a steady state will be established where salt is removed from the active system—the soil solution—and retained harmlessly in the soil.

Thus, there is an excellent opportunity to reduce the salt load contributed by drainage water through better irrigation management. At the same time, such improved management would increase the water use efficiency.

On farm water use efficiency—the proportion of water applied that is used by the growing crop—in irrigation tends to be surprisingly low. A value of 40 percent is often-quoted for the United States. We have demonstrated in research studies at the U.S. Salinity Laboratory that irrigated agriculture can be maintained satisfactorily with efficiencies above 90 percent without adverse effects in terms of salinity. Such high efficiencies would result in substantial reductions in the mass of salt discharged in the drainage water, in the volume of water applied for irrigation and in the volume of drainage water, in an appreciable increase in salt concentration in the drainage water, and in a change in drainage water composition.

Another restraint to improved on-farm water use often is the off-farm distribution system. Typically, in large irrigation projects, water is distributed through large canals feeding laterals that deliver water at the farm gate. The design and operation of the canal system is often such that, at best, water must be ordered some days in advance, or worse, so that water is delivered on a fixed rotation scheme. With such systems the farmer has no control over either the timing or the quantity he receives at any given time.

Recognizing that efficient on-farm water use requires that, to the extent feasible, water be delivered on demand, the U.S. Bureau of Reclamation initiated its Irrigation Management Service. It is the hope that this program, designed to help schedule irrigations on individual fields, can provide sufficient feedback to improve the operation of the delivery system.

All irrigation must be accompanied by drainage. Drainage must remove precipitation and irrigation water applied in excess of crop needs to prevent waterlogging; it must remove the salts that accumulate in the rootzone to avoid salination; and it must remove "foreign" water, or water that seeps into the area from leaky canals, from excess irrigation on adjacent fields or similar sources separate from the field under consideration. To meet drainage demands, one depends on the natural drainage rate, supplemented as needed by drainage installations.

The salt concentration of many drainage waters is such that they are still suitable for production of relatively salt-tolerant crops at essentially full yield if proper management practices are used.

Projections indicate, for example, that irrigation with water containing 6,000 mg/l of salt at a leaching fraction of 0.25 should give full yields of cotton. Thus, selective use of such drainage waters to irrigate appropriate crops offers the potential of reducing by three-fourths the volume of drainage water of which one must dispose. Less costly, or objectionable means can be found to dispose of this reduced volume, while productive use is made of a larger fraction of the irrigation water.

There are, through research in genetics and plant breeding, significant opportunities to develop plants that can be grown effectively with water of higher salinity; there is also some hope that breeding will yield some increase in drought resistance.

The area of plant breeding for salt and drought resistance has been neglected and deserves more attention. If successful, it would lead to some reduction in water used consumptively but its primary benefit would be that water of higher salinity could be used to grow crops economically.

Let me give you a final set of observations. After several lean years, there has recently emerged a strong and lively interest in strenghthening the research capabilities in agriculture and resource development. I wish to utter a word of caution, possibly unexpected from this source, that large increases in research expenditures do not guarantee parallel increases in the solutions to problems. I sense a tendency among some of my peers to press for drastic emphasis on "basic" research as opposed to "applied" research.

Without getting bogged down in definitions I submit that tremendous progress can be made by learning to transfer existing technology and by adaptive research—learning to adapt known principles to existing circumstances; and that research intended to help solve the twin problems of feeding our fellow men and conserving our dwindling resources must keep its eye squarely on the practical goal.

Ivory tower research, or research inspired by curiosity but not directed at some ultimate problem, has an important place and we cannot afford to neglect it. It should, however, be kept in balance. We also must keep in mind that technological answers are not sufficient unless they are compatible with socio-economic patterns. Many of our problems are as much a result of institutional or legal restraints as of technical inadequacies. Such problems, in principle, however, can be resolved as well.

We face an important challenge—in research, in application, and in education. I trust and I pray that we shall have the vision and the decision to meet the challenge.

Thank you, sir.

Mr. AMBRO. Thank you, very much.

We will have your full statement reproduced in the record at this point.

[The full prepared statement of Dr. Jan van Schilfgaarde follows:]

A Perspective on Agricultural Productivity as Constrained by Water Quantity, Quality, and by Energy Supply

(By Jan van Schilfgaarde)[1]

BACKGROUND

Pressures on the world's croplands have escalated since mid-century as our numbers have increased and our diets improved, raising doubts about our long-term food security. The world's stock of stored grains is not drastically diminished and the cushion provided by excess idle land in the U.S. has disappeared. The U.S. is now a major global food supplier.

This increase in world population and economic activity means that land, water, and energy are needed evermore so for the production of food. Yet municipal and industrial sectors are now claiming more and more of our cropland, while water resources and energy are becoming increasingly more expensive and scarce. In the U.S., growth of cities is consuming cropland at a record rate. Between 1967 and 1975 some 2.5 million hectares of prime cropland were converted to urban uses, and an increasing rate is expected for the next 25 years. In the third-world countries, good cropland is already short. Their continued population growth and anticipated cropland loss by urbanization, erosion, salination, waterlogging, desertification, etc., will increase the demands on the U.S. for agricultural production (Brown, 1979).

In 1950 there were still substanatial opportunities for adding new cropland to our agricultural base, especially by irrigation. On a worldwide basis the evidence shows that the newly added lands have lower productivities, suggesting that most of the productive cropland is already being farmed. Prior to 1950, the world-cultivated area expanded more or less apace with population, accounting for most of the increase in food output. From 1950 to 1975, the increase in cultivated area fell far behind that of population, accounting for only one-fourth of the gain in food output (ERS, 1976). The projected increase in cropland for the final quarter of this century is only 10 percent, far less than the projected growth in population for this same period. The world demand for food is expected to roughly double between 1975 and 2000 (U.N. World Food Conference, 1974). If these projections are valid, it is obvious that U.S. agriculture must produce a greater yield per hectare than we ever have. Few things will affect human well-being more directly than an imbalance between people and cropland. Without food or land reserves, the population is particularly vulnerable to a single season of poor weather. As a consequence, irrigated agriculture, which is less dependent on the vagaries of weather, takes on added importance. Although irrigated land is critically important, it will never suffice to sustain us alone.

Thus we must protect cropland against needless enroachment, improve our management of crops, soils, and waters, and conserve and protect our agricultural resources. To accomplish this we need a well-developed national land-water-energy use policy to protect farm land against market-place interests, to conserve these irreplaceable resources, and to implement needed management practices. The times call for a new land ethic,. a new reverance for land, water, and energy, and a better understanding and management of these resources in agricultural production. We need to bring science and technology, in the best sense, to bear on this matter of food production to sustain our progeny over the long haul in a way consistent with the building of a conservative society and, as much as possible, consistent with our present esthetic desires for a pleasing environment in which to live.

There are good opportunities in the U.S. for good science to develop more productive agricultural practices that are more in harmony with the resources exploited—soil, water, energy.

One approach to accomplish this is to greatly expand basic biochemical research—photosynthesis, nitrogen fixation, genetic engineering—in "pure" academic institutions. This has been adocated by the National Academy of Science as a national priority for agricultural research. Such an effort has its proper place in increasing food production, but must be placed in perspective. I propose that higher priority be given to learning to use our natural resources effectively and conservatively by adapting known principles imaginatively to existing eco-

[1] Director, U.S. Salinity Laboratory, AR–SEA, USDA, Riverside, Calif.

logical and socio-institutional circumstances and by further developing these principles to aid in constructive development. This approach is less glamorous than biochemistry. It calls for inputs from more than the physical and biological sciences—from economics, if you wish, but not for myopic benefit-cost analysis.

To illustrate this approach, I will now discuss some important issues of soil-water-energy conservation in irrigated agriculture and the potentals for improving our present inefficient situation.

IRRIGATED AGRICULTURE

Irrigation is an age-old art that predates recorded history. Only about 12 percent of the world's farmland is irrigated, but a substantial portion of the population depends on it. The percentage of production is substantially higher than that based on area. Even with only adequate management, the unit production can be high; double or even triple cropping is often possible. On the other hand, capital costs are generally high, and the energy inputs can be substantial. In the 17 western states, irrigation accounts for nearly 90 percent of water withdrawn. Nationally, irrigation accounts for 80 percent of the water consumed. But in the absence of stored food reserves, irrigated agriculture helps insulate against the vagaries of weather. It also supplies most of our fruits, nuts, and vegetables.

Irrigation in arid and semi-arid regions is always associated with salinity. About one-third of all irrigated land is affected by salinity. To sustain a continuing irrigated agriculture, we must maintain a soluble salt balance; that is, we cannot permit the soluble salts in the rootzone of our soils to build up to a level where they depress crop growth. Salt balance has often been interpreted as requiring that the amount of salt removed in the drainage water must equal or exceed that brought in with the irrigation water. While this simple concept is conceptually sound, it requires refinement before it can be applied to field situations. More specifically, when the concentration of salts in the soil water is low, primary minerals tend to dissolve, adding to the salts in the soil solution; when the concentration of salts in the soil water increases, mineral dissolution stops and certain salts such as lime and gypsum tend to precipitate. As a consequence, the amount of salt that is discharged in the drainage water can be changed drastically—by as much as 50%—by changing the amount of water that is passed through the soil. As a consequence, reducing leaching by reducing the amount of irrigation water applied will result in a reduced quantity of salt discharged. It will also change the composition of the discharged salt, increasing the amount of sod relative to calcium and magnesium. Furthermore, because the precipitated salt accumulating will be chemically inactive, a steady state will be established where salt is removed from the active system (the soil solution) and retained harmlessly in the soil. Thus, there is an excellent opportusity to reduce the salt load contributed by drainage water through better irrigation management. At the same time, such improved management would increase the water use efficiency.

The national concern wth water quality (e.g., the Amendment to the Water Quality Control Act of 1972) is primarily aimed at protecting the quality of surface waters. Often the approaches advanced for achieving control fail to recognize certain natural physical laws that cannot be changed by man-made edicts.

One fact not well understood is tha when plants extract water from the soil they leave most of the salt behind in the remaining water. To sustain irrigated agriculture, extra water must be applied to leach out this salt. This drainage water is unavoidably higher in salts than the applied water. The salt must go somewhere—to either soil, surface water, or groundwater. As discussed above, total salt output is least when leaching is minimum. But with low leaching, the salt concentration in the drain water is high. Setting low concentration standards on drain water can, therefore, increase total salt emission and, hence, pollution of the receiving water. Thus, to intelligently impose environmental controls we need to include the soil and the groundwater as a part of the system that we want to protect. We must consider the trade-offs between various alternatives and choose those that give us the best overall protection. We need to further consider the trade-offs between the needs of agriculture and of industrial and domestic users—the quality needs are different and often incompatible.

The proper operation of an irrigation project requires information on the salinity level and distributions present within the rootzones of the soil of the

project. Only then can valid assessments of the adequacy of project operations be made. At present we do not have adequate monitoring programs to help us protect and conserve our irrigated soil resources, nor do we have in the U.S. an adequate inventory of the extent and location of saline soils, or soil becoming salinized. Projecting present trends and needs into the future, one can easily envision the increased need for adequate salinity inventorying and monitoring programs. There will be more competition for the water now used for irrigation, and water now available for leaching will be diminished; simultaneously there will probably be restrictions placed on the discharge of salt from irrigation projects. With less leaching and salt discharge from irrigated lands, there will be a corresponding increase in soil salinity.

On-farm water use efficiency (the proportion of the water applied that is used by the growing crop) in irrigation tends to be surprisingly low. A value of 40 percent is often quoted for the United States. We have demonstrated in research studies at the U.S. Salinity Laboratory that irrigated agriculture can be maintained satisfactorily with efficiencies above 90 percent without adverse effects in terms of salinity. Such high efficiencies would result in substantial reductions in the mass of salt discharged in the drainage water, in the volume of water applied for irrigation and in the volume of draining water, in an appreciable increase in salt concentration in the drainage water, and in a change in drainage water composition as explained above.

To obtain the full benefits of more efficient irrigation without adverse effects, it is necessary to have carefully controlled water management. Careful control is required to provide the desired amount of water uniformly at specified times. To obtain maximum dry-matter production, either per unit of water or per unit land, it is generally desirable to avoid water stress by maintaining the water content in the soil rootzone uniformly high; for some crops, however, to maximize the harvestable product, it may be essential to program one or more periods of stress. On the other hand, an irrigation schedule that always maintains a fully charged rootzone does not take full advantage of rainfall and/or stored soil water. Furthermore, irrigation must also be managed to avoid excessive salinity of the soil solution.

Irrigation systems should be designed and operated so that control of the soil water content is possible. With conventional gravity irrigation systems, labor and operating costs are minimized by decreasing the frequency of irrigation as much as possible; water use efficiency and crop yield tend to be maximized when frequency is increased. It is not enough to obtain "best" use of land and water; it must also be economically feasible to do so.

Automated solid-set and center-pivot sprinkler systems are obvious candidates for systems with close control; in principle, trickle irrigation is equally suited. Compared to gravity systems, such systems offer greater control, together with decreases in labor requirements, at the expense of increased capital cost and fossil fuel consumption. Gravity systems, however, also can be modified to permit closer control. Laser-controlled precision land leveling allows better areal water distribution over the field and smaller water applications; combined with automation, it has led to dramatic improvements in irrigation efficiency for dead level, flooded systems. Using closed conduit for laterals, rather than open waterways, offers the opportunity for off-on control, as well as capturing gravitational energy for pressurizing delivery systems or controls. In furrow-irrigated areas, furrow length can be reduced—and thus intake distribution improved and tail water drastically reduced—using a "multiset" system. For tree crops, a low-head bubbler system has been developed that provides excellent control, requires minimal pressure—as low as 1.0 m of head—and is competitive in terms of costs.

Thus, numerous opportunities exist for modifying existing irrigation systems to increase the effectiveness of water use. Few of these have found widespread application to date. At least one reason is the lack of incentive, associated with the typical pricing mechanism for irrigation water in much of the United States and the world; another is that many of these ideas need further work to make them acceptable for routine use.

Another restraint to improved on-farm water use often is the off-farm distribution system. Typically, in large irrigation projects, water is distributed through large canals feeding laterals that deliver water at the farm gate. The design and operation of the canal system is often such that, at best, water must be ordered some days in advance, or worse, so that water is delivered on a fixed rotation scheme. With such systems the farmer has no control over either the timing or the quantity he receives at any given time. Recognizing that efficient on-farm

water use requires that, to the extent feasible, water be delivered on demand, the U.S. Bureau of Reclamation initiated its Irrigation Management Service. It is the hope that this program, designed to help schedule irrigations on individual fields, can provide sufficient feedback to improve the operation of the delivery system.

All irrigation must be accompanied by drainage. Drainage must remove precipitation and irrigation water applied in excess of crop needs to prevent waterlogging; it must remove the salts that accumulate in the rootzone to avoid salination; and it must remove "foreign" water, or water that seeps into the area from leaky canals, from excess irrigation on adjacent fields or similar sources separate from the field under consideration. To meet drainage demands, one depends on the natural drainage rate, supplemented as needed by drainage installations.

To avoid yield reductions from salinity, one must maintain a downward flux through the rootzone sufficient to avoid concentrating the soil solution in the rootzone above harmful levels. This flux is generally expressed as the leaching requirement, which is the fraction of the total surface applied water that must percolate through the rootzone. For a typical U.S. irrigation water containing 1,000 mg/l of dissolved solids or less, the leaching requirement for most crops is less than 0.05. Thus, even with the most efficient irrigation management, if uniform areal distribution is obtained, the leaching requirements are likely to be met implicitly. Without uniform distribution some parts of a field always receive too much and some may receive too little water. Drainage requirements, then are closely related to on-farm irrigation management and to the seepage and spills from the distribution system. The adverse effects of excessive water percolation, however, are not restricted to the irrigated farm. As discussed above, the drainage water tends to be of lower quality than the irrigation water, and ultimately one must dispose of it.

There are, then, numerous opportunities for better water use in irrigation with existing technology; new ideas will expand the horizon. It should be stressed, however, that such efforts at conservation will not significantly affect the amount of water used consumptively by crops. Savings come about by impacting water quality, by reducing water use by phreatophytes, and possibly by reduction in evaporation losses and some unrecoverable seepage. Savings also should accrue in reduced energy consumption and reduced erosion. Reduction in evapotranspiration—or consumptive use—is not a viable option for saving water if irrigated agriculture is to be maintained. There are, through research in genetics and plant breeding, significant opportunities to develop plants that can be grown effectively with water of higher salinity; there is also some hope that breeding will yield some increase in drought resistance. The area of plant breeding for salt and drought resistance has been neglected and deserves more attention. If successful, it would lead to some reduction in water used consumptively but its primary benefit would be that water of higher salinity could be used to grow crops economically.

Besides improved on-farm management and better tailored distribution systems, another major component of irrigation water management concerns conjunctive use of groundwater. The supply of groundwater is immense, although most of it is beyond economic recovery. Artificial recharge, from leaking irrigation canals or from excessive irrigation, combined with pumping to recover the water thus stored underground offers opportunities for conserving water. By deliberately drawing the water tables down, space is provided to store excess water available during flood seasons. Pumping of groundwater also provides close control over time and place of water availability, thus increasing the potential level of efficiency of use. A serious problem is the question of salt management. Salt accumulation is one of the major problems facing, for example, the San Joaquin Valley of California. The consumptive use of water of necessity increases the salt content of the remaining water; the better the irrigation management, the higher the salt concentration in the drainage water. Mixing this drainage water with uncontrolled seepage from canals tends to result in water too saline to produce good crops, but too dilute to warrant disposal.

Thus, induced recharge into a closed or slowly draining basin—such as the Tulare of California—is bound to lead to salination and, ultimately, disaster. Properly designed and operated recharge system can, in the right circumstances, aid tremendously in enhanced water management. But to be most efficient, the drainage water not destined for reuse should be kept separate from the water supply if salination is to be avoided.

Not emphasized in the foregoing are the changes in energy consumption associated with changes in irrigation water management. That pumping groundwater for irrigation requires energy is obvious; but even with gravity irrigation there can be substantial energy consumption. Water is often lifted into canals, or pumped out to provide drainage. Excessive irrigation may leach out fertilizers. A shift from gravity irrigation to sprinkler irrigation requires additional energy to obtain the necessary pressures. In devising an irrigation management strategy, energy use must clearly be considered.

SPECIFIC EXAMPLES

To illustrate some of the consequences and opportunities in enhancing water and energy use in irrigation, we now turn to some specific examples.

The Colorado River drains an area one-twelfth the size of the continental U.S. Its basin covers some 64 x 10^6 has in seven western states of the U.S. and in Mexico. Rich in mineral resources, blessed with natural beauty and a wide range of scenery, topography and climate, the land resources of the basin are extensively used for grazing, wildlife, timber production, recreation, and agriculture. About 1.2 x 10^6 ha are irrigated, whereas 0.25 x 10^6 ha are used for nonirrigated cropping. Books have been written about the various potentials and problems in the basin (e.g., Peterson and Crawford, 1978).

The Colorado River probably is the most controlled (and litigated) major river in the world. Its water resources are overcommitted by court decree; its water quality has been deteriorating. Studies suggest that the salinity at Lee's Ferry before man's influence was about half the 600 mg/l now encountered. At Imperial Dam, salinity is now about 850 mg/l and projected to increase with further development in the basin unless ameliorative action is taken; estimates vary, but 1250 mg/l is a representative prediction for the year 2000. Roughly a third of the salt load in the River has been attributed to irrigation. This increased salt load causes economic losses to both agriculture and municipalities. Table 1 shows their relative magnitudes. At the present salinity levels, the municipal cost per unit salinity increase is about 50 times the direct profit loss to agriculture. Thus, the major economic benefits from decreasing the rate of salination of the River will be to municipalities. Only as the River becomes considerably more saline than it now is does the profit loss to agriculture become sizeable.

TABLE 1.—SUMMARY OF TOTAL ECONOMIC IMPACTS PER MILLIGRAMS PER LITER WITH VARYING LEVELS OF SALINITY AT IMPERIAL DAM

[1976 dollars] [1]

TDS milligrams per liter	Agricultural impacts		Municipal costs	Total impacts
	Profit loss	Regional income loss		
800	3,799	20,211	240,500	264,510
850	4,925	26,201	260,500	271,626
900	6,385	33,968	240,500	280,853
950	8,277	44,034	240,500	292,811
1,000	10,730	57,034	240,500	308,314
1,050	13,910	74,001	240,500	328,411
1,100	18,033	95,936	240,500	354,469
1,150	23,377	124,366	240,500	388,243
1,200	30,315	161,223	240,500	432,028
1,250	39,287	209,007	240,500	488,794
1,300	50,930	270,948	240,500	562,378
1,350	66,024	351,248	240,500	657,772
1,400	85,591	455,344	240,500	781,435

[1] Preliminary data from as yet unpublished report, U.S. Bureau of Reclamation.

Public Law 93–320 charges the Department of Interior, in cooperation with others, to develop and implement a plan that will permit further development of the River's water resources without increasing its salinity. For the present purpose, I shall briefly describe some highly variable but significant examples of Colorado River irrigation projects and their relation to water quality in the river.

Some 24,000 hectares are irrigated in the Grand Valley of Colorado by gravity, with water supplied through a set of canals that have grown historically into a crazy-quilt pattern. Partly because of the soils, but primarily because of the

irrigation systems, diversions are very large relative to consumptive use. Estimates vary, but the valley probably adds about 650,000 mg of salt to the Colorado River each year. The valley is underlain by a massive, highly saline, Mancos shale formation. Water spilled from canals or laterals and returned to the river through surface channels adds no significant salt, but water that seeps from water courses or percolates through the rootzone of agricultural land tends to come to chemical equilibrium with the underlying materials and is ultimately discharged with a salt concentration of about 6500 mg 1, the drainage water displacing highly saline groundwater. Thus, a reduction in water throughput through the soil system will result in an approximately proportional reduction in salt loading. Increasing on-farm irrigation efficiency and reducing canal and lateral seepage by lining would reduce the salinity of the Colorado River downstream. At the same time, the salination of parts of the lower valley, intensified by high water tables, would be stemmed and reclamation made easier, eliminating, or at least reducing, the need for additional drainage, and enhancing the productivity of the farms in the valley.

Conceptually, a strong case can be made for a more drastic approach; replacing the existing distribution system with a single water conduit along the northern perimeter of the valley, which in turn would distribute water through closed conduit laterals. The advantage would be that the same benefits are realized as from lining the existing system with, in addition, the delivery of water under pressure at all user points. In principle, such a system would lend itself to demand delivery. It would permit adoption of a wider range of irrigation systems on the farm, depending on the site and crop, available technology, or newly developed techniques. It would provide, in many circumstances, sufficient pressure to operate automation devices, bubbler systems for orchards, or even low-pressure sprinkler systems.

Several disadvantages must also be recognized. First and foremost, the cost would no doubt be higher. More immediate is probably the question of acceptability. The concept under consideration would require consolidation of several irrigation and drainage districts, with separate patronage, management and water rights, into a single unit. It also would likely result in delivery of adequate amounts of water to meet crop needs, but substantially less than established water rights. Suffice it to say that it would be very difficult to obtain broad public acceptance for such a solution.

Farther down the River, the Palo Verde Irrigation District in California diverts water to irrigate 36,000 ha. Again, neither the irrigation water nor the drainage water is pumped. The Palo Verde, however, is an alluvial plain where there are no significant salt deposits that are displaced by the drainage water. The on-farm irrigation efficiency has been estimated at 53%. Clearly, this efficiency could be raised substantially with current technology. Such a change, however, would have essentially no effect on water use efficiency, would have minimal effect on energy consumption and but a minor effect on the salt concentration of the river downstream from the valley, at least after steady state has been reached.

What little effect could be anticipated would result from carbonate precipitation in the soil profile. Considering the costs, both real and imagined, associated with improved water management in the district, the obtainable benefits are extremely small. In an area where, as a first approximation, no "foreign" salts are involved, efforts to improve irrigation efficiency can only be justified on the basis of increased farm income. Providing adequate drainage even for relatively sloppy irrigation is probably cheaper, and certainly more readily accepted by the farming community; neither is a significant social benefit sacrificed.

Still farther downstream, the Wellton-Mohawk Irrigation and Drainage District in Southwestern Arizona is one of the last units within the U.S. to draw water from the Colorado River. The district serves about 26,000 ha of irrigated land and, historically, diverts about 640×10^6 m^3/yr through open canals, and lifts this water some 55 m. A geologically closed basin, salt accumulated in the groundwater before drainage provisions were made. Currently, more than 100 wells pump drainage water into a bypass canal that discharges near the ocean in Mexico; in 1973, the drainage water concentration averaged 3600 mg/l. Were this drinage water to be mixed with the Colorado River water the U.S. delivers to Mexico by treaty, its concentration would be increased by 440 mg./l. Such an increase would have a significant adverse impact on agriculture in the Mexicali Valley, while spilling the drainage water wastes a valuable resource out of a water-short basin. To resolve the dilemma, the U.S. Government plans to construct a desalting plant to treat the drainage water.

A separate paper could be written easily on this particular situation. Suffice it here to observe that a number of alternate solutions can readily be imagined that are more cost effective, less energy intensive, and more in tune with resource conservation. All of those alternatives, however, involve significant social, legal, and institutional complications.

Leaving the Colorado River Basin, we devote a few additional remarks to the San Joaquin Valley in California. The importation of water from northern California has increased the potential for irrigation substantially, while also aggravating a drainage disposal problem. Although the need for drainage has long been recognized and is projected to increase, there are serious objections to the construction of a central drain to transport drainage from the closed valley to the Sacramento Delta, the most accessible outlet. Extensive studies have evaluated alternatives, of which I shall consider only one.

The salt concentration of many drainage waters is such that they are still suitable for production of relatively salt-tolerant crops at essentially full yield if proper management practices are used. Projections indicate, for example, that irrigation with water containing 6000 mg/l of salt at a leaching fraction of 0.25 should give full yield of cotton. Thus, selective use of such drainage waters to irrigate appropriate crops offers the potential of reducing by three-fourths the volume of drainage water of which one must dispose. Less costly, or objectionable, means can be found to dispose of this reduced volume, while productive use is made of a larger fraction of the irrigation water.

In the example quoted, based on an actual water supply near Bakersfield, California, the drainage water from the cotton would have a salinity of 17,500 mg/l. It is possible to carry the concept one step further and to use this water, if it can be collected, once again for biomass production. Although currently no crop plants exist that can be grown economically with 17,500 mg/l water (about 0.4 seawater concentration), there are halopytes that can be grown as wildlife habitat, or as a source for methane production. Thus plants, whether they be conventional crops or species not now used in agriculture, provide the option to make beneficial use of a resource now considered a waste product.

Such a system, however, would require a separate distribution system for the drainage water to be reused and a series of questions would need to be resolved in terms of water rights and pracing. Again, the institutional, as well as technical, problems must be coped with.

These examples illustrate the potential, with present technology, for enhancing resource use in irrigated agriculture. With imaginative scientific and engineering research, the technological potential can be expanded considerably. However, such potential innovations will only be put in practice if the institutional framework is appropriate. I only hinted at the economic, legal, and institutional restraints that are frequently encountered. Science, powerful as it may be, cannot be expected to have its full and potentially constructive impact in the decision process unless its practitioners involve themselves, at least to a degree, in the societal framework where the decisions must be made.

We must recognize that we have lived in a period of plenty. As long as water supplies were abundant, as long as new discoveries of oil exceeded the rate of use, and as long as land was to be had by the homesteader for the sweat of his brow and the guts for tackling its development, concern for ultimate exhaustion was hardly to be expected. We wrote our laws to encourage economic growth and we were successful. But now it is 1979.

Now we must consider the limitations of our economic concepts as well as their strengths. For example, the true costs of exhausted natural resources are not only difficult to determine, but are seldom used in economic evaluations. The farmer who loses 25 tonnes of soil per hectare by erosion is more concerned with his annual income than with the cost to the nation or the loss to his grandchildren. When gasoline sold for $.30 per gallon, we were paying for its pumping and transportation costs, not the value of the petroleum resources. And when irrigation water is even now sold for #3 per acre-foot, that price is based on recovering district operating costs, not the value of the water.

Also, economic laws should not be considered natural laws, but more nearly man-made conventions. They certainly are strongly influenced by institutional constraints. The most obvious example may be the effect of western water law on water use. Even among my neighbors, members of a small independent water company, the argument is heard that we should pump at full capacity, independent of need (or costs!) in order to establish a maximum groundwater right. Resource conservation cannot be achieved except by dedication, or by regulation imposed from within or without.

In view of the difficulty of estimating true costs, alternative criteria should be considered. One possibility is "energy economics" as opposed to "dollar economics," or evaluation of activities in terms of energy efficiency. Although I do not share the view that such a standard, in itself, is valid, I do find it highly instructive and consider it useful as one of several criteria for evaluation. In such terms, an assessment of agricultural progress fares far less well than in terms of crop yield per man hour.

THE CHALLENGE

What do these examples show in terms of the opportunities we have to improve the use of land-water-energy resources in agricultural production? I believe they show that we have a tremendous challenge and a heavy responsibility before us.

I already mentioned the generally low efficiency of water use in irrigation. In some instances, excessive irrigation may be harmless if the excess water is returned to a useable water source without degradation in quality. In general, however, it is a practice that consumes energy, wastes fertilizer, and degrades or wastes water; it may cause erosion and even depress crop yields.

Despite substantial research, irrigation efficiency seems to have changed little over the last 30 years or so. This no doubt is due in part to difficulties in translating research-derived concepts into practical techniques acceptable to the farmer. But in larger part it is due to considerations of farmer economics and water rights. Recently, we have witnessed an increase in irrigation scheduling services and an interest in, if still little adoption of, automation. Such developments hopefully will lead to improved water management without requiring increases in labor costs or irrigation skills.

Best plant response is obtained when the water content in the rootzone is maintained nearly constant. Management to that purpose requires full control over the water and thus water delivery in closed conduits under pressure. Irrigation agriculture is energy intensive. Over 50 percent of the fossil energy used to raise an irrigated crop is used to deliver the water.

At first glance, these two observations appear to argue for opposite courses of action because pressurizing irrigation water requires energy. However, closer examination indicates compatibility. Pressurized water delivery requires far less water than an uncontrolled gravity system. Energy consumed in pumping would be reduced proportionately. Also, adequate, but not excessive, irrigation reduces drainage volumes and fertilizer needs. For some closed conduit irrigation systems only very low pressures are required—on the order of 1 to 2 meters of hydraulic head. The energy required for pressurization of these systems is often available as gravitational energy, without requiring additional fossil fuels.

Thus it is practical to design and install irrigation systems that use no more water than needed. Such systems save water and energy. They also may reduce significantly the degradation of water quality by salination. To remove a part of the third of the salt load in the Colorado River attributed to irrigation will cost the federal government several hundred million dollars. The cost of treating the drainage water from only one valley with 25,000 hectares of irrigated land is likely to exceed $30 million per year. Over 40 million hectares of new irrigation projects are on the drawing boards across the world. Thus the potential is there for substantial savings in terms of water quality, energy, and dollars by choosing a preventative rather than a salvage program. The question is whether we shall have the courage and the ingenuity to upgrade our present systems, and the foresight to plan for good conservation in new developments.

I have taken a few examples of areas where scientists and engineers face a challenge to make their presence felt by offering solutions to problems society faces—solutions that will help to conserve or stretch our precious and limited resource base. On purpose, I have oversimplified my case. As a research scientist and administrator, I am fully aware that many a detailed answer is not readily at hand. In fact, my enthusiasm may even carry me so far as to see researchable problems where none exists.

This leads me to a final set of observations. After several lean years, there has recently emerged a strong and lively interest in strengthening the research capabilities in agriculture and resource development. I wish to utter a word of caution, possibly unexpected from this source, that large increases in research expenditures do not guarantee parallel increases in the solution to problems. I sense a tendency among some of my peers to press for drastic emphasis on "basic" research as opposed to "applied" research. Without getting bogged down in definitions I submit that tremendous progress can be made by learning to transfer

existing technology and by adaptive research—learning to adapt known principles to existing circumstances; and that research intended to help solve the twin problems of feeding our fellow men and conserving our dwindling resources must keep its eye squarely on the practical goal. Ivory tower research, or research inspired by curiosity but not directed at some ultimate problem, has an important place and we cannot afford to neglect it. It should, however, be kept in balance. We also must keep in mind that technological answers are not sufficient unless they are compatible with socio-economic patterns. Many of our problems are as much a result of institutional or legal restraints as of technical inadequacies. Such problems, in principle, however, can be resolved as well.

We face an important challenge—in research, in application, and in education. I trust and I pray that we shall have the vision and the dedication to meet the challenge.

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Mr. AMBRO. Next we will hear from Dr. William C. Ackermann, Chief, Illinois State Water Survey.

You may proceed.

STATEMENT OF DR. WILLIAM C. ACKERMANN, CHIEF, ILLINOIS STATE WATER SURVEY

Dr. ACKERMANN. Mr. Chairman, members of the subcommittees, good afternoon. My name is William C. Ackermann, and I am chief of the Illinois State Water Survey. It is a pleasure to be here and hopefully contribute to the important subject of your hearings.

Through discussions with your staff it was decided that I should direct my comments primarily to questions of water supply and its augmentation. In further consideration of the locations of other members of this panel it seemed desirable to concentrate my remarks on the situation in the Midwest and Eastern portions of the Nation, believing that others will deal adequately with the perhaps more serious problems in the West.

I will first present some information on water use in comparison with available water resources. Second, I will discuss major means for supply augmentation, and finally discuss briefly a number of perceived problems related to agricultural productivity and environmental quality.

WATER USE VERSUS POTENTIAL WATER RESOURCES

Anticipating that in his overview Dr. Leo Eisel of the Water Resources Council would draw upon the recently published Second National Water Assessment entitled "The Nation's Water Resources 1975–2000," I have chosen to bring you some 1978 data on water use and water resources potential from a report now in press entitled, "Water Withdrawals in Illinois, 1978." It is believed that Illinois is quite representative of the Midwest and the Eastern United States and that 1978 was a representative, recent year.

If the members would care to refer to page 3 of my testimony, you will find a table entitled "Summary of Water Use and Potential Re-

sources." On the left-hand side of the page are 1978 withdrawals for public systems, self-supplied industry, power generation, rural, and others. Footnotes explain and qualify the numbers. Public and industrial uses are roughly equal and each is more than seven times the rural use. The dominant figures are for hydroelectric and steam-electric cooling water, but these uses make virtually no consumptive demand upon the water withdrawal.

On the right-hand side of the table are the various categories of existing and potential supplies, with a total of 52.1 billion gallons per day, which seems perilously close to the present demand. One should be reminded, though, that the water used for hydroelectric power is diminished only in its elevation, and the water for steam-electric use primarily in its warming.

RURAL WATER USE

The total rural water use of 220 mgd, as shown in the table, is approximately equally divided among domestic use—82 mgd—livestock—65.9 mgd—and irrigation—71.9 mgd. The irrigation water is mostly supplied during the months of June, July, and August, but is reported here on an annual basis. There has been a substantial increase in the acreage of agricultural lands irrigated from 9,000 acres in 1950 to an estimated 120,400 acres in 1978. Total irrigated acreage, including golf courses and cemeteries is estimated at 172,000 acres in 1978.

SUMMARY OF WATER USE AND POTENTIAL RESOURCES IN ILLINOIS

[In million gallons per day]

1978 withdrawal		Potential supplies	
Category	Ground and surface water total	Category	Ground and surface water total
Public systems	1,773	Ground water [3]	6,900
Self-supplied industry [1]	1,792	Stream flow [4]	43,000
Power generation:		Reservoirs [5]	2,200
Hydroelectric	22,593		
Steam electric	21,391	Total	52,100
Rural	220		
Others [2]	43		
Total	47,812		

[1] Primarily in manufacturing and mineral extraction.
[2] Primarily for waterfowl management areas.
[3] Practical sustained yield.
[4] Available 95 percent of the time.
[5] Existing and potential reservoirs, using ½ the total storage, and assuming a once in 40-yr drought.

RURAL WATER SUPPLY

Farmers have traditionally met their requirements for domestic supplies from wells, springs, or cisterns on their property. There are probably no less expensive methods, but these sources may be limited and may fail during dry periods, which can lead to the common practice of hauling water in tank trucks. There are commonly also problems with water quality with either bacterial or chemical pollution. The preferred solution to this problem in the long run is to supply our rural residents with piped water from central sources where both the quality

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and quantity of supplies can be assured. Slow progress in this is being achieved through the programs of the Farmer's Home Administration and by other institutions and financing. These programs, in my judgment, should be encouraged where needed and financially feasible.

Stock-watering requirements are often met from farm ponds created under programs of the Soil Conservation Service and other agencies, and these, too, should be encouraged where feasible to augment water supplies in an environmentally desirable manner.

MOISTURE AUGMENTATION FOR CROPS

It is now widely believed that added or optimum moisture levels is the next major means for increased crop production in the Midwest and Eastern parts of the United States. This follows the major increments of yield which have resulted from improved fertilization, better seeds, higher plant populations, weed and disease control through application of pesticides, and other management practices.

We will comment on three methods of adding moisture: Irrigation with conventional surface and ground water, weather modification, and application of treated waste waters.

AUGMENTATION BY IRRIGATION

Anticipating that other witnesses at this and other sessions of the hearing will amply discuss Western agriculture with respect to irrigation, I have chosen to concentrate on the circumstance as it exists in the Midwest and East, where irrigation is a rapidly increasing agricultural practice. I have liberally drawn from a paper "Irrigation Principles and Costs for Illinois" by M. D. Thorne.

Every section of Illinois normally receives more water as rain and snow during a year than it loses by evaporation from the soil and transpiration from plants. Nevertheless, there is never a year when soil moisture is not deficient for optimum crop growth sometime during the growing season.

In an average year, potential evapotranspiration exceeds precipitation from May to September. Crops will grow during this period if one or more of the following conditions prevail: (a) Stored soil moisture is sufficient to make up the deficit during the growing period; (b) actual evapotranspiration is reduced appreciably below potential evapotranspiration; (c) additional water is added as by irrigation.

Crops growing on deep soil with high water-holding capacity may get by quite well if precipitation is not appreciably below normal and if the soil is filled with moisture at the beginning of the season. Fine-textured soils with a high organic-matter content have good water-holding capacity.

Evapotranspiration can be reduced by getting fast early growth to help shade the soil, by mulching, or perhaps by transpiration retardants. When soil moisture is limited, evapotranspiration is reduced, but yields are usually reduced also.

Periods of below-normal rainfall in the summer are also usually periods of above-normal temperatures and soil moisture may become severely limiting. Data from Iowa State University have shown as high as 40 percent reduction in yield of corn from 4 consecutive days of visible wilting at the time of silk emergence. Their studies have

also shown yield reductions of soybeans as high as 40 percent from drought during the week after pod filling begins.

It takes at least 20 inches of water to produce a good crop of corn in Illinois. Various sections of the State get from 10 to 15 inches of rain during the growing season. Thus, 5 to 10 inches of subsoil moisture are needed in an "average" year to produce the yields which we have come to think of as normal or satisfactory. If the rainfall during the growing season is below normal in a particular year, more than 8 inches of stored soil moisture or applied water would be needed.

Unfortunately the probability of getting at least an inch of rain per week is lowest in all sections of Illinois during the time corn is normally pollinating—the last half of July. Irrigation can prevent moisture deficiencies during this and other critical periods in crop growth.

We now have 3 years of data from irrigation research on sandy soil in Mason County, Illinois. Corn yields slightly higher than 200 bushels per acre were obtained in 1975 and 1976. The yields from nonirrigated land in the experiment for those years were 70 to 80 bushels. Full-season soybeans yielded 55 and 45 bushels per acre in 1975 and 1976. The yields from nonirrigated land in those years were 30 and 16 bushels, respectively.

If a producer is convinced that it will be profitable for him to install an irrigation system, he must have an adequate source of water. Such sources do not exist at present in many parts of the State. We are fortunate in that underground water resources are generally good in the sandy areas where irrigation is most likely to be needed. Most of the irrigation development to date has taken place in these sandy regions.

A relatively shallow well in some of these areas may provide enough water to irrigate a quarter section of land. In some areas of Illinois, particularly the northern third, deeper wells may provide a relatively adequate source of water for irrigation.

Many farmers are pumping their water from streams for irrigation. This can be a relatively good and low-cost source; but, of course, the stream may dry up in a drought year.

Impounding surface water on an individual farm is possible in many areas of the State, and some farmers are doing that. However, an appreciable loss may occur both from evaporation and from seepage into the substrata. The rule-of-thumb figure is that you probably need to store 2 acre-inches of water for each acre-inch actually applied to the land. In many areas, the water-development costs are likely to be beyond the range of feasibility for an individual farmer. However, such development by groups of farmers, cooperatives or governmental agencies could produce a sufficient water supply in one containment for a number of irrigators.

AUGMENTATION BY WEATHER MODIFICATION

Weather modification through cloud seeding is one of the major means to augment soil moisture and increase crop production, as well as to derive additional benefits from increased stream flow.

Numerous reports containing evaluations of the potential effects of weather modification have appeared in recent years. One can cite the

report of the National Water Commission "Precipitation Modification" by J. D. Lackner in 1971, the 1976 report of the National Academy of Sciences report on "Climate Fluctuations and the Demand for Food," and the recent report of the Weather Modification Advisory Board, all of which point to the considerable potential benefits from weather modification, and to the fact that agriculture is the prime beneficiary.

My comments which follow are taken from a report in press, "Economics of Weather Modification: A Review" by Steven T. Sonka. This report states that because lack of adequate moisture can have severe adverse effects on agriculture, the gross benefits of successful weather modification activities are apparently very high. And, in general, the operational costs of modification activities are small relative to those gross benefits. But the indirect costs of modification activities may be very great.

The most important of these indirect costs is that, in general, those individuals suffering the adverse effects are not the same individuals who are enjoying the gross benefits. Therefore, even if the gross benefits of an individual project are greater than the sum of the direct and indirect costs, the existence of such positive net benefits does not insure that some individuals would not suffer substantial decreases in welfare.

It would seem that comprehensive economic analyses of various types of promising weather modification activities could provide useful information to the public and its decisionmakers. To be credible, such an economic analysis needs to be based on a sound understanding of the physical factors which will be altered and the manner in which they will be affected.

Probably the most important aspect in determining the credibility of any economic analysis, however, is the viewpoint of that analysis. In conducting such an analysis, it should be clear that the goal of the analysis is to determine the effects of the modification activity on the entire economy of a region, not just impacts on those sectors which derive benefits from the planned activity.

In general, crop yields are increased by above-normal rainfall only if the added rain arrives at the proper time. Additional rainfall at inopportune times can decrease yields. A further complication is that the time of beneficial effects typically does not occur simultaneously for all crops grown in a region. Variability, both with respect to natural rainfall and technological performance, is a crucial factor affecting the economic attractiveness of augmented precipitation.

Precipitation augmentation is not expected to eliminate droughts. However, the value of even relatively small increments of moisture for agricultural production and water supplies may be substantial during such periods.

Nationally, a 10 percent increase in precipitation in major crop producing regions has been estimated to increase farm receipts by $217 million—at 1977 prices. The crops considered were corn, soybeans, wheat, and rangeland forage. No price decreases because of this additional output were considered, however.

Increased precipitation may impact negatively on tourism, and the construction and transportation industries. There can also be harmful effects from flooding and erosion.

The type of watershed and amount of naturally occurring rainfall can greatly influence the benefits from increased streamflow for power generation. Therefore, different regions can have quite different benefits from the same quantity of increased rainfall. Cost-return ratios of 1 to 1.2 up to 1 to 14 for differing basins were reported.

Snowpack enhancement is a relatively inexpensive way to augment water supplies in mountain regions and areas which use these water sources. For average years, costs of less than $5 per acre-foot were estimated, including some indirect costs for people negatively impacted by additional snowfall.

Evaluation of the benefits of additional water from snowpack enhancement is an extremely complex problem. Irrigation and hydroelectric power would seem to be the prime beneficiaries of additional water. Any other demanders of water could bid water away from irrigation if they needed it. In some instances, institutional arrangements would need to be altered to allow such transfers. Therefore, estimating the future value of irrigation water and the secondary benefits of agricultural production is especially important. But these values are extremely sensitive to assumptions about the future demand for food and fiber. If future demands allow excess capacity in the Nation's agriculture, the value of augmented irrigation water may be low. But, if future food demands lead to full employment of agricultural resources, the value of snowpack enhanced water may be quite substantial.

AGRICULTURAL WATER PROBLEMS RELATED TO PRODUCTIVITY AND THE ENVIRONMENT

Since both agricultural productivity and environmental quality are of critical importance, and since these objectives can impact each other, it is essential that their effects be made as compatible as possible.

From the viewpoint of water supply, and particularly with reference to agriculture in the Midwest and East we will mention three perceived problem areas which are briefly discussed below.

WATER RIGHTS

A particularly difficult question to address at the Federal level is the question of water rights, because the authority generally rests with the States. As it applies to irrigation in the Midwestern and Eastern States the riparian doctrine generally governs the use of surface waters. Briefly, this states that a person is entitled to a reasonable use of the water which flows adjacent to his land, as long as he does not interfere with someone else's right to use the water. No problem results as long as there is plenty of water for everybody. However, when water becomes limiting, legal determinations may have to be made as to respective rights. Also, there is no provision for the non-riparian farmer who does not have access to a stream.

Ground water is generally attached to land ownership, with the unrestricted right to pump from the underground. Here, again, the system is designed to operate well during times and in places where water is adequate, and problems result when pumping on adjacent lands exceeds the supply and interference commonly results.

Many individuals engaged in water resources management believe that the time has come for Midwestern and Eastern States to adopt permit systems for water withdrawal from both surface and ground sources. But such reforms are slow in coming, and various water using sectors of the economy such as municipalities, industry, and including agriculture are reluctant to lose their existing rights under present laws in favor of a permit system managed by a bureaucracy, even though there are theoretical and rational advantages to doing so.

The consequence of the present water use laws is that where economic advantage exists, supplies are increasingly being over-developed by agriculture and other users. We think that where such over-development occurs, agriculture will be the loser to the interests of municipal and industrial users.

IN-STREAM WATER USES

Over a long period of years the water requirements of aquatic organisms living in our streams, lakes, and estuaries have not received adequate attention in the allocation of our surface water. However, it is true that under the water pollution legislation of the last 10 years water quality considerations for in-stream life are beginning to be considered.

In even more recent times the agencies and individuals concerned with in-stream water use for fish, wildlife, and recreation have become much more active in determining and asserting the in-stream water requirements. This is appropriate because these needs are presently poorly understood, but must be for the inevitable tradeoffs which will be made with other in-stream uses such as navigation, and indeed, the possible conflicting off-stream uses for water supply including irrigation.

The subject is immensely complex even in a physical or hydrologic sense when one realizes that the low flow of streams is largely from ground water drainage. Thus, heavy pumping of the ground water can dry up a stream. The economic and environmental problems are even more complex. It is thought that the Subcommittees will wish to follow this gathering controversy very closely to insure that balanced tradeoffs are made including the interests associated with agrcultural productivity.

LAND DISPOSAL OF WASTE EFFLUENTS

The national attention to the clean streams program during the past decade has tended to shift ultimate disposal of our wastes to the land surface and the underground where it could pollute our agricultural soil and ground water aquifers. The practice of disposing treated wastes and sludges upon farmland has been encouraged and increasingly practiced because of economies and to comply with stream pollution regulations.

In the more recent few years concerns are being expressed because of potential pollution from heavy metals, pathogenic bacteria, and other constituents in our wastes.

The question of land disposal is certainly not resolved, and it would seem prudent that such disposal be limited to certain crops and environments, and that such operations be closely monitored for accumulations of toxic materials.

It should be borne in mind, too, that agriculture produces its own sets of pollutions to our environment through feed lots, the use of fertilizers and pesticides, and through erosion. By and large these problems have not yet been addressed from the point of pollution and environmental quality.

Mr. Chairman, I will be pleased to discuss these or other points in greater detail or to answer questions.

Mr. AMBRO. Thank you, very much.

I am now going to call on Professor Norman J. Rosenberg, Director, Center for Agricultural Meteorology and Climatology, University of Nebraska.

STATEMENT OF PROFESSOR NORMAN J. ROSENBERG, DIRECTOR, CENTER FOR AGRICULTURAL METEOROLOGY AND CLIMATOLOGY, UNIVERSITY OF NEBRASKA

Professor ROSENBERG. Thank you, Mr. Chairman.

First, I would like to thank the committees and their staffs for inviting me to speak with you today on matters of supply and quality of water for agriculture.

I am Director of the University of Nebraska's Center for Agricultural Meteorology and Climatology. The group I lead has considerable experience in establishing water demands by irrigated and dryland crops grown in the Great Plains region. This region spreads from the foothills of the Rocky Mountains eastward to the prairie States. The region is classified as semiarid to subhumid with a rainfall gradient of from 10 to 40 inches, increasing from West to East.

We find that our irrigation in Nebraska and other States in the region that are developing irrigation rapidly requires more water than originally thought necessary. I cite this fact because it has some bearing on the overall water supply picture for the future.

I would also like to point out there are ways in which water supply can be extended. Others have touched upon this in discussing the concept of water use efficiency. The irrigation engineer understands this term to mean: The ratio of reaching the land to that which is applied. I use the term to mean the ratio of crop produced to the amount of water consumed by the crop. Water use efficiency can also be expressed as the ratio of photosynthesis to evapotranspiration. We can effect large savings in water by increasing photosynthesis, reducing water use or, hopefully, by doing both at the same time. A wide range of technologies are available for this purpose. Some of these are well established; others are innovative and I would like to discuss these later in my presentation.

Further, I wish to raise the subject of drought here. In the entire problem of water supply we often tend to forget that climate fluctuates. At any rate we know we have had good years and bad years and that drought is an example of a climatic excursion which has a tremendous impact on our water supply. Conversely, our water supply has an impact on the seriousness of drought as it occurs in different parts of the country at different times.

For our purposes I define drought as an excursion from the normal climatic situation involving a shortage of precipitation sufficient to affect crop production. I emphasize the word "excursion" from the

normal because most of our planning has been based on supposed normals—the normal flow of the Colorado River, the normal temperature, and the normal rainfall in Nebraska, as examples.

Yet, we know that the "normal" rarely occurs and that in all of our planning for water supply we should be considering the extremes, the shortages, the excesses, and so on.

In my prepared statement I devote a few pages to the evidence of the occurrence of drought in the Great Plains in both prehistoric or modern times. I also point out that drought is an experience which affects not only the farmer, but the entire country as well. Drought first affects crop production but there is a ripple effect that reaches the small towns, agribusiness, the larger towns and cities and, more and more these days, the national and international levels. For example, drought in the Soviet Union in the early 1970's has had a very important impact on food prices in this country today.

Many of us working in the Great Plains feel that we do not yet have adequate strategies to cope with drought in the region. In 1974 and 1976 Governors of the drought affected States called in specialists for advice. Most often the advice they received was to "turn to Washington and ask for disaster relief." In fact, however, there are many technologies that have been used successfully in mitigating the effects of drought. Certain of these technologies came into general use after the drought of the 1930's. Windbreaks, the plantation of thousands of miles of trees in the Great Plains region is an example of one strategy which has had a beneficial effect. Ironically, many of these windbreaks are now being torn out because they are incompatible with modern farm machinery and with center pivot irrigation systems. A recent report by the GAO documents this development.

Soil conservation tactics have also been used successfully in mitigating the effect of drought. Minimum tillage and contour farming in Eastern Nebraska helped to stabilize corn yield on dry land during the drought years—1974, 1975, and 1976. Yield under conservation tillage was about 20 percent higher and varied little from year to year. Many farmers growing corn by conventional dryland practice simply abandoned their corn fields in 1974 and 1976.

In view of the fact that drought is a problem that has technological, social, political, and economic facets, the University of Nebraska requested support of the National Science Foundation for an effort to review the "state of the art" in countering drought in the Great Plains. A conference was held at the University of Nebraska, early this year, to address a number of pertinent questions which are detailed in my prepared statement. We started with two assumptions: First, that long range climate forecasting skill will be inadequate, in the foreseeable future, to predict the timing and severity of the next drought. There will certainly be another drought in the Great Plains. Second, we assumed that reliable weather modification technologies will be unavailable to mitigate the effect of the next drought. I take issue with the previous speaker on this question. Personally, I doubt that weather modification will have much to offer in the Great Plains region in the next 20 or 30 years, if then.

The major finding of the technology panel at the conference was this—that, despite experience acquired over many decades, the vulnerability of the Great Plains region, at least for the smaller farmer

and rancher is increasing at this time. Technological factors contributing to this increasing vulnerability include the rapid consumption of fossil water, center pivot irrigation and the use of larger and more expensive farm equipment. These three factors, we feel, are making the Great Plains more, rather than less vulnerable, to the next drought.

Thus technology has, inadvertently, contributed to the recent increase in our vulnerability to drought but technology may well provide new approaches to reverse this trend. Details of these arguments are given in my prepared statement.

The full statement will be submitted for the record. I will be pleased to respond to your questions.

Mr. AMBRO. Without objection, your statement will be printed in the record at this point.

[The statement of Professor Rosenberg is as follows:]

STATEMENT OF NORMAN J. ROSENBERG

First I would like to thank the Committees and their staffs for inviting me to speak with you today on matters of supply and quality of water for agriculture. My name is Norman J. Rosenberg. I am Director of the University of Nebraska's Center for Agricultural Meteorology and Climatology.

The group I lead has considerable experience in determining water demands by irrigated and dryland crops grown in the Great Plains region. This region spreads from the foothills of the Rocky Mountains eastward to the prairie states. The region is classified as semi-arid to sub-humid with a rainfall gradient of from 10 to 40 inches increasing from west to east.

Through our research which began in the mid-1960's and was sponsored in large measure by the Office of Water Research and Technology, we have found that the water needed for optimum crop production in the Great Plains region had been considerably underestimated by hydrologists and irrigation engineers. This serious underestimation of our water demand was due to the fact that formuli developed in the humid parts of the world—Great Britain and the eastern United States particularly—were applied indiscriminately to the semi-arid and semi-humid Great Plains climate.

Water demand can be equated in the humid regions to the amount of energy provided by the sun (technically, to the net radiation which is the difference between the incoming and outgoing radiant energy). In semi-arid regions, however, there is an additional source of energy to evaporate water—that is, the warm, dry air brought in from adjacent dry regions and deserts in which little evaporation can occur so that the radiant energy of the sun simply warms the air. Hence, water demand by crops (evapotranspiration) can be, and usually is, much higher—often double that on clear days in the humid regions.

Our group has also been engaged in finding ways to increase the *water use efficiency* in irrigated and dryland agriculture. I define water use efficiency as the ratio of the crop product produced to the water consumed in the growth of the crop. Water use efficiency can be improved either by increasing the photosynthetic activity of the crop, by reducing its water demand, or by accomplishing both effects simultaneously. With declining water supplies and/or with increasing costs in providing water supplies for agriculture, increasing the water use efficiency becomes a crucial mateer. There are a number of ways in which water use efficiency can be increased and I will describe some of these methods below.

Today, however, I would like to emphasize another aspect of water supply problem. That is the need to develop regional strategies to cope with the effects of drought. We have good evidence, through tree-ring analyses and other surrogates, that severe and protracted droughts occurred in the Great Plains region prior to modern settlement. Weather records beginning in the 1860s also indicate clearly that periods of drought have alternated with periods of better weather.

The first settlers to Nebraska in the 1860s encountered favorable weather. The 1870s were dry, as were the 1890s. In fact, the drought of the 1890s in Nebraska and adjacent states led to a major outmigration. It is hard to characterize the ephemeral dry periods in the 1910s as drought. In the 1930s, of course, the most severe drought on record occurred over a very large portion of the Great Plains

states. I need not remind you of the tremendous political, social and economic impacts of that drought. In the 1950s there was a serious drought centered, primarily, in the southern Great Plains.

Drought began again in the Dakota's in 1973 and continued until the spring of 1977. In greater or lesser degree, drought occurred throughout the Plains region in 1974 and a most serious and widespread drought occurred in the summer of 1976, lasting until about March of 1977. The drought of 1976–77 was one of the most widespread in recorded history. The continental United States, from Illinois and Michigan to California and Washington State suffered from drought in 1976–77.

There is apparently a rough periodicity of major droughts. It is also true, however, that droughts have occurred somewhere in the Great Plains in almost every year of record. Certainly, in every year of record, droughts have occurred somewhere in the United States. We know that the northeastern, southeastern and northwestern United States are not immune from drought.

There are numerous definitions of drought, but for our purposes the following definition will do: *an excursion from the normal climatic situation involving a shortage of precipitation sufficient to affect crop production.* This definition tells us that the Mohabi desert never experiences drought since it rarely rains there. But London, England can and did experience drought in the mid-1970s.

Strategies to cope with drought are not new. Many important governmental efforts to cope with drought took effect in the 1930s and these have, I believe, helped mitigate the impacts of subsequent drought. I refer, for example, to the Great Plains shelterbelt project—the plantation of tree windbreaks on a dense network throughout the Great Plains region. I refer to the rapid adoption of contour farming as a means for reducing water erosion of soils and for trapping and holding more water in the soil for later use by plants. I refer to strip cropping methods used in the small grains regions of western Kansas and Nebraska and eastern Colorado. This technique was introduced to reduce wind erosion and also, in combination with a fallow farming system, to capture and hold sufficient moisture for one crop every other year.

We have good evidence that these and other technological developments, encouraged during and shortly after the drought of the 1930s did, indeed, reduce the impact of subsequent droughts. For example, in eastern Nebraska in the period 1974–1976 yields of corn grown on dryland under conservation tillage practices were stable and at least 20 percent higher than yields under conventional tillage practices.

The drought of the 1930s occurred in the midst of depression and national crisis. Whether the drought or the depression caused the large outmigration from the Great Plains area is not totally clear. Both factors were obviously involved. It is clear, however, that the drought of the 1950s was at least as intense in the southern Great Plains as that of the 1930s. Yet the overall economic and social impacts were smaller. Aside from conservation practices and water resource developments, crop insurance and stabilization programs were also in effect at this time. Irrigation was also considerably more widespread and its impact on the southern and western Great Plains was significant.

We have also learned from past experience that, while the impacts of drought begin at the farm level in terms of crop production and harvestable yields, ripples occur from the farm level to the small town and the larger cities which service the agricultural region. Effects occur that strain the social structure of the affected areas as well as its political stability.

By the time of the 1970s drought a great many changes had occurred in the way that land is used and in the capital intensity of agriculture in the Great Plains. Many new technologies had also become available. The 450-horsepower tractor was becoming a common sight. Thousands of center-pivot sprinkler systems, capable of irrigating 135–150 or more acres in a quarter section, had been installed in the region. The mid-70s was a period of world-wide food shortage and American agriculture became more sensitive to the effects of drought in Africa, the Soviet Union and elsewhere. Further, the closure of diminishing energy supplies with the tremendous energy demands of our large machinery and irrigation systems brought a new dimension to the problems of coping with drought in the Great Plains.

In view of these changing circumstances it appears that the Great Plains region is in need of a set of drought strategies or contingency plans to cope with the inevitable droughts of future years. To help begin the important work of developing such strategies the National Science Foundation through its Applied

Science and Research Applications Division sponsored an interdisciplinary workshop entitled *Research in Great Plains Drought Management Strategies.* The Workshop was held in Lincoln, Nebraska in March of this year. Some 60 social, physical and biological scientists, economists, farmers and irrigators, federal and state administrators, politicians and members of the media were involved.

The participants in the Workshop were divided into four panels centering on the questions of Technology, Social and Information Sciences, Economics and Politics. The groups interacted and challenged one another's suggestions and assumptions with vigor (if not relish). The Workshop was asked to (1) assess the current state of knowledge concerning past and present impacts of Great Plains droughts; (2) assess the future vulnerability of the Great Plains region to drought; (3) suggest strategies applicable on the local, state, regional and national scales to mitigate the effects of drought in the Great Plains and (4) to identify specific research needed in support of drought strategy development. In reaching our conclusions we were also constrained by the following assumptions:

(1) that long range climate forecasting will be unable, in the forseeable future, to predict the onset of the next 'Great Plains' drought.

(2) that reliable weather modification technologies will be unavailable to mitigate effects of the next Great Plains drought.

Using these questions and acknowledging these constraints, the panels reported a very wide range of impacts of drought on all aspects of society and identified a large number of questions requiring answers before workable, flexible strategies can be developed for the region. The report of the Workshop is now being assembled for NSF/ASRA and will be published in hard-cover as well. For the purposes of this hearing, however, I will confine my remaining time to a brief recounting of the findings of the Technology panel which was chaired by Dr. Harold Dregne of Texas Tech University.

The Technology panel concluded that, despite experience acquired over many decades, the vulnerability of the Great Plains region, at least for the smaller farmer and rancher, is now increasing. Technological factors contributing to this increasing vulnerability include the rapid consumption of fossil water, center pivot irrigation and the use of larger and more expensive farm equipment.

The Ogallala acquifer underlying a large portion of the Plains from Texas to Nebraska is being depleted at a rate of 2 or more feet per year. This decline means that, in certain areas, irrigators no longer have the flexibility to respond to droughts by increasing pumpage. The greater cost of energy to pump water will reduce still further the irrigator's ability to cope with protracted drought.

The center pivot sprinkler systems may actually be increasing our vulnerability to drought. These systems permit breaking out of soils too sandy or hilly for surface irrigation—thus increasing susceptibility to wind erosion. Also, center pivots have led to the removal of many shelterbelts since they may interfere with the operation of the irrigation systems. If energy costs make the use of center pivots unfeasible (each pivot in Nebraska consumes from 4,500 to 10,800 gallons or an average of about 7,500 gallons of diesel equivalent fuel per year) abandonment of the sandy lands and their exposure to severe wind erosion will likely ruin them for agriculture.

Reliance on larger and more expensive equipment increases financial burdens on farmers who then increase the area they must farm. When marginal areas are brought back into production—vulnerability to drought increases.

The Technology panel concluded that realistic drought strategies for the Great Plains must be aimed at increasing water supplies, reducing water demands and increasing the acceptability and effectiveness of technologies that affect water supply and demand. Mitigation procedures in drought may involve short term emergency measures and long term measures intended to increase stability of production. Emergency actions can have undesirable side effects—for example, the provision of wells or larger pumps on existing wells may cause the ground water to become depleted even more rapidly.

Among the short term technologies identified by the panel were these:

(1) use of strategic irrigation to make maximum effective use of limited water supplies (irrigating only at critical stages of plant growth, for example).

(2) matching crops and management to moisture supply (planting sorghum instead of corn or reducing plant stands in a cornfield under water stress).

(3) employing special weed control practices (chemicals or fire rather than mechanical tillage).

(4) adjusting livestock numbers (Mennonites in South Dakota shipped their herds to church members in Nebraska for care during the most severe drought months of 1976-77).

(5) constructing new wells and stock ponds.
(6) intensifying dissemination of information on drought mitigation.
Long term measures recommended by the Technology panel were these:
(1) increasing the use of minimum tillage practices to reduce direct evaporation from soils.
(2) improving snow management to increase capture and storage of water.
(3) increasing use of irrigation scheduling services.
(4) modifying crop microclimates to reduce moisture stress (windbreaks of trees or annual and perennial crop plants, reflectorizing crops).
(5) introducing alternative, drought resistant or avoidant species.
(6) improving cultural practices to minimize soil exposure to evaporation.
(7) increasing use of water harvesting techniques (e.g. microwatersheds).
(8) reducing direct evaporation of soil water (surfactuant chemicals, natural or manufactured mulching materials).
(9) selection of new varieties of existing crops for drought tolerance.
(10) altering crop canopy architecture to minimize stress and improve water use efficiency.
(11) increasing use of small water impoundments.
(12) controlling phreatophytic vegetation.
The Technology panel also recommended greater use of remote sensing technologies and specific meterological observations to provide for an improved surveillance on drought affected areas. Much of our information on the severity of drought and its geographical extent has been inadequate in many ways. A recent report by the Controller General of the United States [1] indicates, for example, that drought related loans and grants may not always have been applied in the areas most severely affected by drought.
A full description and discussion of the technologies described above will be provided in the report in preparation for NSF/ASRA. This report will certainly be made available to your committees.
My purpose in this presentation has been 1) to call your attention to the fact that water demands for optimal agricultural production in the Great Plains region may be greater than has been planned for by State and Federal agencies; 2) to indicate that there is potential for using water in agricultural production more efficiently than is generally happening now and 3) to discuss the special case of drought—a recurrent phenomenon on the Great Plains—and the need for strategies to cope with drought.
Drought is in essence a water supply problem. Conservation technologies helped reduce the vulnerability of the Great Plains region after the drought of the 1930s. In my opinion and that of a number of knowledgeable farmers, administrators and physical, biological and social scientists, the Plains are now becoming more, rather than less, vulnerable to drought. Technology has, inadvertantly, contributed to the recent increase in vulnerability but may well provide new approaches to reverse this trend. I will be pleased to respond to your questions.

Mr. AMBRO. I would ask all the previous witnesses to join you so that we can have our discussion. It is rather disappointing that more members of these subcommittees are not here to hear the testimony.

In all fairness, though, Chairman Brown had to Chair a seminar up the hall but he will drop in later.

On the floor right now is something very vital to the Nation and many of us and that is a bill permitting the President standby gasoline rationing authority and everyone wants to make sure their tanks and pumps are filled, so they are on the floor.

I might shift your attention to the foundation of these hearings. They are relatively unique in that we have joined together a very significant subcommittee of the Agriculture Committee and the Science Committee in order to tile that which has gone on in the past and that is primarily the effects of agriculture on the environment.

Usually, in hearings we speak about the impact of nonpoint sources such as chlorinated hydrocarbons, insecticides, pesticides, fungicides,

[1] Federal Response to the 1976–77 Drought: What Should be Done Next? CED–79–26, Jan. 31, 1979.

and anhydrous ammonia leaching into our water supplies as a result of agricultural usage, thereby losing let us say a portion of our aquifers as a result of contamination.

We are attempting to turn it with respect to effects of urbanization on agriculture. That is the crux of it.

For example, we understand that as the result of the population increases and shifts there are planning changes in what is now a sub-urbanization using what was previously agricultural lands. We have a loss of top soil as a result of that. We have increased intrusion of water supply necessary for not only drinking which is the primary use as talked about earlier but a use for agriculture. We have increased sewers and septic tanks and other things contaminating the water supply.

We also have the Federal mandate of secondary sewage treatment which represents in many areas an outflow of fresh water, diminishing the aquifiers.

Let me see if I can get the witnesses straight. Who was it that told us about the aquifiers being diminished. In other parts of the country as a result of secondary treatment reuirements without any capability of tertiary recovery or recharge, we are losing those aquifiers as well thereby diminishing the quality and the quantity of our water.

There are industrial organics as a result of commercialization, intruding on our water supply in the form of a variety of contaminants and I think what we are looking for is some way or some direction with respect to who should focus on these problems in this vast bureaucracy, the Federal level, or should we rely on State and regional governments to do it?

We certainly cannot rely I do not think, except for protection of certain kinds of societal forces to assure agricultural production and water supply let us say on local levels of government. It is so vast a problem, so large a country that we would like to see, I think with these two and other committees being elevated by these hearings on how best to approach this escalating problem.

Dr. Van Schilfgaarde says the days of plentiful water supply are clearly over and our policy is nonexistant. I agree with that.

How do we assure both our agricultural production, which is the model of the world as someone said, and those sociological forces are compatible in 3 sentences of 25 words or less.

Anyone want to start this discussion?

Thank you, gentlemen. Why not take a bite out of it because really, witnesses such as this panel have come from all over the United States. The orientation, though, seems to be too much agricultural and not enough integrated with those urban factors that we want to discuss with respect to effects on agriculture. Let us turn this discussion, if we can, to just that.

Dr. VAN SCHILFGAARDE. If I might make a comment that does not address the question very well and I am sorry I do not have 25 words or less, there is an implication in what you say that we need to put this in an adversary situation between municipalities.

First of all, the question is too diverse but the nature of a solution has to be some kind of an integration, some kind of working together, secondary use of sewage water for irrigation besides solving a municipal problem.

The Colorado River program on irrigation efficiencies to reduce salinity will benefit the City of Los Angeles and not agriculture so

here is an example the other way where agricultural changes are for the benefit of the municipalities.

I think as much as anything you need to find ways of integrating the frequently competing uses into a common system in order to resolve some of the questions that you raise. How we go about that is the $64 question.

Mr. AMBRO. Biomass as you pointed out and the production of alcohol as an octane intensifier and gasoline extender is in that same vein, but can anyone start this by approaching the question of the severity of the competition between agriculture and urban uses throughout the United States.

Mr. KOELZER. I would like to try to put a little perspective on it. I do not visualize this competition is catastrophic and I have talked in terms of certain needs that you must satisfy and certain other opportunities that are pretty low on the economic scale that you might give up if competition for another use is higher.

Without bowing totally to the economist, I think this can be pretty largely evaluated on an economic basis, or let the market forces take care of it. There are certain constraints you have to have in there.

As far as a mechanism for doing this on new projects, I think the Water Resources Council's principles and standards furnish a real good basis for doing this. It does call for the evaluation in economic terms of one use versus another, alternative plans so to speak. It does call for displaying the environmental consequences of any particular use and in the end if there is a serious competition between economic views and environmental use, it will have to be decided in the political arena and this puts the information in that category—that is with respect to future uses.

With respect to present uses, the market forces cannot operate quite that clearly because of existing laws, existing contracts, and a number of things and yet, there are areas in which the market forces does it very nicely and it does it I think in Northern Colorado. I am not sure it is all that bad in Arizona around the Phoenix area and it does it without a lot of bureaucratic restraint.

Mr. AMBRO. Well, Dr. Van Schilfgaarde told us about the loss of land to salinity. There is a loss of land as well from industrial organics—tetrachloroethylene and things of that nature; heavy metals.

Maybe we can narrow the focus and ask in this ever progressive technological society we are gaining the ability each day to identify 4,000 to 70,000 compounds, many of which are, according to the regulators, carcinogenic.

What are the problems of urban impact on agricultural water-quality? Let us start with that.

How do we go about resolving that problem? There will come a point in this Nation if we continue to go this way that none of the water will be fit either to drink, which is its primary function, or to use for irrigation or anything else.

Dr. ACKERMANN. Mr. Chairman, I think it is a fair statement to say that most of our environmental pollution has come about through our urban society: The municipal use of water and the industrial use of water and I think that the present trend is to try to diffuse out into the landscape, and that means agriculture, these residuals of production that come about primarily from our urban society.

I think that it is important, if not urgent, that we give much more serious attention to the question of the pollution of our ground water.

I think it was perfectly logical for our pollution program in this country as it started up to its present high gear, to focus on the streams and on the point sources of pollution. They are much more amenable to solution, much more visible and dramatic and I think we now have that program largely on course so we can look toward, in a few years, a major improvement in the residuals of pollution from point sources, mainly municipalities and industry and mainly into our streams.

But, as I mentioned briefly in my presentation this focus on the stream pollution has tended to divert our residuals onto the landscape and we now have a national policy that even encourages disposal of waste or treated wastes onto the land. It is economical in many cases. It has some short-term advantages to agricultural in supplying water and some nutrients, but, of course, inevitably it contains a lot of things that are undesirable.

I think your point is well taken that the polutants of society are primarily urban generated and we have on the one hand now begun to distribute those pollutants back onto the land, part of which is beneficial and part of which is not.

Another thing we have not really looked at in a sense of research or inventorying our resources is what is the water quality available to agriculture, particularly in the Middle West and East which is the part of the country that I focused on. This is apart from what Dr. Van Schilfgaarde talked about in terms of the salt buildup under Western agriculture.

We conducted a study in Illinois, a sampling of a large number of farm wells and we found that something like 30 percent of the farm wells used for household supplies in Illinois are polluted. The primary pollutant is nitrates partly from barn lots, septic tanks, fertilizers, but we have never really discriminated entirely as to where those sources are.

But, our farm water supplies, and also there is pollution from bacteria, are not subject at all to the kind of monitoring and regulation that the water supplies for cities is.

I think we need to look at what kind of water quality is available to our farmers, to what extent is it causing illness of people and animals. We are not doing very much about that and I think we need to.

The kind of pollution that I am most concerned about is the ground water pollution. This is not a totally new thought, but it certainly is not widely recognized.

Now, part of this is the attention to surface water cleanup which has directed pollution underground, but there are so many sources of pollution to the ground water, and you mentioned septic tanks, but we have waste lagoons in our cities as a way of treating waste water and we have leakage from sewers; pipelines that are leaking. We have road salt spread in the Northern States. We have just a large number of sources of pollution that kind of go out of sight and onto the land and I do not think we are giving nearly enough attention to what kind of buildup pollutants are having in our ground water aquifers.

As it is understood by people working in this business, if we pollute our ground water aquifers it is going to be much more severe than cleaning up the streams.

Mr. AMBRO. Well, you know I wish you had made that statement on the floor of the House a week and a half ago. A subcommittee I chaired authorized considerable money for ground water research in the EPA budget because we believe as you do, that there was not enough being done with respect to ground water research in the environmental, ecological health effects area.

Well, the authorizing committee passed the bill unanimously, but the Appropriations Committee cut it. We tried to restore it and lost. We still have hope on the Senate side that that funding level will be elevated because we see that as the most critical difficulty this Nation is going to face in the very short term with one of the most critical elements in our survival and I agree with you completely.

We have a vote on the floor. I know my friend Ed Jones has some questions. I would just like you to reflect on this before we take a break.

I would like to ask you about something that you just said. We have embarked on a pure drinking water act, or the National Environmental Policy Act.

As a result of the energy crisis the President has generated considerable controversy by suggesting an energy mobilization board which has given a great hope to antienvironmentalists and aroused considerable consternation among proenvironmentalists because they will have waiver authority over a variety of evironmental constraints and I would like to ask what the agricultural community thinks about a shifting away from, or diminishing the kinds of requirements set forth under that series of environmental impacts.

Maybe we will break for this vote and come back and talk about that in say 15 minutes, with your indulgence.

[Brief recess.]

Mr. AMBRO. I would like to reconvene the subcommittees.

Off the record.

[Discussion off the record.]

Mr. AMBRO. Back on the record.

When we left I was asking about the Energy Mobilization Board recommended by the President and the waiver provisions in it and a variety of environmental constraints.

Anybody want to start with respect to a response to that; your attitudes regarding it?

Dr. EISEL. Maybe just to briefly speak to that, I think it could be kind of viewed as the nose of a camel under the tent and as a response of the President and Congress to kind of do something and all of us certainly have spent some time waiting in a gas line in the last month or so, but you really wonder does the kind of inconvenience, the problems to business and this type of thing that has resulted because of the energy shortage and gasoline shortage over the past few months really justify the kind of wholesale walking away from the various environmental rules and regulations and legislation and requirements that have been set up and established over the past 10 years or so.

Mr. AMBRO. Wait a second. In the first place, it is not the Congress that has done it. It is the President who has recommended it.

In the second place, I do not know there is wholesale walking away from those kinds of programs, but with those modifying provisions, go ahead.

Dr. EISEL. That within the area of water resources for example, just looking at the whole oil shale development area that the Water Resources Council over the past year or two in cooperation with the DOE has done an analysis of the water resources availability within major river basins in the Western United States for the development of oil shale, coal development from mine mouth generating sites and this type of thing and there are some very substantial problems both from the viewpoint of developing adequate water resources as well as the various environmental problems associated with the development of those water resources.

I think there is a lot of sympathy with the concerns of the President and the Congress over putting together some kind of solution to these energy shortages and not seeing fantastic delays in building synfuel plants over water.

I would hope perhaps instead of just eliminating a lot of these requirements that essentially some kind of mechanism can be put together to require a speeding up of the necessary procedures required to meet the regulations.

Mr. AMBRO. Anybody else want to comment on the whole question? Given the current overpumping and salinity problems for example in the Colorado River, what will be the impact on agriculture of using 10 percent of the amount of the Colorado River waters currently used for agriculture for shale mining and processing as proposed in the President's program?

Somebody want to talk to that?

Professor MARTIN. I think that will speed up the upper basin's development of their water which will, of course, cut down the water available for Arizona through the Central Arizona Project sooner. As you may know, the project is being built to transport 1.5 million acre-feet of water into the center of the State; that is, it is sized like that so it can do that in the early years but even current projections show that within 20 years after its completion it would only be carrying maybe as little as one-half million acre-feet.

Developing the water in the upper basin just speeds that process. It is their water. They have the right to it under the compact.

Mr. AMBRO. Is it a source of concern?

Professor MARTIN. Well, I cannot figure it out, frankly. I have been studying the central Arizona project for 20 years and I cannot figure it out.

Mr. AMBRO. The reason why I asked that question if you want to narrow things to a specific and move to something more general, I think the question has to become, should we try to develop a national policy to reduce urban and commercial and industrial use of water or to better manage it on a national scale?

Regionally, there have been attempts for example, to develop water management or water budget policies and incidentally, I asked for that breakdown in terms of region because you have Long Island, for example where we rely solely on a very fragile and vulnerable aquifer lumped into the Middle Atlantic States. We are quite different from our behemoth neighbor to the West, New York City, which has all the water piped in from tunnels which are quickly diminishing in the upper reaches of the United States and Canada and New York State.

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If we lose those aquifers we have no hope, especially even in terms of present Corps of Engineers capability to build tunnels to get the water from other sources, so that will be a barren wasteland. That is why I wanted the breakout.

How about a national policy of some kind, Mr. Koelzer?

Mr. KOELZER. I do not believe I would like to see a uniform national policy because I think obviously, the impact in Long Island vis-a-vis other places where they are competing for water is going to be different, such as oil shale development in Colorado competing with some agriculture use further down the Colorado River.

I cannot speak to your problem in the East, but it seems to me that in the Colorado River basin, first there is a certain amount of ownership by States which presents the legal barrier to doing something. As for the development of the water supplies that are still there, I think the economics of it is almost going to dictate that this remaining supply be developed for oil shale as opposed to the other uses. It is going to be a higher economic value use and from an energy resource point of view; a higher value use. I am not concerned about the transfer of that water to that use. I think there are some serious environmental problems which probably can be met and solved, perhaps not on the crash basis that the President is talking about, but they certainly need to be considered.

Mr. AMBRO. Well, I will relieve you of my quasi-metaphysical line of interrogation and turn the questioning over to my friend, Ed Jones.

Mr. JONES. Thank you, Jerry.

Well, gentlemen, I am not going to keep you long but I do not want to say this, that this panel has really been an eye opener and all the testimony has been real good. You do excite me a little bit but at the same time you sort of scare me about some of the things you have said and especially you, Mr. Koelzer. I believe it was you and I have written so many notes here I cannot find them all, but when you said that, the loss of prime agricultural land scares me to death.

As a member of the Agriculture Committee it sort of bothers me when we have to be concerned with the use of the only thing in America that we have got today that is helping to balance our payments with the problems that we have in other places of the world.

You point out very well that we are exporting a very large amount of our grain crops, our wheat, our soybeans, and our corn, but I would hate to see us lose some of the prime agricultural land we have today when I know and a majority of the people in my field are quite well acquainted with the fact that countries like Brazil, the Government of Brazil as an illustration, I am informed that they are spending as much money to clean up land in that country to put into agricultural products as the land in our country is selling for today. That is a considerable amount of money.

If we have a water problem that is going to take some of our prime agricultural land out of production, and I do see and understand what you are talking about when we are using as much of our water supply as we are for agricultural production, then something has to be done about it.

I am not sure, but it seems to me that some sort of planning needs to be done either by our committees here and you know, we do not respond to the need until the need has arrived and maybe not even then in this field of politics. It is a little different from what we are sometimes engaged in, in the private sector, but it seems to me we have some problems there that we need to be responding to as far as getting rid of the sale from the water for irrigation purposes and one of alluded to the fact that we might be able to develop a plant resistant to saline water.

Anyway, I believe you are the one who alluded to that. To me, that is the way to approach it if we possibly can.

I think what you said in your testimony was that we have been looking for a short-term solution rather than where we should be going with some long term.

We have been knowing for a long time out in the West and many of the other areas of the country that we are running out of water and that we are going to have to without a doubt, approach some plan that will either produce some salt resistant varieties of various crops and plants, citrus and so forth or desalt the water faster than we are doing today.

But with the acreage of land that we have in this country today, 2 billion acres is used in agriculture the majority of which is forestry and I think Dr. Eisel said 422 million acres is cropland and 46 million acres are irrigated I thought that was a little high but that may be right today. It is not all in production, of course.

Now, with all that ability we have and the expertise that agriculture has and the colleges that were here this morning, folks who were heard today and you, there is no doubt in my mind that if we have to do it, we can do it very easily. We can feed the world. I think the best thing that the United States has going for it today is the agricultural expertise, research, the know-how that we have.

It is hard for people like Jerry to help me sell a program of that sort because his field has been in another area and we do not have many people in agriculture in the Congress, less than 35 people who even engage in that field in the House.

Mr. Koelzer, did you wish to respond?

Mr. KOELZER. Congressman, I certainly did not mean to scare you and I hope I can relieve you.

Mr. JONES. You are going to make me go to work.

Mr. KOELZER. So you can sleep a little better tonight, first I would like to make it clear that when I said I was not quite as concerned about losing prime agricultural land as I was talking about irrigated areas.

Now, when I talk about this prime land in nonirrigated areas that is taken over by suburbia, I think that is a matter of very great concern because once gone, it is gone.

Now, this is not true in Fort Collins where I live. Let us say that we lose a square mile of irrigated land that is prime land, but remember, the irrigated land is a combination of both land and water and when it is taken over by urbanizing Fort Collins that land goes out

of production at that particular point in time. A new municipality comes in and the square mile is developed for urban purposes and it takes just about the same amount of water to supply a square mile of people as it did the original square mile of irrigated land.

After the municipality uses it, at least 70 percent of that water goes back to the river system and if you go in for rock lawns and things like that, you can get up to 90 percent going back to the river system. This water is then reusable at some other location to develop 70 to 90 percent of a square mile of irrigated land at some other location so there is not the net loss in irrigated lands that one would think when he sees only that land being developed for urban uses.

The net loss is not that great and in northeast Colorado the statistics are there to show this net loss is not occurring to the extent one would think. There are tradeoffs, of course. If you are going to develop that land somewhere else, you are going to have to pay some cost in developing the irrigation system. You may be losing environmental values of open space and so forth.

Mr. Congressman, it is very nice to live next to a cornfield and these all have to be considered, but the point I wanted to make is that what seems like a simple thing for people to say we cannot lose that prime land in the irrigated areas is not necessarily a total loss.

Mr. JONES. Then I believe what you are actually referring to is not the overall loss of prime agricultural land in the country but it is in isolated or specific areas of the country.

Mr. KOELZER. Certainly that is true.

Mr. JONES. You did not mean just everywhere. I gathered when you started quoting those percentages of exports that we do export and all I thought maybe that is what you were referring to.

Mr. KOELZER. I was referring more to irrigated areas in the West.

Mr. JONES. To isolated areas?

Mr. KOELZER. There are quite a few statements in Colorado that we cannot just lose that prime agricultural land. I do not quite agree with that.

If you develop it somewhere else 50 miles down the river system, if it is economically justifiable to do it, it is not a total loss. We have some quality problems that are going to come from it, but these are tradeoffs.

Mr. JONES. Of course, one thing we are doing is that we are losing a quarter of a million acres each year of prime agricultural land that someone referred to this morning as being blacktopped roadbuilding.

Mr. KOELZER. These are the real concerns.

Mr. AMBRO. Will you yield?

Mr. JONES. Yes, Jerry.

Mr. AMBRO. I appreciate that, Ed.

Do I understand you to respond that you can move from one piece of prime agricultural land downstream to another piece of prime agricultural land without considering that is a loss of prime agricultural land?

Mr. KOELZER. We do not move to another piece of what is currently prime agricultural land. We move to a piece of potentially irrigable land; at present only sagebrush.

Mr. AMBRO. Well, maybe I do not understand the definition of prime agricultural land. Are you saying irrigable land has the potential of becoming prime agricultural land?

Mr. KOELZER. Oh, yes. We have a surplus of such land in most Western States.

Professor MARTIN. There is no shortage of land, just a shortage of water.

Mr. AMBRO. In the area I come from which is a burgeoning suburbia, and when people move out to the counties that I represent and developers come in, not municipalities, but developers come into those municipalities and strip the topsoil, we have lost forever the prime agricultural land. It might take another 10,000 years if we then came back and stripped the housing off of it to regenerate that layer of topsoil so that has been lost to us forever, and I think in what is now a suburbanization, it is a national phenomenon that has to be recognized, and we have, therefore, lost as a bottom line prime agricultural land.

Mr. KOELZER. I think it is true in your area, but it is not true in many areas of the West where prime agricultural land is made up of a combination of the land resource and the water resource.

Mr. AMBRO. The followup to that is if, indeed, the question becomes one of water usage and, therefore, depletion in the decades to come, to turn irrigable land into prime agricultural land, we have a net loss both in terms of water and other potentials.

Mr. KOELZER. A percentage of net loss, yes. It is not 100 percent. It is more like 10 to 30 percent.

Mr. AMBRO. Maybe I am splitting hairs.

I thank the chairman for yielding.

Mr. JONES. Dr. Ackermann, I want to continue what you had to say a moment ago about the rural water supply specifically. This is something of interest to me.

Being a rural person myself and having lived in a rural community all of my life—in fact, on the farm—I have been terribly interested in the Farmers Home Administration's work in supplying loans for the rural communities that have provided their own water supply, a safe water supply that you mentioned awhile ago, and although progress has been slow in this field, I would like to point out to the panelists here that the Farm Credit Act of 1978 was written by my subcommittee which has provided larger sums of money for these purposes than we had before, and we are flooded today with people who are trying to move back to the more rural sections of the country where they are taking some of our prime agricultural land like they are at Fort Collins and building homes on them and building a small new community.

They are really doing something good for the country, I think, when they do it, and probably for the health of the children and others, and the Farmers Home Administration has been swamped with applications to provide the funding for these purposes, both loans and grants, and I am sure that you know a lot about it and are familiar with it.

In my judgment, this is an absolute plus to provide clean water and eventually a better sewage system. It is happening to some communities today, but not many, but it will, and I think just as the REA was developed and the rural telephone cooperatives were developed, and we are moving in that direction altogether, and it seems to me that in the area that you talked about, clean water supply, that probably the Government through the Farmers Home Administration has contributed

about as much to that good idea and to the help of putting in into being as any area that I know of.

Dr. ACKERMANN. May I respond?

Mr. JONES. Please do.

Dr. ACKERMANN. Let me say I think your analogy to REA and rural telephones is a very good one. I have used it myself, and in my written testimony which I did not say here orally, I commented that the program of the Farmers Home Administration of providing piped water from central supplies is a very good program and should be encouraged, and progress is positive, but it is very slow.

Mr. Jones, this is the ultimate solution for the farmers to get decent water. I might point out to you that it is not an impossible dream.

The island of Puerto Rico, part of the U.S. territories, is almost entirely supplied by water from central systems, and Puerto Rico is a relatively poor island. It has a high rural population. It is very mountainous, and yet, those people have found a way to bring good water to their citizens in this diffused rural setting, and I would say, if it can be done in Puerto Rico, it can be done in most of the United States, and I really commend you for supporting that program. I think it is a very wholesome one.

At the moment, the need is so much greater than the resources being applied that there is no question in my mind, and I have looked into this, that only the highest priorities are being met, and that is where the need is greater for a rural water supply from a central system, and it is very economically feasible to meet that need by that way.

Yes. I do not visualize that will take care of the irrigation water requirements in the Midwest and the East. I lived in Tennessee for 18 years, by the way, so I am familiar with that State, but in order to bring good water for household use and for animal use, feed lots, animal drinking, we have to answer a lot of the rural water supply problems.

Mr. JONES. I think you are exactly right; and by the way, you mention Puerto Rico. Much of that water supply has been financed by the Farmers Home Administration in this country, a good amount of it has and they have done a splendid job.

Dr. VAN SCHILFGAARDE. I would like to come back to a comment you made earlier. Two or three years ago, a symposium was held under the auspices of Mr. Wittwer who was here earlier where a related question came up; a group of plant scientists decided they could not identify a single case where a new variety had been bred specifically to be adapted to the environment; that, in fact, it was the other way around. We have a policy of adapting the environment to the plants we already have. The exceptions were by luck. There were many plants developed that could adapt to the environment.

More recently I was with a group in California where the question of plant breeding for salinity was discussed, and those there could only identify the equivalent between three and five people across the country who were engaged in this who were plant breeders; considering the nature of the problem, the size of the problem within the United States, but even more so worldwide, it is striking that we have something on the order of three plant breeders either employed by

universities or the Department of Agriculture who are spending their time breeding plants for salt tolerant conditions.

Well, this idea, however, has been around for 30 years.

Professor ROSENBERG. I am going to have to run, but on this topic I must add one thing. The concept that I mentioned, the designing of plants to have architectures adopted to the environment, smaller leaves or larger leaves or taller or shorter, whatever, is required to meet stresses, one that sicentists have talked about for a long time, but we are beginning to break through.

We have received one grant from the National Science Foundation and one from SEA that was discussed this morning to begin such a program of analyzing of just what are the environment/plant interactions that will lead to even better adaptation and I think that is a hopeful sign.

Mr. JONES. Jerry, I will say one other thing before we leave. I want to tell this panel as a professional agriculturist that what we are trying to do—and here is Jerry, a man that comes from the city and George Brown does, too—he primarily represents that group and we are trying to put something together here gentlemen, that will help the whole of this country and we need your help and you have done a real good job of bringing this message to us.

Now, if we can get the whole Congress to believe this, why we will have a better place to live. I appreciate it very much.

Mr. AMBRO. I would like to thank Chairman Jones for those comments.

I must say if my constituents knew I came from the city they would run me out.

Apart from that, I would like to echo the sentiments and thank you very much for your patience and for regaling this large committee with your wisdom.

I would like to, as well though, ask your indulgence for just one more thing. As we asked the earlier panel, we would like to follow up and round out the record with written questions for your response and if you could be kind enough to accede to that request, I would appreciate it and we will be sending all of you some questions.

I would like unanimous consent at this point to install in the record the statements of the California State Grange, the National Food Processors Association and the Geological Society of America.

[The documents referred to above are as follows:]

(sheet) page 1 of 2

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THE
GEOLOGICAL SOCIETY
OF AMERICA

Office of the President

July 12, 1979

Honorable Ed Jones
Chairman, Subcommittee on
Conservation and Credit
Agriculture Committee
Congress of the United States
House of Representatives
Washington, DC 20515

Honorable Jerome A. Ambro
Chairman, Subcommittee on
Natural Resources and the
Environment
Science and Technology Committee
Congress of the United States
House of Representatives
Washington, DC 20515

Honorable George E. Brown, Jr.
Chairman, Subcommittee on
Science, Research and
Technology
Science and Technology Committee
Congress of the United States
House of Representatives
Washington, DC 20515

Dear Congressmen Jones, Ambro, and Brown:

Thank you for bringing to the attention of the Geological Society of America the forthcoming Congressional hearings on the interactions between agricultural production and environmental quality. The letter suggests that the concerns of your Committees involve both the distribution of land uses and the impacts on the environment of different ways of managing land, water, and air resources. The Society is pleased to have this opportunity to comment briefly on each of these broad topics from the perspective of the geological sciences.

First, land-use planning and the management of onland activities for the benefit of present and future generations must begin with a *firm base of knowledge* about the earth and the land itself. While it is accepted that mapping of the distribution of geologic hazards such as earthquake zones, coastal and riverine areas subject to floods, or unstable land surfaces prone to landslides and avalanches is essential to intelligent land use planning, there is an equally important but perhaps still too often unrecognized need to develop a firm knowledge of the mineral reserves and resources if planning is to be in the best interest of not only future generations but also the present one. For example, mineral resources

such as gravel and construction materials that are essential to urban development can be made unavailable by planning decisions, or plans for their extraction (and land reclamation) can be made an integral part of the metropolitan planning process. Vital mineral resources in forested and agricultural regions must be appraised to assure both their protection and the opportunity for their development as policy dictates.

We are aware that it may appear to be both self-serving and platitudinous to call for better basic information about the land, its structure, the processes acting upon it, and the mineral resources that lie beneath it. However, bitter experience, as you are aware, has documented the consequences of our failure to use knowledge about the earth in the planning process, as houses slide from their foundations, highways are disrupted, and whole communities are water logged as a result of poor drainage. The Geological Society wishes to call to your attention the extensive work in geology relative to land-use planning, at many different scales and degree of detail, being pursued at the local, state, and Federal level. The Association of American State Geologists has drawn attention to such efforts, and many State geological surveys are providing information in a form appropriate to the needs of decision makers. Several references illustrating this work are attached to this letter; they may prove useful to your staff in devising criteria which should be part of the planning process--if we are to assure adequate evaluation of the benefits and costs of trade-offs inherent in land-use planning.

A second area of interest to which the Society would like to draw your attention relates to the importance of a *perspective of geologic time* in the evaluation of the environmental impact of different land uses. This is particularly true in evaluating the impact of runoff of water and sediment from the land surface into water courses, which will be addressed at the hearings. In discussing questions of the magnitude and consequences of loss of soil from the uplands and the impact of this nonpoint source of pollution, most people tend to draw conclusions from measurements made over only limited space and time. A longer range, geological perspective is needed in evaluating changes in the upland soil resource, to judge more thoroughly the effects of policies directed toward use and protection of that resource from virtually irreversible deterioration. Similarly, a perspective of thousands of years based on stratigraphic studies (illustrative examples are cited on the attached list) provides the only scientific basis for evaluating the impact of human activities--within the context of the highly variable natural climatic and hydrologic background of soil formation, erosion,

and deposition. Because the economic costs of erosion control can be immense, it is important that policies for such control be developed in the context of these natural forces if they are to be more than merely wasteful and ineffective.

This letter and the very brief list of references provided with it are simply directed toward sources of information which provide a point of view that may be useful in your deliberations. Dr. Chris Bernabo of Congressman Brown's staff is familiar with the work of geologists in many of these areas.

The Society appreciates the opportunity of responding to your inquiry. I am sure that the geological profession is most willing to assist in providing important information relevant to these difficult policy issues involved in land-use decisions and environmentally sound land management.

Very truly yours,

Leon T. Silver

by

Leon T. Silver
President

Enclosures

GEOLOGY, LAND USE, EROSION AND ENVIRONMENT

Selected Illustrative References

Geologic Mapping and Land Use

Illustrative Map Series of State Geological Surveys

Illinois State Geological Survey
Geology for Planning in St. Clair County, Illinois

Maryland Geological Survey
Towson Quadrangle: Geologic and Environmental Atlas (1974)

Louisiana Geological Survey
Underground industrial waste disposal in Louisiana; surface impoundment of petrochemical and other industrial wastes in Louisiana (1971)

Missouri Geological Survey
Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain (1972)

Pennsylvania Topographic and Geologic Survey
Environmental geology for land-use planning (1972)

Geological Society of America: Symposia on Geology and Planning

U.S. Geological Survey: "Nature to be Commanded...Must be Obeyed," Professional Paper 950, San Francisco Bay Area Study

Human disturbance and the historical development of Linsley Pond (1978) Brugam, R.B., Ecology, v. 59: 19-36.

The chestnut pollen decline as a time horizon in lake sediments in eastern North America (1974) Andersen, T.W., Canadian Jour. Earth Sci., 11:678-685.

Diaton stratigraphy and human settlement in Minnesota (1975) Bradbury, J.P., G.S.A. Special Paper 171: 74 pp.

Climatic changes in southern Connecticut recorded by pollen deposition at Rogers Lake (1969) Davis, M.B., Ecology 50:409-422.

Some chemical observations of post-glacial lake sediments (1966) Mackereth, F.J.H., Phil. Trans. Roy. Soc. B 250:165-213.

Pollution history of the Savannah River estuary (1979) Goldberg, E.D., Griffin, J.J., Hodge, V., Koide, M., and Windom, H., Env. Sciences and Technol., v. 13:588-594.

History of metal pollution in southern California coastal zone (1974) Bruland, K.W., Bertine, K., Koide, M., and Goldberg, E.D., Env. Sciences & Technol., v. 8:425-432.

Landscape evolution and soil formation in southewestern Iowa (1967) Ruhe, R.V., Daniels, R.B., and Cady, J.G., USDA, SCS, Tech. Bull. 1349, 242 pp.

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Polynology and sedimentology of Holocene deposits in southern Lake Michigan (1976) King, J.E., Lineback, J.A., Gross, D.L., Ill. State Geol. Surv., Circ. 496, 24 pp.

N/Ag - Env. hearings.

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July 23, 1979

To: The Honorable Ed Jones
Chairman
House Subcommittee on Conservation
and Credit
Agriculture Committee

The Honorable Jerome A. Ambro
Chairman
House Subcommittee on Natural Resources and
the Environment
Science and Technology Committee

The Honorable George E. Brown, Jr.
Chairman
House Subcommittee on Science, Research
and Technology
Science and Technology Committee

Dear Congressmen Jones, Ambro and Brown:

In regard to your request for input regarding a hearing on interaction between agricultural production and environmental quality, we enclose the comments of one of our members.

The National Food Processors Association (NFPA) is a non-profit trade association with over 600 members operating canning plants in 41 states, Puerto Rico and American Samoa. Members of NFPA pack 90% of the total U.S. production of canned fruits, vegetables, soups, juices, meat and poultry products, seafoods, baby foods, puddings and specialty items.

We appreciate the opportunity to submit this information.

Sincerely yours,

Raymond F. Altevogt

Raymond F. Altevogt

RFA:po

Enclosure

Agricultural Production and Environmental Quality

Purpose:

Identify and understand relevant issues relating to the interaction between agricultural production and environmental quality.

Issue Areas:

1. Interface of urban/industrial activities on farming.

   A. Removal of sulfur from industrial smoke stacks is causing increasing sulfur deficiency in soil areas low in native sulfur. Impact is cost of sulfur fertilizer in agriculture and cost of reduced yields until need is defined. Need is to recognize sulfur requirements for agricultural production when establishing air quality standards.

   B. Encroachment of urbanization/industrialization onto prime agricultural land with permanent loss of productivity. Impact is that agricultural lands are a non-renewable resource. Need is zoning for use of non-productive land for urban/industrial development. Need also is for more reasoned flexibility in upgrading marginally wet lands to prime productivity through drainage.

   C. Effects of man-made ozone (industrial pollution) levels on crop productivity. Impact is reduced yields to varying degrees depending on crop cultivar and ozone level. Need is to fund research to develop resistance in crops and to control emissions within practical levels.

   D. Optimizing urban/industrial need to dispose of waste materials and to derive agricultural benefits from their application to land. Impact is potential soil/water/air damage from components of waste. Need is to establish, through research, criteria for waste material content, waste material application and land management which will both preclude long term environment damage and maximize crop production benefit from use of urban/industrial waste.

2. Management of air, water and soil resources to insure long-term sustainability of agricultural production.

   A. Air management in this issue area relates primarily to effects of man-made toxic pollutants and is discussed in 1-C above.

B. Water management in the arid region of the U.S. Impact is limited supply to meet both agricultural and expanding urbanization/industrial needs. Need is both conservation (recycled/efficient use) and development of additional supplies (dams, diversions, canals, etc.)

C. Water management in the temperate region of the U.S. Impact is rate of developing agricultural use. Need is to base growth rate of agricultural use on defined recharge capacity---as well as to develop conservation programs.

D. Soil management to equalize soil-removing and soil-building forces. Impact is gradual and permanent loss of productivity where soil loss conditions are present and are allowed to continue over a period of time. Issue is both ethical and technical. Ethically, preserving agricultural productivity should be considered a shared custodianship (for future generations) between both the producer and the public being served. Destructive exploitation of productivity by the producer should be prevented; the cost of prevention should be shared by society. Technologically, objective definitions and application of practices and programs are needed.

N/for Ag/Env. hearings -

EDWIN KOSTER
MASTER

MARJORIE BROWN
SECRETARY

EXECU COMMITTEE
LLOYD V. PIPER
DAVID AUSTIN
S. E. RAFTER

CALIFORNIA STATE GRANGE

JOHN WELTY
LEGISLATIVE DIRECTOR
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SACRAMENTO, CALIFORNIA 95817
Phone 455-2656

July 17, 1979

TO: SCIENCE AND TECHNOLOGY COMMITTEE'S NATURAL RESOURCES AND THE ENVIRONMENT SUBCOMMITTEE

The California State Grange would be pleased to respond to the U. S. Congress concerning "the impact of urban/industrial activities on farming" in California. Representing 50,000 rural family farmers, the California State Grange in 1978 at its 106th annual session passed resolution Agriculture No. 2:

"SUPPORTING S.B. NO. 193—
FARMLAND PRESERVATION"
Clear Lake Grange No. 680

1. WHEREAS, the Grange which was founded for the purpose of assisting the farmer and promoting assistance to growers, processors and consumers of agricultural commodities; therefore, be it
2. RESOLVED: the California State Grange supports retaining control within local governments over releasing agricultural preserve land from contract for purposes other than farming.

The one thing that all parties agree to is that prime agricultural land should be preserved. Republican candidate Houston Flournoy commented "Prime agricultural land must be preserved if California is to maintain its position as number one producer of the nation's food." California supplies 25 percent of the table foods of the United States and over 250 diverse crop and livestock commodities annually. In addition, the Golden State is the supplier of 40 percent of all fresh produce — vegetables and fruits — consumed here and accounts for 10 percent of total American agricultural exports.

The question is who is responsible for land use planning; Federal, State, local governments, or citizens movements. A new policy of the federal Environmental Protection Agency is to

Protect those farmlands for agriculture and "from irreversible conversion to uses which result in its loss as an environmental or essential food production resource".

There are in California 100.2 million acres of which farming occurs on 36.1 million. However, most of the cash returns from crops is produced on about eight million acres of irrigated land. A considerable amount of the rich soil acreage is close to expanding urban communities, such as Sacramento, Salinas, Modesto and several other cities.

That "protection" could be considerable. The agency administers five acts that directly apply, according to Costle. They are the Clean Water, Clean Air and Clean Drinking Water acts, as well as the Resources Conservation and Recovery Act and the Insecticide, Fungicide and Rodenticide Act. For example, the agency can:

Rule where new sources of potential pollution may build.

Approve or disapprove the location of sewage treatment plants and interceptor sewers.

Disapprove sites for solid waste disposal.

Review environmental impact statements of other federal agencies and where the five acts under which it is authorized apply, can veto a project or order its redrafting.

Approve or disapprove financing for waste water treatment in river basins.

In the meantime, Agriculture Secretary Bob Bergland has issued orders to assist local agencies in programs to save land for production of food and fiber. Bergland said he expects all agencies "to step up their assistance" to local people to save farmland from the encroachment of other uses. "We will continue to recognize and respect the rights and responsibilities of landholders in making private land-use decisions," he said. But he noted federal agencies oversee numerous programs which affect and sometimes encourage the irreversible conversion of land from farm to non-farm uses.

Back in California, the Senate Committee on Governmental Organizations claims it is a prime responsibility of state government to provide for comprehensive land use planning to avert leap-frogging urban development and ecological devastation facing the United States.

Senator Garamendi proposed a bill where state agencies would have "the responsibility ... to minimize the amount of land which is annually converted from agricultural to non-agricultural uses." The agencies also would have to "minimize the encroachment of industrial activities" in farm areas, "especially if such actions deprive croplands of needed water resources or produce pollutants which reduce crop yields." Under his bill, he said, the agencies and the governor would be required to make annual reports to the

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Legislature on acreage taken out of farm production "or adversely affected by their actions." Garamendi said the federal government is taking action to reduce the impact of federal projects on crop acreage.

The most dominant force in land management is the free market. The tax assessor will assess agricultural land on the urban fringe for its current, agricultural use unless he interprets market data which lead to higher, speculative uses. When this occurs, he then reassesses the agricultural land at this higher use regardless of the fact that the land in question is preserved under the Williamson Act. As a result, property tax assessment policies place inordinate pressures on landowners, especially farmers, to convert their soil to other uses because most land was assessed on its potential use.

Proposition 13 took all that fringe agricultural land that was taxed at its potential use and reverted it to its 1975 base. This dramatically reduced taxes collected by our cities. This impact has reduced the motivation for continued urban sprawl.

The California State Grange feels that all segments of society have a role to play in managing California's land, Federal, State, Local and citizens. Federal government needs to be responsible for their actions in regards to its lands and actions as does State and Local municipalities. Citizens need be responsible for the free market and limitations upon government.

In addition, the California State Grange feels inheritance taxes, both federal and state, place an onus on small farmers making it difficult for them to pass their land on to the next generation, since land is valued at the time of death on the basis of its development potential, according to its private, economic use. This tax policy encourages parceling farmland for urban purposes.

Sincerely,

John C Welty

John C. Welty
Legislative Director
California State Grange

JCW:gl

Mr. AMBRO. Now, having done all that, I wish to thank all of you and I will recess these hearings until 10 o'clock tomorrow morning in room 2318.

The meeting is adjourned.

[Whereupon, at 4:55 p.m., hearing in the above-entitled matter was recessed, to reconvene at 10 a.m., July 26, 1979 in room 2318, Rayburn House Office Building.]

AGRICULTURAL PRODUCTIVITY AND ENVIRONMENTAL QUALITY

THURSDAY, JULY 26, 1979

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON NATURAL RESOURCES AND ENVIRONMENT; COMMITTEE ON AGRICULTURE,
SUBCOMMITTEE ON CONSERVATION AND CREDIT,
Washington, D.C.

The subcommittees met in joint session, pursuant to a recess previously taken, in room 2318, Rayburn House Office Building, Hon. Jerome Ambro, presiding.

Present: Representatives Ambro, Jones, Brown, Walker, Madigan, and Jeffords.

Staff present: (From the Subcommittee on Natural Resources and Environment) Ian Marceau, staff director, and David Clement, technical consultant.

Mr. AMBRO. I would like to call the meeting to order and this is a bit of change in our printed schedule and a departure from our format of yesterday.

I would like to call up as a panel, Professor Leo Walsh, University of Wisconsin, Dr. Cecil Lue-Hing, director, Research and Development, Metropolitan Sanitation District of Chicago, and Dr. Rufus L. Chaney, research agronomist, Biological Waste Management and Organic Resource Laboratory, USDA.

We will, of course, include all of your statements in the record.

STATEMENTS OF A PANEL CONSISTING OF PROF. LEO M. WALSH, DEPARTMENT OF SOIL SCIENCE, UNIVERSITY OF WISCONSIN; DR. CECIL LUE-HING, DIRECTOR, RESEARCH AND DEVELOPMENT, METROPOLITAN SANITATION DISTRICT OF CHICAGO, AND DR. RUFUS L. CHANEY, RESEARCH AGRONOMIST, BIOLOGICAL WASTE MANAGEMENT AND ORGANIC RESOURCE LABORATORY, USDA

Mr. WALSH. I would like to start out by saying we appreciate the opportunity to testify to this group and we compliment you on identifying this as one of the problms facing agriculture and municipalities.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92–500, resulted in the development of several programs to improve water quality in this Nation. Included were programs to

improve the quality of wastewater effluent being returned to our surface waters, and programs to find more environmentally acceptable and cost effective means of disposing of wastewater sewage sludges. The latter objective has been a particularly difficult problem because:

1. Improvment of wastewater effluents is generating additional quantities of sludge;
2. Ocean dumping of sewage sludge is being banned;
3. Incineration of sewage sludge is less attractive because of high energy costs to burn the sludge, and additional expense to meet more stringent air pollution standards; and,
4. Land acceptable for lagoon and landfill sites is becoming very scarce, especially in the densely populated areas where much of the sludge is generated.

The principal methods of sludge disposal which are, or can be, environmentally acceptable at the present time are:

1. Landfills and permanent lagoons;
2. Incineration and landfill of the ash;
3. Pyrolysis and landfill or land application of the residue; and direct application of sludge to land.

The land spreading alternative includes three distinctly different suboptions. First, land disposal results in the application of the highest rate of sludge which can be made and still maintain normal plant growth.

Second, land reclamation results in the use of sludge at rates—usually very high—needed to reclaim minespoils or other marginal land and third, land utilization results in the use of sludge at rates which will make effective use of nutrients in, and soil conditioning properties of, the sludge. Each of these programs; that is land disposal, land reclamation and land utilization can be employed where land is used for either agricultural or nonagricultural purposes.

Suitable landfill sites are becoming very expensive and indeed, difficult to locate near urban areas, and they result in the concentration of potentially hazardous materials which could cause an environmental problem some time in the future.

Incineration and pyrolysis satisfactorily reduce the volume of the sludge but these processes are expensive and energy consumptive, and the residue from each process must still be disposed of.

Coincineration and copyrolysis of sludge with solid waste maybe promising since it can be accomplished with little or no supplemental fuel and these processes may yield some usable byproducts. It should be pointed out, however, that they are in the very early stages of development. Even if these options prove to be successful, it will be several years before they could be widely used by waste-water treatment plants.

Because of the problems previously noted with other alternatives, land spreading of sewage sludge is, in many instances, the most environmentally acceptable and cost effective method of disposing of sewage sludge. The trend towards land spreading received further support in 1977 when EPA directed that communities consider the application of sewage sludge to land as one of their alternatives for sludge disposal. These requirements have forced municipalities to look much more closely than ever before at land spreading as an alternative.

Most sludges can be spread on marginal lands and on forest and recreational land with little, if any, environmental hazard if precautions are taken to prevent the sludges from being carried into lakes or

streams in runoff water. However, the limited acreage of marginal and nonagricultural land near urban centers constrains the amount of sludge which can be applied to these lands. Furthermore, the fertilizer value and the soil conditioning value of the sludge often is not fully realized when the sludges are placed on nonagricultural land.

Environmental and economic considerations will favor the application of more sludge to agricultural land in the future. As with all management decisions of this nature, environmental tradeoffs result. Land application of sludge is not without its potential problems and hazards. But, since it appears to be one of the most feasible alternatives at the present time, we must find means of reducing any hazard that might be involved with this practice.

The remainder of my presentation will address itself to use of sludge on agricultural land as a fertilizer and soil conditioner.

The concept of applying sludge on agricultural land is sound because sewage sludge is a low analysis fertilizer of variable composition, and it serves to improve the "condition" of the soil. Hence, nutrients and organic matter previously "harvested" in the form of plant and animal products and consumed by humans are "recycled" to the soil.

Only about 30 percent of the sludge presently generated is applied on land, but more will likely be applied in the future. From an estimated 5 million tons per year in 1976, the sludge generation rate is expected to reach at least 8 million tons by 1980, and perhaps 16 million tons by 1990.

Adding to the problem of increased amounts of sludge is the decreasing use of two previously used methods of sludge disposal—ocean dumping is to be phased out by the end of 1981, and incineration has become much more costly due to more stringent air control regulations and the high cost of fuel.

The cost for handling, transporting, and applying sludge on agricultural land is relatively high, as compared to supplying equivalent amounts of nutrients with commercial fertilizers. Therefore, most of the expense of getting sludge applied to agricultural land must be borne by the municipality in order for farmers to find the use of this material economically attractive. Even though the transportation and handling costs adds significantly to the municipality's total cost for land spreading, this alternative is still generally more cost effective than other alternatives which a municipality may have for the disposal of sludge.

Several basic considerations underlie my discussion on the benefits and potential problems associated with land utilization of sludge. These include the following:

1. Agricultural land is a valuable natural resource, and the flexibility of its use for various cropping systems and its productivity must not be impaired or compromised by land spreading of sludge.
2. The agricultural system must be managed so that benefits from sludge are realized without sacrificing crop quality or yield.
3. A land spreading program must be developed which will not exceed the finite limits of the soil regeneration and attenuation processes.

The benefits of utilizing sewage sludge on agricultural land have been documented in numerous research trials over the past decade. These benefits are usually reported in terms of improved crop yield, reduced fertilizer requirements, and improvement of the physical con-

dition of the soil. Since the positive aspects of utilizing sludge on land are well documented, I have simply listed below the most important benefits without making further comment.

1. Recycles plant nutrients. Sludge contains significant amounts of all essential plant nutrients. However, when applied at nitrogen utilization rates, the total plant requirements for phosphorus, calcium, magnesium, sulfur, zinc, copper, boron, and manganese will usually be applied.

2. Acts as a "slow release" fertilizer. Nitrogen and other nutrients are released from the organic matter in sludge slowly throughout the growing season, thus improving nutrient recovery and reducing leaching losses as compared to commercial fertilizer.

3. Improves the soil's physical condition. The organic matter in sludge improves soil tilth, and it increases the soil's ability to absorb water and hold nutrients. This helps reduce erosion and natural runoff.

4. Cuts waste disposal costs. Land application is usually less expensive than other disposal methods, except when the sludge must be transported long distances.

5. Reduces environmental pollution. Considering all the environmental tradeoffs, land utilization of sludge has less detrimental effect on the environment and a more favorable cost/environmental risk ratio than does alternative methods of sludge disposal. Furthermore, when sludge is applied at nitrogen utilization rates, the soil is a very effective medium for destroying pathogens and attenuating the potential hazards from heavy metals and other toxicants.

The major problems involved with application of sludge to agricultural land are:

1. Possible surface and ground water contamination by overloading of nitrogen and phosphorus;
2. Yield reductions due to overloading with heavy metals or salts;
3. Food chain accumulation of potentially toxic elements;
4. Pathogens and related considerations; and
5. Esthetic concerns, public acceptance, and political considerations.

A brief discussion of each of these potential problems follows:

1. Overloading of nitrogen and phosphorus.—The crop requirements for nitrogen and phosphorus are well defined, and reasonably good estimates of the release of these nutrients from the sewage sludge can be made. Phosphorus is strongly absorbed by soil particles and does not leach. Furthermore, within the rates of application made in utilizing sludge on land, it does not accumulate to phytotoxic levels in soils. Since the amount of phosphorus applied generally is not of agronomic or environmental concern, recommended rates of sludge are usually based on the nitrogen requirement of the crop and the concentration of nitrogen in the sludge. If these recommendations are followed, optimum growth will be insured, and loss of nitrogen to the ground water will be minimized and held within tolerable limits.

2. Yield reductions due to overloading with heavy metals or salts.—Heavy metals are known to cause toxicity to plants. Since municipal sludges contain these metals, it is understandable that farmers and other agriculturists have been concerned about the effect of these elements on crops. The metals of greatest concern in terms of soil productivity are copper, nickel, and zinc. Other potentially phytotoxic elements found in sludge include cadmium, manganese, molybdenum,

iron, aluminum, chromium, arsenic, selenium, antimony, lead, and mercury, but these pose very little hazard because they either have a very low solubility in soils or they are present in extremely low concentrations in the sludge.

A great deal of research effort has been directed toward the heavy metal question. By and large, these studies have shown that substantial amounts of these metals can be applied in sludge before phytotoxicity will occur. When municipal sewage sludges are applied to land based on the nitrogen loading rates, the metals applied on a short-term basis will be well below the amount needed to cause phytotoxicity.

Lifetime loading rates of the metals have been suggested by USDA Cooperative Research Committees, EPA, and several State regulatory agencies. With the exception of sludges which contain unusually high concentrations of metals, sludge would have to be applied for many years before the lifetime loading rates are equaled or exceeded. Furthermore, the lifetime loading rates currently suggested are very conservative, so it is unlikely that phytotoxicity would occur even when these rates have been equaled.

Sewage sludge is often relatively high in soluble salts. If a crop is established immediately after the application of sewage sludge, these salts may adversely affect germination and early seedling growth. However, if precipitation occurs between the time the sludge is applied and the crop is planted, the rain will leach the excess salt out of the topsoil and crop growth will not be impaired.

3. *Accumulation of potentially toxic elements in the food chain.* Sludges do contain some elements which are potentially toxic to man and animals. These include cadmium, copper, lead, mercury, and nickel. Lead and mercury are strongly "fixed" by soils and are not taken up by plants when applied at rates commonly made with a land-spreading program. Copper and nickel phytotoxicity does occur when excessive amounts of these elements are applied. However, even when phytotoxicity occurs, only moderate increases in the plant tissue concentration of these elements are observed, and these concentrations are well below those suggested for the upper limits for ingestion by animals or humans. Therefore, our only serious concern about land spreading of sludge, in terms of food chain accumulation, is with cadmium, since excessive levels of this element in the diets of animals or humans have been shown to cause kidney abnormalities and other health problems.

Cadmium has been found in sludges in quantities sufficient to cause an increase in the concentration of cadmium in plants which are consumed by humans and animals. Because of the health implications, ingestion of significantly more cadmium than present background levels by humans is undesirable.

The impact of spreading sewage sludge on agricultural land in this regard can be reduced by applying sludge to soils which have a neutral or alkaline pH, by cropping sludge treated soils to plant species which accumulate relatively low levels of cadmium, and by planting crops in which only the grain or fruit is harvested because most of the cadmium in plants is found in the vegetable tissue.

Furthermore, there is some indication from current research that sewage treatment plant operations can be altered to lower the avail-

ability of sludge cadmium. For example, use of ferric chloride to improve effluent quality results in the coprecipitation of cadmium in extremely insoluble iron phosphate minerals.

Except in home garden and truck garden situations, agricultural products enter the overall marketing and distribution system. As a result, crops from sludge-treated land would be greatly diluted with crops from lands not treated with sludge. Except in densely populated areas, only about 1 percent of the cropland would be required for land spreading. Therefore, if recommendations are followed with regard to the application of sewage sludge, the increase in the amount of cadmium ingested by man would be negligible.

Some would argue, however, that any increase in soil or plant levels should be avoided because of present or future health considerations. I feel this is a situation where we must compare the potential environmental risks which are involved. In other words, are the long-term risks of land spreading, in terms of the cadmium issue, greater than those which might be associated with attempting to incinerate and/or landfill all the sludge which is being generated?

Research studies clearly show that very little food chain accumulation of cadmium occurs when a land-spreading program is well managed, and that this program would not result in a significant increase in the ingestion of cadmium by humans. If this is the case, application of sludge to land clearly results in less environmental risk than the other sludge disposal alternatives. Furthermore, as noted previously, land spreading utilizes a valuable resource which, with other alternatives, is partially or wholly destroyed.

Sludges sometimes contain organic contaminants such as PCB's. These do not accumulate in the food chain as a result of land spreading of sludge because they are not assimilated by plants. However, care should be taken to prevent the direct ingestion of these toxicants by animals. In general, animals should not graze sludge treated pasture until precipitation has washed the sludge off the leaves.

The question regarding heavy metals and accumulation of potentially toxic elements is very complex. However, I will not comment further on this topic since it will be covered in more detail by Dr. Chaney.

4. *Pathogens.* The public has been understandably concerned about the possible transmittal of disease organisms through a land-spreading practice.

Raw sewage sludge does contain many disease organisms and should not be land spread. However, secondary treatment of sewage sludges and stabilization by heat, lime, or other means eliminates most pathogens. There have been no reports of public health problems due to the land spreading of sewage sludge. In a few instances, problems with animals have occurred, but this has been when they were forced to graze pastures recently treated with sludge and, as a result, directly ingested the sewage sludge.

5. *Aesthetic concerns, public acceptance and political considerations.* There is a "human waste stigma" associated with land spreading of sludge. The objections frequently center around the nuisances of odor, insect and weed problems, and the potential problems due to pathogens and parasites.

With careful management nearly all potential nuisance and health problems can be eliminated. Even so, strong objection to land spread-

ing often occurs because this is a highly visible method of sludge disposal. It comes to the attention of a large number of individuals from a broad range of occupational, cultural, social, and political backgrounds, and sludge generated in one governmental entity is often spread in another governmental entity. No matter how agronomically effective and environmentally acceptable a land-spreading practice may be, some people will strenuously object to the disposal of someone else's wastes on their land.

Public acceptance is an extremely important consideration but I will not comment further since Dr. Lue-Hing will address some of these issues in considerable depth.

Concluding observations:

1. Improvement of the quality of effluents from waste-water treatment plants will continue to generate more sludge. This, in addition to elimination of ocean dumping and restrictions on incineration, will result in land spreading of sludge to be even more cost effective and environmentally acceptable in the future.

2. Through emphasis on pretreatment and other programs, the "quality" of the sludge being generated needs to be improved with regard to toxicants and pathogens and thus reduce some of the public concern.

3. Soil, crop and sludge management systems which will protect our natural resources and minimize the accumulation of toxicants in the food chain need further refinement. Present guidelines and recommendations appear to minimize these problems, but continued surveillance and research is needed.

4. The logistics of transporting sludge from the areas of production—that is, cities—to areas of need—agricultural land—must be developed which are economic, environmentally acceptable and do not antagonize the public.

5. Through public participation and educational programs, mechanisms and procedures must be developed to improve the public's understanding and acceptance of the practice of utilizing sewage sludge on agricultural land.

6. Regulatory agencies and the public must recognize that some environmental risk is associated with any method of sludge disposal. We must minimize the risk of any alternative selected, but we cannot completely eliminate all risks. In some cases, land-spreading programs have been severely curtailed because of unduly restrictive environmental requirements.

This completes my formal presentation.

Mr. AMBRO. Now we will hear from Dr. Lue-Hing.

Dr. LUE-HING. Mr. Chairman, the perspective that I bring to this hearing is that of a political subdivision whose responsibility it is daily to deal with this problem, a very important problem of managing the waste generated at the level of the municipal agencies.

We have prepared a report which has been summarized. We will submit the report for the record and I will read a short summary version.

The utilization of municipal sludge in agriculture has become increasingly popular among municipal waste treatment agencies. It offers the advantage of recycling nutrients back to the land and of reclaiming lands bespoiled by strip mining. Sludge is first stabilized

by anaerobic digestion, composting or other suitable means and then applied to crops before and/or during the growing season. Yields of grain and forage are increased by the nutrients and water supplied while the organic matter present accumulates in and imparts favorable characteristics to soils.

The process of land spreading of municipal sludge affords the opportunity for urban areas to recycle the fertilizer value to the farming areas from which the organic matter and nutrients originate.

The recycle of municipal sludge, rather than nonproductive disposal by methods such as landfilling and incineration, is in keeping with the goals set forth by Congress in the Resource Conservation and Recovery Act of 1976 which was designed to encourage the recycle and reuse of wastes. Municipal sludge utilization is also in keeping with the national goal of energy conservation; since for every ton of sludge nitrogen utilized in agriculture, a corresponding savings in the energy needed to produce a ton of chemical fertilizer nitrogen occurs. About 420 gallons of crude oil are needed to produce 1 ton of nitrogen fertilizer. The sludge utilization process itself is a low energy consumer compared to the process of incineration which requires about 50 gallons of fuel oil to burn a dry ton of sludge.

The sludge management option of landspreading, however, is not the lowest cost method available for municipal agencies. For example, the processes of landfilling costs the Metropolitan Sanitary District of Greater Chicago District about $70 per dry ton, while landspreading costs nearly $200 per dry ton. However, landfilling is not a final solution to municipal sludge management; since it repeatedly requires the acquisition of new land, while landspreading essentially solves the sludge management problem into perpetuity.

Under proper management, sludge application to land sites once acquired can be used indefinitely. Landspreading is essentially attractive, because it is the most environmentally acceptable permanent solution to municipal sludge management, consistent with the national goals of recycle and reuse as well as energy conservation.

One of the principal constraints to increased adoption of the landspreading option is the proposed EPA regulations of February 6, 1978. These proposed regulations will have a decided adverse cost impact upon municipal agencies now conducting land application operations. Agencies contemplating the adoption of this alternative are likely to be discouraged. The regulations severely limit annual and total sludge applications to land to the extent that very large acreages will be required and exorbitant operational costs incurred.

For example, the district's ongoing landspreading site in Fulton County, which consists of 15,000 acres of land, is now utilized for landspreading of about 175 dry tons per day of digested lagoon sludge. If the proposed regulations are adopted, land requirements would increase to nearly 350,000 acres and total costs, now about $19 million per year would reach $111 million.

Because sludges now being processed by other management options contain more than the EPA-proposed limit of 25 ppm per day of sludge to be applied to lands at the District's Fulton County facility. This will necessitate the acquisition of nearly 800,000 additional acres of land and the expenditure of about $292 million annually to operate

this expanded facility under the requirements of the EPA-proposed regulations.

Small communities would also be severely impacted by the EPA regulations. We have estimated that a community of 15,000 population with the relatively low sludge cadmium content of 40 ppm would experience a fivefold increase in landspreading costs if the EPA regulations are adopted.

Sludge management programs are becoming more complex and costly because of the decreasing use of ocean disposal which is due to be phased out by the end of 1981; and reduced interest in incinceration, which has become extremely expensive due to more stringent air pollution control regulations, and the high cost of fuel.

Ironically, the centers of greatest population density, which produce the largest volumes of sludge, are located either in coastal areas where ocean disposal was once heavily practiced or in critical air sheds where new and significant stationary sources of air pollution are not acceptable. Thus, with fewer viable alternatives available, it is not difficult to understand that municipal sludge management programs are extremely sensitive to external stresses, particularly to overly stringent Federal and State regulations.

The Federal and State Governments can play a more effective role in solving the municipal sludge management problem by making Federal and State lands available for land application of sludge. Local agencies experience severe difficulties in acquiring land parcels needed to implement sludge management programs.

The Blue Plains treatment facility in the District of Columbia is an example where Federal encouragement and assistance in acquiring land would have been beneficial in solving a difficult sludge management problem for a major urban area. Since 1972, the Blue Plains plant has attempted to solve its sludge management problem by requesting approval from EPA for an incinerator complex.

While the EPA took the position that it could not approve the incinerator complex because of air pollution problems, another Federal agency, the USDA, at the same time raised objections to suggested alternatives such as composting. As a consequence, this problem is still in search of a long-term solution.

As is well known, strip mines are a major environmental problem in the United States today. The chief difficulty has been that strip mining removes the existing topsoil, and subsequent weathering of exposed soils caused polluted surface water to flow to receiving streams.

Current regulations call for storing topsoil, and replacing it upon completion of mining; but there are many existing strip mine sites which this new law does not affect.

Municipal sludge has a naturally high humus content, and has been successfully used for restoring topsoil to strip mine land. The district's Fulton County site has extensive strip mine land, and this land is now producing row crops, corn and soybeans. District sludge has been reclaiming land in Palzo, Ill., and other sites.

Mr. AMBRO. Doctor, if you would suspend at this point. I will come back and hear the rest of your testimony. We have a vote on the Department of Energy bill which comes out of this committee, and it would be less than appropriate if we did not make that vote, so we will be right back.

[Brief recess.]

Mr. AMBRO. Well, we are back, and I think, Doctor, you were about to tell us about the chief problem in utilizing sludge.

Dr. LUE-HING. The chief problem in utilizing sludge for reclaiming strip mine land is an institutional one. Both the coal mining companies and State and local agencies are reluctant to adopt this concept. Many still believe that municipal sludge is a liability, rather than an asset, and resist its use.

The district has been very active in promoting sludge use for strip mine reclamation. However, success in gaining the interest of coal companies and State agencies has been limited.

It would be a tremendous benefit if existing resistance to utilizing this valuable product for strip mine reclamation were alleviated.

Most local agencies are very interested in having local farmers utilize their sludges as fertilizers in everyday farming operations. However, many farmers find little incentive to participate in these programs because of the complicated administrative procedures, including those for obtaining operational permits instituted by some State and local governments. This is unfortunate, since sludge utilization offers many benefits to the farmer, including increased crop yields and savings of up to $45 per acre in chemical fertilizer costs.

One of the problems encountered by local sludge-producing agencies is the resistance by citizens and citizens groups to sludge utilization sites. Many citizens are very supportive of the sludge utilization concept, but are extremely reluctant to allow municipal agencies to place such sites near their local communities. This resistance will surface even when sites are well planned and located far from populated areas.

The district, for example, has found that citizen resistance to its Fulton County site has been a significant problem. Certain lands, owned by the district at Fulton County, are not now currently used for sludge application because of local citizen resistance. It would be extremely useful to municipal agencies in dealing with this problem to have State and Federal support during the planning and land acquisition process.

We hope that our comments will be helpful to the mission of these hearings. A more detailed report of the district's views is attached for insertion into the record.

Thank you for the privilege and the opportunity to make these comments.

Mr. AMBRO. Thank you, very much. I might say I know Chicago is one of the most progressive municipalities in the United States with respect to waste management. When I was a local official, I visited Chicago many times.

Tell me one thing before we go on. How far is Fulton County from Chicago?

Dr. LUE-HING. It is 195 miles southwest of Chicago. We own about 15,500 acres of it.

Mr. AMBRO. Fine. The report of the Metropolitan Sanitary District of Greater Chicago which was attached to your statement will appear in the record at this point.

[The report referred to follows:]

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

INSTITUTIONAL AND OPERATIONAL ASPECTS OF LAND APPLICATION OF SLUDGE

A STATEMENT OF

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

Prepared for the

SUBCOMMITTEE ON
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of the

COMMITTEE ON
SCIENCE AND TECHNOLOGY

and the

SUBCOMMITTEE ON
CONSERVATION AND CREDIT

of the

COMMITTEE ON AGRICULTURE
U.S. HOUSE OF REPRESENTATIVES
NINETY-SIXTH CONGRESS

Presented by:
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Director
Research and Development

July 26, 1979

INSTITUTIONAL AND OPERATIONAL ASPECTS OF THE LAND APPLICATION OF SLUDGE WITH RESPECT TO AGRICULTURAL PRODUCTIVITY AND ENVIRONMENTAL QUALITY

INTRODUCTION

The purpose of this document is to present the institutional and operational aspects from the perspective of a local political subdivision having the responsibility for sludge management, including utilization and/or disposal.

Municipal sludge management is without question the most perplexing problem facing municipal wastewater treatment agencies today. In many instances, sludge volumes either have increased dramatically within the last 5 years or will within the next 5 years, because of the completion or anticipated completion of new or upgraded wastewater treatment facilities; the cost of sludge management schemes usually absorb 40% to 60% of an agency's operating budget; long-term planning is not practical because of the lack of Federal and State policies and management criteria; and the uncertainty of support by local citizens.

Interest in the land application of sludge is increasing because of the decreasing use of ocean disposal which is due to be phased out by the end of 1981; and incineration, which has become extremely expensive due to more stringent air pollution control regulations, and the high cost of fuel. Ironically, the centers of greatest population density, which produce the largest volumes of sludge, are located either in coastal areas where ocean disposal was once heavily practiced,

or in critical air sheds where new and significant stationary sources of air pollution are not acceptable. Thus, it is not difficult to understand that municipal sludge management programs are extremely sensitive to external stresses, particularly to overly stringent Federal and State regulations.

PROPOSED RESOURCES AND CONSERVATION AND RECOVERY ACT CLASSIFICATION CRITERIA

While EPA policy announced in October, 1977, promotes and encourages water conservation, wastewater reclamation and reuse, and evaluation of sludge utilization options, proposed regulations may discourage local wastewater agencies from aggressively pursuing a sludge utilization alternative.

On February 6, 1978, the EPA published in the Federal Register (Vol. 43, No. 25, pages 4942-4955) its "Proposed Classification Criteria; Solid Waste Disposal Facilities" (regulations). These regulations were proposed pursuant to the authority of sections 1008(a)(3) and 404(a) of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2803 and 2815, 42 USC 6907(a)(3) and 6944(a), and pursuant to the authority of section 495(d) of the Federal Water Pollution Control Act as amended by the Clean Water Act of 1977 (PL 95-217).

These regulations "apply to the land disposal of sludge resulting from the treatment of domestic sewage." This is done by defining solid waste to be "sludge from a waste treatment

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plant." Sludge is defined as "liquid waste...from a municipal ...wastewater treatment plant."

The proposed regulations have several minor aspects which will not be discussed here. The major parts of the regulations which will have the severest impact are presented in Table 1. As can be seen in Table 1, the regulations limit the amount of sludge cadmium which can be applied to a food chain crop. Both the yearly amount and the total amount which can be applied to a specific site are limited. The regulations also restrict fertilization of leafy vegetables, root crops and tobacco to municipal sludge with a cadmium content of 25 ppm or less, on a dry weight basis.

These regulations, therefore, will specifically control the amount of sludge applied at municipal sludge utilization sites where municipal sludge is utilized as a fertilizer and soil conditioner for growing crops.

Municipal sludge is an excellent source of nitrogen and phosphorus and has a high organic matter content. Therefore, interest in its use in agriculture by municipalities is readily understandable.

MUNICIPAL SLUDGE PRODUCTION

The Water Resources Council estimates that the sewered population in 1970 was 135 million while for 1985, 176 million is projected. The estimated population served by sewers was 67% in 1970 and 75% projected for 1985. Farrell* estimates that per capita daily sludge production was .055 kg for primary

*Olexsey, R.A. and I.B. Farrell. "Sludge Incineration and Fuel Conservation," NEWS OF ENVIRONMENTAL RESEARCH - USEPA, 1974.

TABLE 1

Proposed EPA Regulations for Solid
Waste Disposal Facilities*

257.3-5(a)

Any site that is currently or will in the future be used for the production of food chain crops complies with either subparagraph 1 or subparagraph 2 of this paragraph.

i. The annual application of cadmium from solid waste does not exceed the maximum additions below.

Years	Maximum Annual Cadmium Addition kg/ha
Present to Dec. 31, 1981	2.0
Jan. 1, 1982 to Dec. 31, 1985	1.25
Beginning Jan. 1, 1986	0.5

ii. The maximum cumulative amount of cadmium applied to any hectare of land does not exceed 5 kilograms on soils with a cation exchange capacity (CEC) of less than 5, 10 kilograms on soils whose CEC is between 5 and 15, and 20 kilograms on soils whose CEC exceeds 15.

257.3-5(a)(1)(iii)

Solid waste containing cadmium concentrations in excess of 25 mg/kg dry weight is not applied to sites where tobacco, leafy vegetables, or root crops are or will be grown for direct human consumption.

* Federal Register, February 6, 1978.

plants, .091 kg for primary and secondary plants and 0.11 kg for plants with primary, secondary and tertiary processes. The degree of wastewater treatment influences sludge production.

Assuming in 1970 that 50% of the U.S. population was served only by primary and secondary plants and the other 50% were served only by primary plants, annual sludge production would be 3.96 million tons or 10,849 dry tons/day. For 1985, assuming all municipal plants have tertiary treatment plants, annual sludge production would rise to 7.78 million tons or 19,332 tons/day.

The Metropolitan Sanitary District of Greater Chicago (District) during 1977 distributed an average of nearly 900 dry tons of sludge per day. This represents about 8.2% of the 1970 national sludge production and indicates how large urban areas have much more severe problems than smaller communities.

As can be seen, the ever-increasing requirement for better wastewater treatment will have a profound effect upon municipal sludge management. Based on the above estimate, municipal sludge production will at least double by 1985 from 1970 levels. However, other estimates suggest that sludge production will quadruple during this period.

Regardless which estimate is accepted, it is evident that the problem of ultimate sludge disposal is not decreasing, but rather increasing.

CURRENT MUNICIPAL SLUDGE DISPOSAL AND UTILIZATION PRACTICES

There are many combinations and variations of sludge disposal alternatives available to municipalities, but the basic processes are:

1. Land Utilization
2. Incineration and Ash Disposal
3. Ocean Disposal, and
4. Landfill--Nonproductive Containment

Incineration

Incineration essentially involves the combustion of the organics contained in sludge. Normally, this means that approximately 30 to 53% (dry weight) of the sludge remains in the form of ash which must be disposed of on land. The primary advantage claimed for incineration is that it reduces the volume of the material for disposal. However, the process requires much energy in order to burn the high-water-content sludge, while the fertilizer value of the sludge is simultaneously destroyed. The process also incurs significant costs for sludge dewatering, and the ash does require a land disposal site. The incineration process also releases significant quantities of pollutants to the air, including volatilized metals. Air pollution control technology for removal of metals is expensive and is not likely to meet the emerging and increasingly more stringent governmental regulations.

The current fuel shortage has cast an additional gloomy shadow on sludge disposal by incineration. The steadily increasing cost and decreasing availability of natural gas and oil will affect the desirability if not the feasibility and practicality of this process in the foreseeable future.

Olexsey and Farrell present some data on auxiliary fuel consumption in seven cities of the U.S. The weighted average consumption of No. 2 fuel oil necessary to burn 1 ton (.907 metric tons) of dry solids was found to be 51.6 gallons (195 liters). If this figure is rounded to 50 gallons (189 liters) per ton nationwide and one assumes that the practice of sludge incineration were adopted nationally, then the U.S. would require at least 9×10^8 gallons (34×10^8 liters) of crude oil per year. In 1972, the nation was consuming about 50×10^6 gallons (19×10^7 liters) per year (Olexsey and Farrell, 1974*) for sludge incineration. Clearly, unless alternative methods for sludge disposal are available to municipalities, sludge incineration will be at variance with the long-term fuel conservation goals of this nation.

In addition to the energy required to incinerate sludge, one must also consider the fact that incineration destroys the nitrogen and other agronomic nutrients contained in the sludge. This nitrogen must be replaced and, of course, it takes energy to make the required inorganic fertilizer for replacement. For example, the replacement of one ton of nitrogen fertilizer requires approximately 420 gallons of crude oil.

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* op.cit.

Clearly, if we can recycle the nitrogen content of sludge for agricultural production, we can reduce the amount of energy required for fertilizer manufacture and the corresponding cost of food production.

Ocean Disposal

Ocean disposal offers, to coastal cities, a readily available ultimate sink for sludge. This has been practiced by many U.S. cities, including Los Angeles and New York, However, this means of disposal is not available to inland cities and has many disadvantages. Any nutrient value contained in the sludge is wasted while the organics present tend to deplete the dissolved oxygen of the disposal site. Such disposal could significantly affect coastal fishing areas as well as reduce ocean bathing areas. This method of disposal has come under increased governmental scrutiny and has, in fact, been prohibited as of the end of 1981 by the U.S. Congress. Costs are very low for this process.

Landfill Operations

Landfill operations are practiced by many cities, and included under this general term is sludge lagooning. Landfill operations waste the organic content of sludge, while considerable expense is involved in sludge dewatering either for lagoon decanting operations or prior to landfill operations. Disposal sites are difficult to acquire and usually rendered useless for other purposes following landfill and some are never returned to the tax rolls. Few sites can be used for

20 to 30 years after being landfilled with municipal sludges. Oftentimes, such sites will produce methane gas which could cause a potentially dangerous situation for other land uses.

Land Utilization

Land utilization of sludge has become a method which is being increasingly considered by many municipalities in the U.S. and, indeed, throughout the world. It offers the advantage of recycling nutrients back to the land, and of reclaiming lands bespoiled by strip mining. Sludge is first stabilized by anaerobic digestion or other suitable means before application on land. Such stabilization eliminates obnoxious odors and fly problems. Yield of grain and forage crops are increased by the nutrients and water supplied by irrigating with digested sludge. Digested sludge organic matter accumulates in and imparts favorable characteristics to soils because of its normally high humus content. The process of land spreading of sludge affords the opportunity for urban areas to recycle the fertilizer value of sludge to the farming areas from which much of the organic materials and nutrients originate. With the current shortage of fuels, and the high requirements for inorganic fertilizer production, sludge recycle for agricultural production offers a ready opportunity to reduce the energy requirements of the agricultural sector. Also, since many municipalities can offer their sludge at practically no cost to the farmer, a significant cost savings

is effected both for the farmer and the municipality which pro-
duces the sludge.

CURRENT PRACTICE OF SLUDGE MANAGEMENT IN THE UNITED STATES

The EPA in 1977 commissioned Sverdrup, Parcel and Associates, Inc. to analyze a survey of sludge management practices in the U.S. This survey was conducted of those municipal agencies who belong to the Association of Metropolitan Sewerage Agencies (AMSA). Questionnaires were sent to all AMSA member agencies and included over 98 plants serving a population of 54 million people or roughly one third the sewered population of the U.S.

Table 2 contains a summary of the municipal sludge management techniques which were reported on in the survey. As can be seen, 97 plants gave information on their sludge management techniques representing 3,652 dry tons per day of sludge or roughly 40% of the sludge produced in the U.S.

The greatest tonnage of sludge was sold or given away but for all intents and purposes, ocean disposal and incineration rank equally in tonnages disposed of. Land application of sludge, in terms of tonnage, appears to be equally as popular as landfilling. Lagooning as a final disp method finds rather limited favor with municipalities it is used for temporary storage by many agencies.

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

TABLE 2

SUMMARY OF SLUDGE DISPOSAL OPERATIONS FROM A
SURVEY OF THE ASSOCIATION OF METROPOLITAN SEWERAGE AGENCIES†

Disposal System	# Plants	Dry Tons/Day	% of Plants	% of Tonnage
Sale and Give Away	8	953	8.2	26.1
Ocean Disposal	19	833	19.6	22.8
Landfill*	27	461	27.8	12.6
Land Application*	14	402	14.4	11.0
Lagoons*	7	108	7.2	2.96
Incineration**	22	595	22.7	24.5
	97	3652		

* Does not include incinerator ash.

** Incinerator ash is disposed of in landfills (18 plants) and lagoons (4 plants).

† SLUDGE HANDLING AND DISPOSAL PRACTICES AT SELECTED MUNICIPAL WASTEWATER TREATMENT PLANTS -- APRIL 1977 -- USEPA, MCD-36.

The significance of this information is that nearly 40% of the municipal sludge is being used for land application and that all of this sludge will be impacted by proposed RCRA regulations. It is also easily seen that ocean disposal and incineration represent nearly 50% of the municipal sludge being disposed of currently. With the ban by Congress on ocean dumping by 1981 and the effect of the current fuel shortage on incineration, it is obvious that municipalities have severe sludge management problems. It is certain that many municipalities will face a sludge management crisis of large magnitude unless there is a change in current EPA Policy of severe regulations of land application.

Land application of sludge is the most logical choice for municipalities facing the problems of fuel shortages, bans on ocean dumping, and the lack of landfill space. With the severe regulation of this alternative, municipal sludge management and, therefore, in turn wastewater treatment will be in serious jeopardy.

IMPACT OF REGULATIONS ON SLUDGE APPLICATION TO LAND

Cost--Large Urban Areas

The RCRA regulations will have a significant cost impact upon existing municipal sludge management operations especially those land application sites owned and operated by municipalities.

The District currently operates the largest sludge application to land project in the U.S. whereby approximately 175 dry tons per day of sludge are applied to a 15,000 acre site owned and operated by the District in Fulton County, Illinois.

Since 1971, the District has operated this site where approximately 40,000 bushels of corn and several hundred tons of animal forage are produced annually, using municipal sludge from the District's facilities as a fertilizer and soil conditioner.

It is of interest here to note that 40,000 bushels per year of corn could supply the annual protein requirements of a population of 4,600 people.

In Table 3 are contained the cost impacts of the RCRA regulations on the Fulton County operation. As can be seen, the current application rate in Fulton County is 20 dry tons per acre, but this must eventually decrease to 0.7 dry tons per acre by 1985 because of the regulations. Because of the loading rate limitation and the requirement to stop sludge application, after the soil has reached the proposed maximum cadmium loading of 20 kg/ha as specified in Table 1; land requirements will increase to over 330,000 acres. This much land, of course, cannot possibly be obtained, and the existing Fulton County operation would have to be terminated.

Unit costs would increase from the current level of $8.67 per wet ton to nearly $52.00 per wet ton by 1986. The resultant annual cost of $111,730,000 could not possibly be afforded by the District, and the operation would be terminated.

Fulton County is not the only sludge management method utilized by the District at the present time.

The District currently has a program whereby air-dried aged Imhoff sludge (Nu Earth) is given away free to the public

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TABLE 3

MSDGC Liquid Fertilizer Program Costs for Fulton County

	Present Regulations	Proposed USEPA Criteria		
		Present to Dec. 31, 1981	Jan. 1, 1982 to Dec. 31, 1985	Beginning Jan. 1, 1986
Application Rate Dry Tons/Acre/Yr.	20.0	2.8	1.7	0.7
Additional Land Required Acres	0	82,000	132,000	331,000
Unit Costs $/Wet Ton	8.67	19.52	26.22	51.37
Annual Costs $/Year x 10^3	$18,857	$42,456	$57,028	$111,730

Annual costs based on 2,175,000 wet tons/year.

for non-food chain uses. This program has been considerably reduced in scope since 1978; but in 1977, this program amounted to an annual sludge distribution of 130 dry tons per day.

The District also produces a heat-dried fertilizer which is sold to a broker on a competitive bid basis. The broker in turn has developed a market of buyers who apply the solids to land. In 1977, approximately 131 dry tons per day of heat-dried fertilizer were sold

Sludge is stored in the District's lagoons where digested solids are concentrated and then distributed to sod farmers, land developers, and to large landscaping projects. In 1977, approximately 190 dry tons per day of lagoon sludge were distributed by this process.

Summary of sludge type, quantities distributed, and associated operational costs are presented in Table 4.

The proposed EPA regulation will force the District to virtually eliminate the heat-dried sludge, Nu Earth and lagoon sludge program, since all these sludges contain more than the 25 ppm of cadmium limit noted in Table 1. Therefore, the current distribution to citizens and buyers could not continue, since the District could not guarantee the end use of the sludges so distributed.

As noted previously, incineration and landfilling have material disadvantages,and the District has every reason to believe that sufficient landscape would not be available for

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TABLE 4

1977 MSDGC O & M SOLIDS HANDLING AND DISTRIBUTION UNIT COSTS SUMMARY

	Dry Tons Distributed (DT/D)	Processing Cost ($/DT)	Distribution Cost ($/DT)	Gen. Disposal & Misc. Cost ($/DT)	Applied Unit Cost ($/DT)	Approx. Expenditure ($)
Heat Dried	131	181	(20)*	29	190	8,080,000
Lagoon Solids Distribution (Slackline)	Slackline-190	-	16	2	18	1,250,000
	Digestion-117	41	-	6	47	2,010,000
					65	3,260,000
Contract Lagoon Cleaning**	Removed-253	-	35	-	35	3,230,000
	Digestion-121	29	-	6	35	1,550,000
					70	4,780,000
	Transp.-82	-	49	9	58	1,740,000
Fulton Co.	Digestion-82	41	-	6	47	1,410,000
	Application-163	-	73	10	83	4,940,000
					188	8,090,000
	Imhoff Prod. 49	49	-	8	57	1,020,000
Nu Earth	Nu Earth-130 } 349	-	4	1	5	640,000
	Grit 219 }				62	1,660,000
					Total	26,870,000
Composting	Prod. - 2.8	197-264	16	-	213-280	

* Revenue
** Weighted average unit costs for WSW and Calumet

landfilling, and sufficient fuel would not be available for incineration. Therefore, the District would be forced to virtually abandon these programs, which in 1977 distributed more than 450 dry tons of sewage solids per day, or the equivalent of the total daily sludge production of the County Sanitation Districts of Los Angeles County projected for the year 2000. The only viable alternative would be to utilize these sludges at Fulton County for application to land. However, the District would be faced with the proposed EPA regualtions, which severely limits total and annual sludge application rates, and which would require the acquisition of extensive additional acreage.

Contained in Table 5 are the costs associated with a Fulton County site operating with the inclusion of 163,000 dry tons per year (450 tons/day) of heat-dried, lagoon, and Nu Earth sludge. As can be seen because the loading rate, both annual and total, has been restricted by the EPA regulations in Table 1, both costs and required acreages are exorbitant. Due to the additional sludge to be disposed of at Fulton County, total costs approach nearly 292 million dollars and total acreage approach 800,000 acres. Since 1977, the total District expenditure for all sludge disposal was about 27 million dollars. It is obvious that this projected total cost could not be borne by the District.

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TABLE 5

COSTS FOR EXPANDING FULTON COUNTY TO INCLUDE
HEAT DRIED, IMHOFF AND LAGOON SLUDGE

	COSTS - IMPLEMENTATION OF EPA REGULATIONS		
	$/D.T.	Total Cost ($ x 10^6)	Additional Land (acres)
Existing Program*	1114	111	331,000
Expanded Program**	1114	181	464,000
		292	795,000

* Costs based upon 2,175,000 wet tons per year.

** To expand Fulton County to receive an additional 163,000 dry tons per year of heat-dried, Imhoff, and lagoon sludge.

Cost--Small Communities

The cost impact for small communities is also expected to be significant. In comments made to the EPA by the District, regarding draft regulations issued on May 12, 1977, it was shown that sludge application to land costs for a small community would increase from $6.79 per wet ton to over $30 per wet ton depending on site conditions. These costs were developed assuming a relatively low sludge cadmium content of 40 ppm and a community population of 15,000. A cost increase for sludge utilization of nearly 500% is going to be difficult for many communities to absorb and will have a significant adverse impact.

Application Rates

Data collected from the states of Wisconsin, Michigan, Indiana, Minnesota, and Ohio show that for the EPA total cadmium application limits of 5, 10, and 20 kg/ha, fifty percent of the sludge from these states could not be applied at more than 30 tons/acre (lifetime) to soils with a cation exchange capacity (CEC) of 5 or less. Even soils with CEC values over 20 would be restricted to total sludge applications of 120 dry tons or less, for 50% of the cities in these states.

If one considers a sludge application rate of 15 tons/acre, which is a moderate nitrogen application rate, and subjects this rate to the EPA annual application limit of 0.5 kg Cd/ha, then the sludge cadmium concentration cannot exceed 15 mg/kg. In a survey of the states of Wisconsin, Indiana, Minnesota, Michigan, Ohio, New Jersey, and New Hampshire, only 30% of the

acilities in these states produced sludge with cadmium levels below 14 mg/kg. In other words, only 30% of the facilities could apply sludge (at 15 tons/acre) to satisfy crop nitrogen needs.

The EPA regulations restrict applications for leafy vegetables, root crops, and tobacco to sludges with a cadmium concentration of 25 mg/kg or less. Only about 50% of the cities surveyed in Wisconsin, Indiana, Minnesota, Michigan, Ohio, New Jersey, and New Hampshire could meet this restriction.

It should be clear that the proposed regulations will severely impact a high percentage of municipal treatment agencies, particularly those larger agencies which together produce the major portion of municipal sludges nationwide. .iere are municipal agencies, such as the Milwaukee Sewerage Commission, the Metropolitan Sanitary District of Greater Chicago, and the City of Houston, which market a dried sludge product on a national basis. The proposed regulations can be interpreted to mean tha such marketing must cease, since these products have a cadmium level above 25 mg/kg.

Many municipalities will be forced to other sludge management methods simply because it will not be economical to apply sludge at the rates dictated by the EPA proposed regulations. The regulations would force these agencies to co.tinuously acquire new lands when total application limits are reached, and to supplement annual sludge applications with

chemical fertilizer, since they will not be able to satisfy crop nutrient requirements. For many local agencies, the land application alternate will no longer be viable under such conditions.

Long-Term Planning

The EPA at this point in time has no finalized regulations for sludge application to land. The planning involved in the design funding, and construction of public works facilities with useful life spans as long as 40 years is difficult enough without having to plan on the basis of regulations in a state of flux.

The District experience has been that it takes between 6 to 10 years to plan and design large waste treatment facilities. For extremely large and complicated sludge management systems even longer times would be required.

Source Control for Cadmium

There is a suggestion in the proposed regulations that compliance with the 25 ppm sludge cadmium limit can be achieved through vigorous enforcement of an industrial waste control or pretreatment ordinance. In Table 6, are shown data on the industrial and non-industrial cadmium discharges to District plants and plants in New York and Pennsylvania.

As can be seen, the industrial contribution to the District plants of Calumet, Egan, Hanover Park, North Side, and West-Southwest averages only 38% of the total cadmium loading, which

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Table 6

Comparison of Industrial and Non-Industrial Cadmium Discharges to Municipal Treatment Plants

	% Industrial Contribution	% Non-Industrial Contribution
Calumet*	11	89
Egan*	-	-
Hanover Park*	49	51
North Side*	42	58
West-Southwest*	39	61
District Average	38	62
New York, NY **	39	61
Allegheny County, PA ***	37	63

* Plants operated by the District.

** Klein, C.A., et al, "Sources of Metals in New York City Wastewater," JWPCF 46, 2653 (1974).

*** Davis, J. and J. Jacknow, "Heavy Metals in Wastewater in Three Urban Areas," JWPCF 47, 2292 (1975).

is consistent with data for New York City and Allegheny County, Pennsylvania.

In the study of sources of metals in New York City wastewater, it was found that 33% of the influent cadmium came from electroplaters, 6% from other industries, 12% from runoff, and 49% from residual sources. Thus, the non-industrial percentage of influent cadmium was 61% for New York City.

The conclusion from this data is that domestic and/or commercial inputs of cadmium to municipal systems represents a significant, if not major, contribution. In fact, a recent study by Gurnham*, conducted for the National Science Foundation, supports this conclusion.

Gurnham studied the cadmium content of various commercial products, and found that powdered laundry soap, bath soap, fabric softener, toilet tissue and even toothpaste contain significant levels of cadmium, as well as other metals.

It may not be possible therefore for municipalities to significantly reduce their sludge cadmium levels, unless there will be control placed upon residential and commercial sources of cadmium. Unfortunately, however, municipal wastewater treatment agencies have no jurisdiction over these metal sources.

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* Gurnham & Associates, Inc., CONTROL OF HEAVY METAL CONTENT OF MUNICIPAL WASTEWATER SLUDGE, Supported by National Science Foundation, April 1979. Grant # ENV77-04355.

Federal Specifications for Cadmium

As noted in the previous section, although domestic and residential sources of cadmium represent a major portion of the input to municipal systems, industrial sources are significant. The majority of the industrial input is from plating operations where cadmium is used for corrosion protection.

Federal Specifications QQZ325 requires a zinc and cadmium coating, while Federal Specifications QQP416 demands cadmium coating exclusively. Cadmium is a relatively cheap and highly effective corrosive resistant coating. The Department of Defense often insists that only cadmium coatings be used for certain applications. It is estimated that within the jurisdiction of the Metropolitan Sanitary District of Greater Chicago that approximately 100 contractors and subcontractors are engaged in cadmium-related work for the U.S. military. A correspondingly high number of similiar contracts may be expected in other large urban areas.

Current estimates suggest that the various agencies of the Federal Government utilize between 40 and 50% of the nations cadmium plating capacity--thus much of the cadmium circulating in the environment is the result of Federal activities.

OVERLAPPING STATE AND LOCAL INVOLVEMENT

State and local agencies also have statutory responsibilities for funding, permit approval, plans and specifications approval, environmental monitoring and control, and siting approval for land application projects. Quite frequently the discharge of

these responsibilities result in overlapping and redundant actions at three levels of government; e.g. Federal, State, and local. These actions can result in excessive and unnecessary capital and operational costs to the local operating agency.

FUNDING

While the Federal Solid Waste Criteria are designed to promote and encourage the recovery and utilization of sewage sludge, few if any, municipal sluge application to land projects have been funded under the Federal Construction Grants program. There seem to be two main reasons for this current situation. First, there exists no established criteria for design engineers to evaluate the cost effectiveness of municipal landspreading projects. Secondly, deadlines for meeting water quality and effluent regulations require that definitive conclusions be made, and plans implemented for compliance with these regulations. The result is that the land-application of sludge management option is quickly eliminated from consideration as a competitive alternative.

LAND AVAILABILITY

One of the chief problems with implementation of many sludge application to land alternatives is acquiring the needed land. It is simply very difficult for local agencies to acquire contiguous land acreages of sufficient size to apply reasonable amounts

of municipal sludge. It would be extremely beneficial, if the Federal and State governments were to make some of their lands available for sludge application. A policy of allowing fertilization of Federal and State lands with municipal sludge would go a long way toward encouraging and promoting the concept of sludge utilization.

STRIP-MINE RECLAMATION

As is well known, strip mines are a major environmental problem in the U.S. today. The chief difficulty has been that strip mining removes the existing topsoil, and subsequent weathering of exposed soils causes polluted surface water to flow to receiving streams. Current regulations call for storing topsoil, and replacing it upon completion of mining; but there are many existing strip-mine sites which this new law does not affect.

Municipal sludge has a naturally high humus content, and has been successfully used for restoring topsoil to strip-mine land. The District's Fulton County site has extensive strip-mine land, and this land is now producing row corps, corn and soybeans. District sludge has reclaimed land in Palzo, Illinois, and other sites.

The chief problem in utilizing sludge for reclaiming strip-mine land is an institutional one. Both the coal-mining companies and state and local agencies are reluctant to adopt this concept. They still adopt the concept that municipal sludge is

a liability, rather than an asset, and resist its use.

The District has been very active in promoting sludge use for strip-mine reclamation. However, success in gaining the interest of coal companies and state agencies has been limited.

It would be a tremendous benefit if existing resistance to utilizing this valuable product for strip-mine reclamation were alleviated.

USE OF SLUDGE BY LOCAL FARMERS

Most local agencies are very interested in having local farmers utilize their sludges as fertilizers in everyday farming operations. However, many farmers find little incentive to participate in these programs because of the complicated administrative procedures, including those for obtaining operational permits, instituted by some state and local governments. This is unfortunate, since sludge utilization offers many benefits to the farmer, including increased crop yields and savings of approximately $45 per acre in chemical fertilizer costs.

CITIZEN RESISTANCE

One of the problems encountered by local sludge producing agencies is the resistance by citizens and citizens groups to sludge utilization sites. Many citizens are very supportive of the sludge utilization concept, but are extremely reluctant to allow municipal agencies to place such sites near their local communities. This resistance will surface even when sites

are well planned and located far from populated areas.

The District, for example, has found that citizen resistance to its Fulton County site has been a significant problem. Certain lands, owned by the District at Fulton County, are not currently used for sludge application because of local citizen resistance. It would be extremely useful to municipal agencies in dealing with this problem to have State and Federal support during the planning and land acquisition process.

Mr. AMBRO. All right, we will now hear from Dr. Rufus L. Chaney who will tell us a bit about the heavy metal problems.

Dr. CHANEY. It is now clear that within required constraints, the use of sewage sludge on agricultural or disturbed land can provide substantial public benefit. I will address the composting of sewage sludges, benefits from sludge use, and aspects of heavy metals that limit the safe use of sludge. I will further address the need for and success of industrial pretreatment to remove metals at their source so that sewage sludge can be applied to cropland with beneficial results and with limited risk.

The Beltsville aerated pile method of composting was developed to stabilize and pasteurize undigested sewage sludge. This technology utilizes natural thermophilic bacteria and fungi to oxidize unstable organic matter. Temperatures of 55° to 80° Celsius are achieved throughout the compost pile which effectively destroys enteric pathogens. Dewatered raw or digested sludge is mixed with woodchips, placed in a pile having a triangular cross section, covered with finished compost, and aerated periodically. After 21 days, the undigested sludge has been transformed into compost, after which it is usually placed in "curing" piles for 30 days of further composting before screening to separate the residual woodchips from the compost.

In contrast to the undigested sludge which is a malodorus, Jello-like mass of 20 percent solids requiring immediate disposal, the compost has an earthy odor, is peatlike, has 50 percent to 60 percent solids, can be stored until a convenient time for use, and can be easily and uniformly spread on land with conventional equipment.

Papers reporting the development of this technology are shown in the reference list—12, 22. Composting has won rapid acceptance within the sludge-handling community. This process has been adopted by many small and large cities, including Bangor, Maine, and Durham, N.H., Camden, N.J., and Washington, D.C.

The Blue Plains Water Pollution Control Plant in Washington, D.C., has been composting 275 wet tons of dewatered raw sludge per day since February 15, 1979.

Institutional constraints on locating new composting facilities can be severe. An example is the local situation in surban Maryland where Montgomery and Prince Georges Counties have been unable to agree on where to locate a composting site.

Composting is a sludge-stabilization process. The compost product must still read "ultimate disposal." The importance of composting is that it provides sewage treatment authorities with new options. Seasonal problems with other sludge utilization methods do not pose limitations on compost use, as compost is easily stored without causing malodors. Users can haul the compost to various application sites and stockpile it until needed.

Composted sludge contains mostly very slow-release organic nitrogen (N). This is both a convenience and a limitation. Nitrogen in heat-dried activated sludge is organic N, but most of it becomes available to plants in the year it is applied; low application rates—1 to 2 tons a year—are effective for use as a fertilizer.

For example, Milorganite is 6 percent N, and thus would provide 120 pounds of N per ton. Only 10 percent of the nitrogen in composted undigested sludge is available to plants during the first year, 5 percent the second and 2 to 3 percent in subsequent years. This allows higher

rates to be used as a soil conditioner for the revegetation/renovation of disturbed lands—coal and gravel mine spoil, and land disturbed by urban development—and as a component of horticultural potting media.

On the other hand, because it contains 1.5 percent N, and only 10 percent of this N is available during the first year, composted sludge would supply only 3 pounds N per ton. Thus, first year corn would require 60 tons of compost per acre. Compost can also be used as a soil conditioner and a phosphorus fertilizer. Supplemental inorganic fertilizers may supply the rest of the crops' N requirement.

Use of compost in revegetation/renovation of disturbed lands and construction sites, in turfgrass production and maintenance, in parklands, in different agricultural systems, in horticulture—both as nursery soils amendment and in potting media—and in home gardens would provide great public benefit from ultimate disposal of both sewage sludge and sludge compost. A recent report noted that demand for organic wastes actually exceeds the present supply of low metal sludges (25).

As a soil conditioner, sludge and compost reduce soil bulk density—compaction—increase soil aeration, decrease soil crusting, increase water storage capacity of the soil, and increase rooting development.

The soil conditioner benefit can last for a long time. We have one cooperative experiment with the University of Maryland where dewatered digested sludge was applied in 1972 at rates of 0, 25, 50, and 100 dry tons per acre. The plots were split with either:

1. No additional fertilizer, or
2. Chemical fertilizer added at recommended rates for corn in Maryland.

Yield of corn grain from the 100-ton per-acre plots was 50 to 100 percent greater than the fertilized control plots. No significant yield response to fertilizer was seen on the 100-ton-per-acre plots until 1976.

Fertilized sludge plots still yield 20 to 70 percent more than the fertilized control with year-to-year variation. Not all of the beneficial aspecs of sludge and sludge compost have yet been elucidated. Research in these areas is continuing.

Problems can result from improper sludge use. On the other hand low metal sludges now appear to offer little risk to the food chain even when poor agricultural management practices cause reduced crop yield. USDA has prepared recommendations to help prevent both short-term problems, that is, nitrate contamination of ground water, malodors, pathogens, soluble salt toxicity, initial toxicity, and long-term problems, for example, heavy metals, persistent chorinated hydrocarbons, nonpoint source pollution.

The short-term problems are generally controlled by specific management techniques. For example, nitrate contamination of ground water is prevented by basing the annual application rate of sludges and composts on the N requirement of the crop to be grown. In this way, the slowly released sludge and compost N represents even smaller risk to the environment than from inorganic fertilizers.

Potential problems from heavy metals are of two types:

1. Phytotoxicity, or injury to plants; and
2. Absorption and accumulation of sludge-applied metals by plants allowing entry to the food chain. These are long-term problems be-

cause the metals remain in surface soils for a very long time, with a half-life on the order of 1,000 years.

Heavy metal phytotoxicity depends on the metal concentrations in soil, the metals added—Zn, Cu, Ni and Mn—have caused phytotoxicity, soil pH and organic matter levels, and the crop grown.

Soil pH is of overriding importance, because metals are bound less tightly by the soil at lower pH and hence, are more available to be absorbed by and to injure plants if present in excess. Crops differ widely in susceptibility to heavy metal toxicity, with most vegetable crops and legumes being sensitive, and few crops like corn being very tolerant (2,6).

Recommendations to prevent phytotoxicity from reducing crop yields generally include:

1. Use of low metal sludges;

2. Ceasing sludge application after a cumulative level of heavy metals is reached; and especially,

3. Maintenance of soil pH at 6.5 or above. Not all farmers maintain soil pH at this rather universally recommended level. Soil pH has generally declined in the last decade since farmers no longer receive USDA support payments for purchase of limestone. Crop losses on acid-sludged soils can be alleviated by liming. Liming agricultural soils to pH 6.5 is a highly recommended practice whether sewage sludges are applied or not.

The other major concern of sludge-applied heavy metals is possible contamination of the food chain. Although a few elements other than cadmium (Cd) are of some importance (Se, Mo, Fe), problems with these elements are easily identified by sludge analysis, and can be controlled at the source or by proper site management.

Cadmium is of special concern, since crops—especially leafy vegetables—can accumulate excessive Cd without being injured by it. In contrast, when Zn, Cu, or Ni kill plants, the level of these elements in the plant does not pose a significant risk to domestic animals that may ingest the plant material.

Injury to humans from soil Cd absorbed by crops—rice—was observed in Japan with the "Itai-itai" disease. There, both a renal tubular proteinuria, and an osteomalacia were found in farmers who ate the Cd-enriched rice grown in fields contaminated by mine wastes. These wastes enter the river upstream; most of the contamination is believed to have come from waste ponds during a severe rainstorm.

Mr. AMBRO. What are renal tubular proteinuria and osteomalacia?

Dr. CHANEY. Osteomalacia is a bone disease. It is a result of the dietary cadmium interfering with calcium absorption. It leads to repeated breaks in the bones and some of the Japanese peasants who suffered this disease had so many breaks in their bones they were permanently bent over.

Renal tubular proteinuria is a damage to the tubular part of the kidneys. It causes protein to be in the urine; sugars, phosphates, and so are excreted. It interferes with the performance of the human kidney, and is the first health effect observed from eating too much food-borne cadmium.

Mr. AMBRO. Thank you.

Dr. CHANEY. Sludge-applied Cd is definitely a potential hazard. It is persistent, remaining available for plant uptake and subject to man-

agement for many years. It is a subtle or invisible phenomenon since plants do not exhibit injury until plant Cd levels have reached concentrations higher than those which constitute risk to animals ingesting the crop.

Finally, it is bioaccumulated—20-year biological half life—in the kidney cortex which is the critical organ; Cd is a greater risk to longer lived animals, especially humans.

The most important controls on impact of sludge applied Cd are:

1. Percentage of diet grown on Cd-enriched soil;
2. Soil pH. Lower pH allows much greater uptake;
3. Crops grown on treated land—greatest impact would come through leafy and root vegetables, followed by food grains and fruit crops, followed by feed grains and forages;
4. Cd levels in soil; and
5. Levels of other metals and organic matter in soil.

Recommendations to prevent adverse effects of sludge Cd applied to land include:

First: Limits on sludge Cd concentration;
Second: Limits on sludge Cd:Zn ratio;
Third: Cumulative and annual limits on Cd application (kgCd/ha);
Fourth: Maintaining soil pH at 6.5 or above; and
Fifth: Growing feedgrains which are mixed well in the market place.

Applications of sludge to cropland ordinarily used for tobacco or leafy and root vegetables should be avoided since metals are especially accumulated by these crops.

Formulating recommendations and regulations for sludge Cd application to private cropland has been especially difficult. In cases where sludge is applied to publicly owned land dedicated to sludge disposal, such as the Fulton County, Ill., site owned by the Metropolitan Sanitary District of Greater Chicago, proper management can be regulated. Dedicated sludge disposal site operators can manage soil pH at 7.5, calcareous, grow only Cd-excluding cultivars of feedgrains, monitor crop composition, and assure mixing of the grains in the marketplace or disposal of animal viscera at slaughter. Through public ownership, the possible future development of the sites for homes and gardens can be prevented.

On the other hand, private cropland is not subject to such management controls. As noted above, soil pH is not maintained within the desired range by all farmers. Moreover, farmers grow any crop they choose in order to gain maximum economic return, not just feedgrains. A grain farm can easily be switched to a vegetable farm or a field of homes with gardens.

Recommendations by USDA include soil pH management, limited cumulative applications of Cd, and limitation of sludge Cd:Zn ratio—equal to or less than 0.015. If soil pH is always maintained at 6.5 or above, limitation of cumulative applied Cd protects the food chain from unusual levels of Cd.

If soil pH falls below 6.5, crop levels of Cd and Zn increase. However, before high levels of crop Cd are reached, phytotoxicity from Zn, Cu, Ni, and Mn will reduce crop yields, thereby preventing substantial contamination of the food chain. Further, the increased Zn in the crop effectively reduces absorption of crop Cd by the animal intestine after ingestion (16, 16, 26).

Research has shown that leafy vegetable crops significantly increased in Cd and Zn content, derived from acceptable sludges applied to acid soil did not increase kidney Cd of experimental animals (7,8).

Other feeding studies with sludges and crops grown on sludges having a high Cd:Zn ratio showed rapid accumulation of Cd in kidneys. Further, crops grown on acid soils having a high Cd:Zn ratio also have greatly increased plant Cd levels.

In my experience, sludges which do not have identifiable industrial Cd sources are low in Cd and low in their Cd:Zn ratio. As discussed below, pretreatment of industrial wastes containing Cd can improve Cd content and Cd:Zn ratio of sludges.

Even domestic sewage sludges contain greater amounts of metals than unpolluted soils. Sewage contains metals from the water supply, from human wastes, from all the products we discard to the sewer, from the pipes conveying the water and wastewater, and from street runoff. However, domestic sludges have low levels of metals compared to sludges impacted by inadequately treated industrial wastewaters. Sludge composition surveys have shown that median sludge Cd contents are 13 to 16 ppm (table 1), whereas mean levels are higher, and the known range is 0.6 to 3410 ppm Cd. In my experience, metal levels in domestic sludges do not exceed those shown in Table 1, for example, 25 ppm Cd.

I believe that evidence now clearly shows that pretreatment can make sludge safe for use on private cropland. Many sludges from exclusively domestic sources contain only 5 to 10 ppm. Cd. Some large cities produce sludges with low Cd and with low Cd:Zn ratio, including Washington, D.C.; Baltimore, Md.; Philadelphia with two plants; Denver with two plants; Oakland, Calif. It seems inconsistent that these cities have low Cd, low Cd:Zn ratio sludges, yet cities like Chicago, New York (4 of 10 plants), and Dayton produce sludges that have a high Cd content and high Cd:Zn ratios. Certainly sources other than domestic ones must be contributing to these increased levels of Cd.

Recent studies in Chicago, Los Angeles, New York, and elsewhere indicates that only 1 to 3 parts per billion of Cd are added to the water during domestic use. This level is similar to that reported for the total sewage of cities without identifiable industrial Cd sources.

Some cities have achieved the goal of "domestic" quality sludges by passing and enforcing industrial waste control ordinances. Philadelphia has reduced sludge Cd from 35 to 15-to-20 ppm at its southwest plant, and from 200 (1970) or 105 (1975) to 20-to-30 ppm at its northeast plant. Other problem metals have been similarly controlled (Pb).

In 1977, a certain Western city (5 to 10 MGD) learned it had a high Cd sludge from researchers studying the sludge. City workers prepared an ordinance, found three Cd sources by analyzing wastewaters in different sewerlines, and worked with these sources to remove Cd. In January 1978, sludge Cd was 178 ppm, while it has now dropped to 20 to 40 ppm. One small plater chose to go out of business before the Cd survey was completed. A large captive plater switched from Cd to Zn plate. Another controlled its wastes.

Cadmium in the Minneapolis-St. Paul metro sludge has fallen from 300 to 100 as a result of simple abatement efforts by a large Cd user. Cd in Los Angeles County sludge—Nitrohumus—has fallen from 90

to 60 ppm during a period of increased enforcement activity. The sludge Cd level in a small town (1MGD) in the Northeast has fallen from more than 1,000 ppm to about 100 ppm; this was city No. 25 in our survey (4) and nearly all Cd in the sewage came from a factory manufacturing bug-lites.

Again, pretreatment can reduce sludge metals to domestic levels, allowing much greater benefit (higher cumulative sludge application) for equal risk of phytotoxicity and little or no risk of food chain Cd problems.

A serious problem exists in pretreatment: EPA has not yet promulgated Federal standards, and enforcement would occur 3 years after promulgation. Cities are often threatened with relocation of a factory to another city or State which does not enforce pretreatment, or has less stringent standards; this loss of jobs is more than some cities are willing to fight.

It seems unreasonable for the Federal Government to force other compliance schedules on cities if it is unable to provide a national standard for pretreatment. It took great courage for Philadelphia to enforce a limit of 0.1 mg Cd/L when Chicago enforces a standard of 2.0 mg Cd/L, New York City one of 5 mg Cd/L, and Los Angeles one of 15 mg Cd/L.

However, 0.1 mg Cd/L is low enough in nearly every case to achieve sludges of low Cd content and low Cd:Zn ratios. This is lower than the 0.5 mg Cd/L proposed by EPA. EPA proposed to allow cities to enforce at a lower level if needed to allow less expensive land application of sludge.

If managed properly, these levels—0.1 mg Cd/L—are achievable by using presently available technology. By reducing the volume of Cd-wastewater, an industry may reduce its impact at higher Cd concentrations.

As described above, the situation allowing highest potential risk from use of Cd-enriched sludges is use for home gardens. In this case, individuals intentionally grow and consume leafy and root vegetable crops that tend to accumulate Cd. They can eat sludge-grown crops as a high percentage of their diet, and may allow soil pH to be acidic, et cetera.

GAO identified this as a special problem in its 1976 report (9) and advised EPA to take necessary action. Although several products having a high Cd and high Cd:Zn ratio have been relabeled as "not for use on food crops," or withdrawn from the market, many sludges are still given to homeowners—most never having been analyzed for their heavy metal content. Although retail marketing of sludge-based products and sludge giveaway programs will be addressed by RCRA 4004 and CWA 405d, these actions will not likely be promulgated for several more years. Early solution of potential problems from use of contaminated sludges on home gardens seem clearly in the public interest.

Thank you.

Mr. AMBRO. Thank you, gentlemen.

I think we have a good cross section; much information with respect to sludge in this context, but no one mentioned and I might address this to you, Dr. Walsh, first, the use of sludge to produce methane gas. Now, we already have a sludge solid waste methane demonstra-

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tion plant at Pompano Beach. Another plant is being built in New York City.

Do you and the other panelists regard methanization as a viable alternative to land spread?

Dr. WALSH. Mr. Ambro, I am not very familiar with the civil engineering aspects of sludge disposal, the sludge utilization problem, and I would like to defer to Dr. Lue-Hing who is more familiar in this area.

Dr. LUE-HING. Mr. Chairman, methanization is practiced in several areas of the country but not in the context of the question you asked.

Methanization results from a stabilization process. You can capture or let go the methane that is produced.

There are some examples. If a facility captures most, if not all of the energy, it is utilized on the site.

In Chicago we capture currently about 84 percent of the gas produced from digested sludge. We have just let contracts to capture the remaining 26 percent. There is usually very little energy left over once the recovered methane is used in the sewage treatment plant for utilization heating and pumping, so while methanization is a very important aspect of the stabilization which should precede land utilization, it is not the answer. It is one thread in the weave of the whole problem. It is very important. It does permit recycling, reuse. It reduces cost, but it is not the total aspect.

Dr. WALSH. I might add that after the process is completed, you still have the metals and some of the other undesirable materials to dispose of in some manner. It has no effect on that aspect of the problem.

Mr. AMBRO. Well, let me ask you, Dr. Chaney, could you just explain a touch of the engineering or the design that goes into the pretreatment process? Tell us something.

Dr. CHANEY. OK; I will address cadmium since that is the one of greatest concern. Cadmium is usually plated from a cyanide bath; cyanide keeps cadmium soluble at alkaline pH. In order to remove the cadmium from the water you have to destroy the cyanide. Further, you have to destroy the cyanide before you can dump the wastewater into the sewer.

You oxidize cyanide with chemicals like chlorine or ozone. Then you adjust the pH and let the metals precipitate out. You form a very insoluble cadmium carbonate, but you have to filter the water before you release it to the sewer because some of the small cadmium particles do not settle out quickly enough.

Mr. AMBRO. Is that system fail-safe with respect to the removal of all cyanide?

Dr. CHANEY. It is only as fail-safe as the operator.

Mr. AMBRO. Are you accepting one risk for another?

Dr. CHANEY. Regarding the oxidation of the cyanide?

Mr. AMBRO. Yes.

Dr. CHANEY. Well, if they are being forced to oxidize the cyanide at the plating factory, the vapors can not be released to injure workers at the sewage plant, but that is a separate question. There are some new noncyanide plating baths which are much easier to get the metals out of the wastewater. By using countercurrent rinses; platers can reduce the amount of waste water remarkably.

Many of our big corporations are either going away from cadmium-plated parts, or meeting the pretreatment standards in their own in-house plating operations.

Mr. AMBRO. Does Chicago do anything in this regard?

Dr. LUE-HING. Yes, sir; we have had the most sensitive industrial waste program in place in this country, the oldest one, the most extensive one. It has been in place since 1967 and we spend currently at least $3 million a year to maintain that system. The problem of removing cyanide from industrial wastes is not an easy one. There are some parts that cause a problem. For example, when we start at the Federal level we estimate that between 40 and 50 percent of the Nation's total cadmium-plating capacity is utilized by various agencies of the Federal Government. For example, the Department of Defense has specifications which are exclusive for cadium and there are very good reasons for this.

The Navy cannot afford corrosion in certain critical instruments and critical instruments of navigation and warfare.

Mr. AMBRO. It is mostly in the form of cadmium plating on metals?

Dr. LUE-HING. Yes, sir. Then again, we find the larger centers attract the type of industry which are subcontractors in the Department of Defense.

In Chicago, we believe we have at least 100 subcontractors to prime contractors to the Federal Government which utilize that. I am not blaming the Federal Government. What I am saying is there needs to be some reassessment of the amount of cadmium that we use in industry. The blame does not necessarily rest with the local community for failure to put in control systems. We have one in place and we think it is a very effective system. The records show that our system, while the cadmium content of our sludges might be higher than many large communities, we have reduced percentagewise at least as much as all the other newer communities that have instituted control procedures. It is our volume, our size, and the industrial complex that we serve that, in part, creates the problem for us in Chicago.

Mr. AMBRO. I know you have a problem, of course, with the Navy specifications and the Air Force calls for cadmium plating of steels as well.

Dr. WALSH. I would like to make an observation regarding the cadmium issue in the broader respect, if I might.

Obviously, it is one of the most serious considerations we have in the question of sludge disposal on land but the problem is of most concern for those that smoke. Smokers are at or very near the limits that health officials feel you should ingest in terms of total cadmium. Of the total amount of cadmium ingested, about half comes from food and half from cigarettes. A recent article in Science Magazine indicated that approximately 50 percent of the cadmium taken in through your lungs is retained in your kidneys or other vital organs, whereas only about 3 or 4 percent of what you eat is retained in your body. This points out that the cadmium in cigarettes is probably more of a hazard than the cadmium in food.

Mr. AMBRO. Why the higher level in smokers? Is it because it is a leafy crop.

Dr. WALSH. No. When cadmium comes into the body through the lungs there is a much higher retention of that cadmium than there is in terms of what is ingested in leafy vetegtables.

Mr. AMBRO. How does it get in the cigarette smoke?

Dr. CHANEY. It is a volatile element and the temperature in a cigarette is high enough that cadmium is vaporized and you inhale that cadmium as part of the smoke.

Mr. AMBRO. Why does not the generation of cyanide as well remove the cadmium from the body? It does not interact beneficially?

Dr. CHANEY. Apparently not. We know from autopsies that cigarette cadmium is in the kidneys. Let me make one short comment.

In Japan after the Itai-itai disease, the Government promulgated standards stricter than those proposed by our EPA regarding cadmium in industrial effluents—but they still do cadmium plating in Japan.

I would agree that one of the real problems cities have is the lack of a Federal pretreatment standard regarding cadmium. Without that, it is very difficult for any city to really force industries to put on these controls. If everybody had to meet that effluent standard then their costs—costs of cadmium-plating parts are estimated to increase by 2 to 20 percent, depending on the part, and so on. But, if everybody has to meet those effluent standards then we do not have companies put out of business and no one district, no one State is hit unfairly.

Mr. AMBRO. Well, does not the Department of Agriculture participate with EPA in some form of interagency liaison group? Cannot you and EPA stimulate one another to develop a standard or to at least think about it?

Dr. CHANEY. It has been talked about for 5 years. It has been attempted to be promulgated once or twice in the last 1½ years and withdrawn. It is in limbo again. I do not know when we are going to see a cadmium pretreatment standard.

Those who are interested in land use of sludge need to be interested in why EPA has not issued that standard.

Mr. AMBRO. Well, what is your opinion, Dr. Chaney?

Dr. CHANEY. Partly the reason is the misuse of information from a New York City report about the impact of waste-water cadmium on sludge. Work since then in New York and other cities show the domestic contribution of cadmium is small.

As I pointed out in my statement, many cities have now shown that domestic sewage wastes are 1 to 3 ppb of cadmium. When your sewage influent is 1 ppm (1,000 ppb) you know you have a very large industrial cadmium load. People have been arguing about the domestic cadmium contribution back and forth, but I think today this issue has become pretty clear. It has taken quite a long time, but we ought to be able to move ahead with identification of cadmium sources, enforcement of pretreatment, and production of acceptable sewage sludges.

Mr. AMBRO. Can anyone tell us how much sludge is produced in the United States each day?

Dr. LUE-HING. A good number currently would be close to 4 million tons annually. That breaks down to about 11,000 tons per day, I think. But of 4 million tons annually, it is a good estimate.

Mr. AMBRO. Can you thumbnail an estimate as to how much land it would take to dispose of it?

Dr. WALSH. In a recent report we did for EPA, we estimated on a national basis it might require about 1 percent of the cropland if all sludges were spread on level.

Mr. AMBRO. One percent of the land of the United States?

Dr. WALSH. One percent of the croplands.

Mr. AMBRO. In 1 year?

Dr. WALSH. Yes.

Mr. AMBRO. So in 90 years it would take up all of the United States.

Dr. WALSH. No. This is based on applying sludge at the nitrogen utilization rates which could be repeated annually.

Mr. AMBRO. Would it require extensive redesign of agricultural equipment?

Dr. WALSH. In my opinion, it would not require extensive redesign. We presently have some equipment in agriculture which injects the sludge beneath the surface. Also there are other methods which can be used to directly incorporate the sludge, even if it is surface applied. There is no question that it does add some cost if direct incorporation is necessary and desirable.

Mr. AMBRO. Well, how would you transport, let us say, sludge from high-generation centers on the east coast to land areas of potential beneficial use?

Dr. WALSH. I think the people in Chicago have found when you go very far it has either to be barged, carried by tank car, or moved in a pipeline.

Mr. AMBRO. Did you say tank car?

Dr. WALSH. Yes; it can be transported by tank car.

Mr. AMBRO. Are you talking about liquefied sewage now?

Dr. WALSH. I am speaking of liquefied sludge. It can be reduced in volume by composting but this also adds expense so you have to balance one cost off against the other.

Mr. AMBRO. Well, I thank you, very much. I would like to now turn to my friend from California, chairman of another Science Committee, for any questions he might have.

Mr. BROWN. I was interested in this question of the use of sludge as an energy conversion measure since we are highly energy conscious at this particular point, and I would like to find out how this 4 million tons of sludge per year—is that the figure you used?

Dr. WALSH. Yes; 4 million tons of digested sludge.

Mr. BROWN. If applied to the land, how much nitrogen fertilizer would that replace, so that I can use that figure of 10 barrels of oil for a ton of nitrogen fertilizer to compute how many barrels of oil we would save by the land application of sludge?

Dr. CHANEY. In that report that Dr. Walsh mentioned, I think it was 4 million acres at 100 kilograms of nitrogen.

Dr. WALSH. Or if we look at it another way, if we have 4 million tons of sludge a year and if it contains 5 percent nitrogen, that would be 200,000 tons of nitrogen per year.

Mr. BROWN. Nitrogen equivalents?

Dr. WALSH. Yes; and if 10 barrels of oil are required per ton of nitrogen, that would be 2 million barrels of oil.

Mr. BROWN. That would be conserved by replacing the nitrogen with the sludge application?

Dr. WALSH. Yes; but it is not quite that simple because all of the nitrogen in the sludge is not immediately available. It is released over

a long period of time. In any case, there would be a significant saving in energy.

Dr. CHANEY. You also might consider the savings in energy from land spreading versus incineration.

In many cities they have experienced enough savings that they have shut down sludge incinerators and land-spread the sludge.

Mr. BROWN. If it takes a barrel of oil to incinerate a ton of sludge, we are talking about another 4 million barrels of oil; in fact, the savings from not incinerating is greater than the amount of spread. It adds up to a total of 6 million barrels a year if you are comparing incineration versus land application. That is a substantial saving.

It has to be offset, I guess, by the energy cost of transporting sludge.

Dr. WALSH. That is right.

Mr. BROWN. What is the preferred mode of transporting sludge for land application today? Can it go by railcar or truckline and so on?

Dr. WALSH. Both methods would be used. It depends on the type of sludge you have to transport and the distance.

In Chicago, liquefied sludge has been barged as it has been transported in railroad cars.

Dried sludge could be transported in either railroad cars or barges.

Mr. BROWN. What about pipeline transportation?

Dr. WALSH. That, too, is an option, and it currently is estimated to be the cheapest option. However, institutional constraints often limit pipeline development. In Illinois, we now transport the sludge almost 200 miles on a barge. If a pipeline were used, we could run into institutional problems by having to cross over 6 counties and get easements from each county for 200 miles. These problems are enormous and are not easily resolved so transportation in a pipeline, while it is estimated to be the cheapest method, could create some serious institutional problems before it could be put in place.

Mr. BROWN. Did you say that Chicago is transporting sludge 200 miles?

Dr. LUE-HING. Just under 200 miles southwest of Chicago.

Mr. BROWN. By barge.

Dr. LUE-HING. By barge. We maintain a farm. We produce enough corn annually to supply the protein requirements of almost 5,000 people. That is another benefit in the preservation aspect, quite apart from the energy and conservation aspect we mentioned earlier.

We also grow very high quality beef on this farm.

Mr. BROWN. The availability of land seems to be a major problem. I know it is in this region where everybody wishes to avoid having sludge operations in their county or in their neighborhood or whatever.

How do we resolve this problem? It seems to me that around every city there is obviously a large amount of land that could be used for sludge disposal if it were not for public attitudes and institutional barriers. Am I correct?

Dr. LUE-HING. That is right. There is usually enough land. Access to that land is the problem and the access is precluded by institutional constraints.

We believe that if there is sufficient cooperation between various agencies of government, from the Federal down to the local agencies, we can overcome the problem.

For example, if we go on to the west coast, Seattle is interested in a reforestation program where forests would be the place for this sludge management program.

In the Midwest we are more interested in agricultural production because that is indigenous to our area and so on and there is usually enough land, but there is a lot of cooperation between the various levels of government.

Currently, the box seems to stop at the wrong place because local units of government are quite restricted in their ability to acquire land for virtually any purpose. However, when that purpose happens to be sludge management, there is an instantaneous reaction adversely—well, an adverse reaction to the location of this site next to my swimming pool or my property or that type of thing and it is happening across the country.

We do believe we can solve the problem, but it requires the coming together of the forces of government and a process of educating the public that the program is helpful to everybody; that it is desirable; that it is the most environmentally acceptable; that it is cheaper and conserves, but we need the cooperation of various levels of government.

Mr. BROWN. Since the Department of Agriculture has the most experience in transferring technology to users and educating them as to its value, can we learn something from this process about how we might go about bringing together the forces of the community?

Dr. CHANEY. Yes; I think you are leading into the role of the Soil Conservation Service, and the Extension Service. At this time, the USDA Soil Conservation Service's staff are being trained to help develop sludge management plants for cities.

I have participated in several training conferences, particularly in the Northeast, where I know we are getting ready to help make those plans. I think one of the real constraints is the quality of the sludge. If a sludge is not a low metal-digested sludge, and you can't recommend it unequivocally for use on private land, then the institutional constraints are more severe.

I wanted to come to Washington, D.C., as an example. We all hear about the problems of finding a composting site and trenching sites. Nobody points out that every day 300 wet tons of filter coke-digested sludge are applied on croplands for fertilizer benefit; that is the digested sludge comparable to say, the Fulton County program, except this is a very good sludge and unequivocally recommended by State and Federal agriculture people. But we seldom hear about the one that works. We only hear about the ones that do not work.

Mr. BROWN. All right now, let me again refer to the Department of Agriculture. Are there problems within the Department with regard to your ability to focus on program of this sort which, in a sense, are somewhat outside of the normal purview of the Department?

In other words, do you interface between the urban and agricultural problems here? You have to work on city people to help them with sludge management problems. If sludge can be of benefit to the agricultural community you probably have to work on the agricultural community to get them to accept the value of this.

What I am asking is are there other institutional problems within the Department that inhibit a larger scale or more aggressive pro-

gram in this area that perhaps needs to be removed in some fashion?

Dr. CHANEY. Two years ago I agree with you that there were substantial limitations on USDA as being ready to help cities solve their sludge problems. Even now, as I mentioned earlier, the Soil Conservation Service is beginning to gear up. There has been a change in SCS's view on their role in helping cities with sludge management. I do not know what caused that change, but this happened since 2 years ago.

Some individual State's agricultural extension services have played a strong role—Wisconsin, Pennsylvania, Illinois, and Indiana—in terms of helping farmers learn how to use sludge beneficially and so on. I think the lack of a Federal standard from EPA on sludge use on cropland again makes it difficult for anybody to commit to a farmer sludge use is the accepted practice; sludge use is legal in most States, and you can go ahead and advise about sludge use, but the view does differ among States as to what is acceptable at this time.

Mr. BROWN. Can we make a case for the retention of agricultural land in the vicinity of cities, in part on the grounds that it provides indispensable service for cities in terms of problems such as disposal of sludge?

Dr. CHANEY. I know people who do and they make their case very strong.

Mr. BROWN. We have this as a potential blight in our own community right now. There is a petition to retain farmland within the city limits for environmental reasons as much as anything else, but as the contribution, the farmland—and this would be an additional contribution, would it not, to the farmlands?

Dr. CHANEY. Sewage authorities would not hunt for land within the cities because of the problems when neighbors get upset. Dr. Lue-Hing can describe their experiences about people that do not have a valid reason; but when people have a valid reason due to mismanagement—maladors—you know they have the highest opportunity to kill a project. We have available in the East badly disturbed land. In the Pennsylvania coal mine areas and so on. Cities could ship compost or liquid sludge of low metal content up there to help heal the sores in our countryside. Every city has gravel spoils which could be healed by sludge and compost.

Dr. WALSH. At the State level I think the extension service and the researchers have been very successful in terms of apprising the agricultural community of the benefits and the use of sludge.

In Wisconsin for instance, our two major metropolitan areas, Madison and Milwaukee, are both engaged in a land-spreading program and in both cases, we have more farmers requesting the sludge than is available for spreading.

The objections are coming from farmers who are not getting the sludge and, in many cases from rural nonfarm residents. These people, in many cases, control the politics of that local community so the problem gets back to one of an institutional or political nature.

Dr. LUE-HING. In a direct answer to your question regarding the acquisition of land within an urban area, there is a lot of merit to it and we practice that in Chicago. We have maintained a farm within an urban area next, let us say, 200 feet from houses worth $100,000 since 1969. That farm was 7 acres. It has now grown to 150 acres. We have no complaints from the residents because the sludge is indigenous to that

area. It comes from that area, was generated in that area, and we farm right there and it is a very harmonious existence.

It can work. It is working if we can find some mechanism to have access to properties.

Dr. CHANEY. One last point on that is the need to have agronomists on city sanitation authority staffs. Chicago took the lead in this by having a substantial agronomic staff. They conducted research and education programs. Although the extension service in many States is providing help with demonstration programs where the citizens can see it, the cities can benefit by having at least a farm boy on their staff, somebody who has gotten a BS in agronomy and can do agronomy with that sludge rather than dump the sludge.

Mr. AMBRO. I would now like to turn to the cochairman of these hearings, the chairman of the Subcommittee on Conservation and Credit of the Agriculture Committee, Ed Jones.

Mr. JONES. Thank you, Chairman Ambro.

I apologize for being late this morning. I had no choice except delay coming here until now. I have no questions. I am very much interested in the subject because I did miss part of the testimony and so I am not going to burden the witnesses with some questions that might not be as pointed as they should be.

I did listen with a great deal of interest to what George Brown asked and I appreciate, gentlemen, the responses you gave.

I am aware of the fact that we have a real problem as far as sludge disposal is concerned and that we do make the best use in the world of it, if we can.

Thank you very much, Chairman Ambro.

Mr. AMBRO. Thank you very much.

I would like to, before relieving you of further burdens ask you as I did other witnesses if you would mind if we kept the record open and ask you in writing some questions later on and if you will respond for the record, I would appreciate it.

Gentlemen, I appreciate your testimony and your responses and your patience very much and I would like to think you on behalf of both subcommittees for your appearance.

In advance of the next panel on air pollution impacts, I turn to my good friend from Vermont, James M. Jeffords who would like to provide us with the benefit of his wisdom in the form of a statement.

Happy to see you.

Mr. JEFFORDS. Thank you, very much, Mr. Chairman. I expect this afternoon to be sitting up there with you.

Mr. Chairman, I will be brief and like to have my full statement inserted in the record at this point if I might.

Mr. AMBRO. Without objection, your full statement will appear in the record at this point.

[The full statement of James M. Jeffords, follows:]

TESTIMONY OF CONGRESSMAN JAMES M. JEFFORDS

Mr. Chairman, I am here today to encourage our colleagues to move expeditiously in the deevlopment of a broad based National Environmental Monitoring System. You are to be applauded for your interest and efforts here today. It was just over a year ago that I appeared before the Committee on Science and Technology with a similar statement on this subject. The situation we face today relative to energy magnifies the necessity for a system such as the one I

will discuss with you today. There is little question in my mind that this country must become energy independent and in doing so a massive move to such synthetic fuels as "*Shale Oil*" and *Coal* will take place thus an even more important reason for the development of an extensive atmospheric deposition monitoring system. I doubt that I need to reiterate the many criticisms of the nation's monitoring programs that have appeared over the past several years; one need only cite the national research council's report on Perspectives on Technical Information for Environmental Protection, which said, "The Nation's information on environmental quality is deplorably and unnecessarily bad." This does not mean that much monitoring is not being done, not that much of this monitoring is not producing good, useful data. As a matter of fact, outstanding work is being done through the National Atmospheric Deposition Program, a research program sponsored by University Agriculture Experiment Stations of the North Central Region—NC141. This work is being done by competent individuals as Dr. Ellis Cowling, Dr. John Fulkerson, and Dr. Kye Jones.

The problem that overall, we do not have a good measure of the nation's environmental quality, because some of the monitoring does not have appropriate quality controls, some is too narrowly focused, some data are incompatible and, too, there are gaps.

Also, I want to applaud Bob Bergland who through certain reorganization efforts announced yesterday has paved the way for greater visibility and activity in this area.

As a result of this lack of an adequate national environmental quality monitoring program, those of us in Congress who are responsible for passing judgment on environmental statutes do not have a solid basis for assessing the success or lack of success of the laws we pass. Moreover, we continually face new environmental crisis because we lack the environmental monitoring that might have warned us of the emerging problems.

I think we can take the current inadequacy of environmental monitoring as given. What we need to do is investigate ways of developing an adequate national system. As Mr. Larry Miller of the environmental protection agency said before this subcommittee at hearings 2 years ago the most important thing "is the establishment of some kind of a national policy, a national board on environmental monitoring to set goals and objectives, and to define the responsibilities of the various agencies performing environmental monitoring." He went on to say, what we need is "some kind of national umbrella looking at the big picture." But at present we do not know how to set up this "national umbrella," and that leads us to the bill enacted last Congress, The National Climate Act. For a "prototype" or "experimental" environmental monitoring program.

This is the concept that we start small, with one or more specific, delimited environmental monitoring programs, that can both produce useful information concerning defined environmental needs and at the same time serve as experimental projects giving us experience in how a more complex, ultimately national environmental monitoring system might be set up. We need experience in many facets of running a national, coordinated environmental monitoring system: how to cordinate programs among different agencies that are conducting monitoring for specific mission needs; how to coordinate programs at different levels of government, Federal, state and local plus private and academic programs; how to ensure compatibility among the different systems; how to establish quality control; how to incorporate new and innovative techniques in existing programs. Furthermore, we need a better feel for the combined capabilities of the current disparate monitoring programs and some mechanism for getting feedback from users and potential users of environmental monitoring so that we can determine gaps and shortcomings in the nation's monitoring.

More paper studies of environmental monitoring are unlikely to give us the answers we need. We do not need further reiterations of the problems, nor further speculations on what might be done. It is time to begin some actual monitoring experiments designed to answer specific needs and at the same time to give us some actual operating experience in the processes that would be appropriate to a future national system.

I therefore believe that the concept of the bill you propose is the way to proceed. what is needed at this point is consideration of what monitoring program, or programs, to choose for the experiment. The program should be chosen to meet the twin goals of providing data that meet a real environmental monitoring need and of providing operating experience in dealing with the various institutional and management problems that a national environmental monitoring system would entail.

I would like to suggest two possible monitoring projects that would meet both these objectives; furthermore, they are projects for which two to four years of data—the period of the proposed experiment—would be useful and meaningful.

ACID RAIN

A problem of growing importance is acid rain. The adverse effects of this phenomenon have been well demonstrated in Scandinavia, where increasingly acid waters have eliminated fish from thousands of lakes. Moreover, it appears that acid rain reduces forest growth, increases leaching of nutrients from forest soils, affects predatory-prey relationships, disrupts the metabolism of some organisms, and increases corrosion of materials and structures. Acid rain is becoming a major problem in our northeast, where rainfall is consistently recorded at 10 times more acid than normal. In the Adirondacks, where increased acidity in recent years has eliminated fish from nearly half the lakes above 2,000 feet, lakes have been limed in an attempt to reduce their acidity and thereby restore the lost fisheries; however, Swedish experiences in liming acid lakes suggest that problems of mercury contamination may result.

All in all, the acid rain phenomenon is very complex, our understanding of the causes, sources, and effects of acid rain are limited. Acid rain appears to originate with emissions of sulfur and nitrogen oxides, often from thousands of miles away. These emissions, it is believed, transform in the atmosphere to sulfates, which are washed to earth in precipitation. It is further believed that the increased acidity is directly damaging to biota and materials, but recent research also suggests that acid rain releases aluminum from the soil and that it may be toxic to fish.

A major impediment in our better understanding of this complex phenomenon is a lack of monitoring data. In its recent study of environmental monitoring, the National Research Council noted that despite the recognition of acid rain problems, no national network exists for monitoring the acidity of rainwater and particulates that fall to the Earth, though one is planned, which would involve several Federal agencies. The National Research Council urged that such a network be established, "following prototype studies."

Such a prototype, it seems to me, could be designed also to fulfill our desired goals by giving experience in managing a complex, diverse monitoring program. For monitoring acid rain would require the air monitoring of emissions, their transport, and their effects on precipitation—a project involving the coordination of efforts across geographical and political subdivisions; in addition, the effort would require various kinds of water quality, soil leaching, and ecological monitoring to ascertain the effects of the acid rain. Thus a comprehensive acid rain monitoring project would necessarily involve the management of the diverse efforts that would be essential to a national environmental monitoring system. And the potential hazards from acid rain surely justify a concentrated effort to delineate the scope of the problem.

BENCHMARK SURVEY

Also known as "baseline monitoring," a benchmark survey would involve the establishment of base levels of various environmental parameters—such as levels of selected chemicals in air, soil, water, and biota as well as the distributions and populations of certain biota—so that in the future changes in these parameters could be detected and, possibly, associated with changes in environmental quality. Such a survey should include measurements in all types of environments—urban, suburban, and rural; polluted and pristine: It would serve as a snapshot, a benchmark, of today's environmental quality, against which we could in the future assess the progress—or lack of progress—in abating pollution through environmental statutes.

For the purposes of the proposed experimental monitoring management project, a benchmark survey would have to be limited carefully to a select number of environmental parameters and, possibly, to certain geographical areas—perhaps specified river basins and/or a sample of communities. In any event, the selection of parameters should be based on insuring that the data collected would serve usefully as benchmarks, and at the same time on involving the management problems of coordination disparate systems.

A benchmark survey is not a new idea: It was a major recommendation of the President's Science Advisory Committee's 1965 report Restoring The Quality of Our Environment. Unfortunately, that recommendation was never im-

plemented; so today, even when we measure the levels of acidity in precipitation or the levels of toxic chemicals in our nation's waters, we do not know if what we measure today is more or less than it was a decade ago. We are not sure if things are getting better or worse, nor at what rate.

The benchmark survey concepts outlined in 1965 in Appendix y3 of "Restoring the Quality of Our Environment" are no less pertinent today than they were then.

In conclusion, I think the proposed experimental monitoring management effort is a necessary step in the development of a National Environmental System. Such an experiment should be focused on a real monitoring need, such as the acid rain problem or the conduct of a benchmark survey, for the real need will provide goals against which the success of the experiment can be assessed. How well did it coordinate, how well did it guarantee data quality? The answers to such questions will tell us much about the feasibility of ultimately establishing a National Environmental Monitoring System. I strongly support your efforts here today of setting the stage for the development of a better understanding of agricultural and environmental relationships.

Mr. JEFFORDS. I would like to speak to you and have asked to speak to you because I think that from my own particular interests I may be able to at least shed some alarm on what I see as coming in the future.

On the one hand I have been very interested in the problems with our disappearing farmlands. We are losing some 4 billion tons of soil a year from erosion; some 3 million acres a year from perverted uses and now I see fast approaching on the scene the dangers from environmental matters.

Mr. Chairman, I have been interested in the acid rain problem and have worked with Mr. Brown in that area to try and monitor and set up monitoring programs on that. Also, I have become interested as everybody has recently in the synthetic fuels. I have a Bill in and because of that I have become cognizant of the implications of what is going to happen to this Nation.

Primarily, I am concerned about what is going to happen if we meet the President's commitments with respect to replacing some 5 million barrels of oil a day. That could mean if we go primarily the coal route, more than double the amount of coal we are mining and the amount of coal we are burning and the amount of pollutants in the airways.

That leads me to the problem I discussed before with these various committees and again, with Mr. Brown's Bill about the absolute lack we have right now nationally of any base study or data studies to establish benchmarks as to what is going to happen when we go into these areas of synfuels or whatever, to be able to really give us a good idea as to where we are starting from and what impact we are going to see upon our land and agricultural production capacity by virtue of the additional pollution that will come about as we shift from an OPEC based energy to our own local based energy production.

I would like to just express my sincere concern that we need to find and to provide data that will meet the real environmental monitoring needs and provide operating experience in dealing with the institutional and management problems.

Mr. Chairman, I think it is extremely important that we ensure that the various monitoring that is going on is coordinated and we need to do this and need to establish a real systematic approach to finding out what is going on in the country and to date, we have not done that.

Fortunately, as I say, the tools are there in the legislation but it is going to be essential that we monitor very, very closely what is going on so that we move forward and see changes in our society it is going

to result in a tremendous additional burden upon our areas for polluting and all that we must know, such as the effects of a baseline approach. We do not have the information now.

Also, I do not believe the necessary monitoring programs are in place, nor are they being properly coordinated to give us that kind of baseline data. I think it is essential and I would hope the various committees would do all they can to insure this monitoring does take place and that essential information is available.

With that, and with my full statement in the record, I just want to say I appreciate this opportunity to raise my great concern over the direction this Nation is going and the lack of data that we have now to determine as to what we are going to do to this country in the way we are going.

Mr. AMBRO. Well, I would like to thank you for a very enlightened statement. I think your leadership in environmental matters in the House is well known.

I would like to say there is a bit of a hopeful sign and the subcommittee Chair and the full committee as well provided money for programs, one of which was anticipatory with respect to acid rains and associated problems.

As you know, my amendment was unsuccessful on the floor in restoring the money cut then by the Appropriations Committee. The hopeful sign is that the Senate was more responsive and restored the money for precisely the kind of things that your statement talks about and you just mentioned. That is not to say that the Senate is a more enlightened body than this one, but after a bit of proselyting and because of the very serious concerns especially with respect to increased coal burning and synfuels which may come on line, the problem of acid rains and emissions of sulfur and nitrogen and greenhouse effects and things of that nature, why the kind of things that will be anticipated as a result of those programs, I think, are essential for the well-being of the Nation.

If we can hold the funding levels at least as a start this year, we will be on our way to meeting some of the concerns we all express.

Mr. JEFFORDS. Those of us who live in the Northeast and who have been aware of the acid rain problem and seeing it grow some tenfold over the years, with the fish dying in our lakes and all these problems experienced in Scandinavia, give us good reason to be alarmed not only for ourselves in the Northeast, but the rest of the country who will experience some of these problems.

Thank you, Mr. Chairman.

Mr. AMBRO. Thank you.

Our other participants on air pollution impacts will consist of Dr. O. C. Taylor, assistant director, Statewide Air Pollution Laboratory in California; Dr. Jay S. Jacobson, plant physiologist, Boyce Thompson Institute, Cornell University; and Prof. Ellis B. Cowling, School of Forest Resources, North Carolina State University.

Gentlemen, I will be happy to tell you that we will include your entire written statements in the record and you can proceed in any way you think most appropriate.

Let me welcome you on behalf of both subcommittees and ask you now to proceed.

If you will, Dr. Taylor, provide us with your overview.

STATEMENTS OF A PANEL CONSISTING OF DR. O. C. TAYLOR, ASSISTANT DIRECTOR, STATEWIDE AIR POLLUTION LABORATORY, CALIFORNIA; DR. JAY S. JACOBSON, PLANT PHYSIOLOGIST, BOYCE THOMPSON INSTITUTE, CORNELL UNIVERSITY; AND PROF. ELLIS B. COWLING, SCHOOL OF FOREST RESOURCES, NORTH CAROLINA STATE UNIVERSITY

Dr. TAYLOR. Thank you, Mr. Chairman.

Mr. Chairman and members of the subcommittees, there is a great deal of information already developed on the impacts of air pollutants on agricultural crops.

Much of this has been developed with industrial pollutants starting with some 100 years or more ago; and more recently, we have become concerned about the photochemical pollutants. Much of the research in the past has been done with single pollutants under more or less controlled conditions and used to identify the types of responses that plants give, and some of the things that I feel we need now is to expand this type of research in several directions.

One is to develop better techniques for the assessment of the effects in the field. In other words, we can take the research that has been used up to this point and we know the responses of the plants but it is very difficult to extrapolate that to field conditions because we know different varieties of crops respond differently to a specific air pollutant and there are many environmental conditions that affect their responses.

As was just stated a moment ago, it is quite apparent that the changing of energy sources is going to have a big impact on air pollutant impacts in various parts of the country, in the West specifically where we have avoided using sulfur containing fuels for so long and have a severe problem with the oxidant air pollutants.

We are very much concerned now with the prospects of imposing sulfur oxide and other pollutants on top of that, Mr. Chairman.

Another area that needs a great deal of attention is the interaction of these pollutants with various agricultural practices and with the various organisms that share an ecosystem.

Just to give a little bit of history on this, the photochemical air pollutants that we are concerned with consist of nitrogen oxide, ozone, and peroxide nitrates. All of these are produced from photochemical reaction of hydrocarbons. In the presence of sunlight and ozone is the one that is most important as far as the air pollutants in the United States are concerned.

We recognized injury from the oxidant air pollutants some 40 years ago, but it has only been in the last 20 or 25 years that we have really gotten into the subject and examined the effects of these pollutants on agriculture ecosystems.

During the past 15 years, the interest has increased tremendously, and there is a lot of scientific information and description of the responses of plants to these pollutants, and I will not go into that because there are many publications that discuss it in detail but to just mention a few, the early work and up until about 15 years ago, much of our recognition of the photochemical or ozone effects on plants was in terms of visible symptoms on the leaves.

Much of the assessment of the economic loss in the United States has been based on field surveys and observations of leaf injury and then interpreting this to provide some kind of a monitoring assessment of the injury.

We do know now that there are many other things that happen. One is that the photochemical oxidants stimulate the formation of necrotic and/or chlorotic injury, which cause leaves and fruits and flowers to abort and drop from the plant. This reduces production on crops without very often visible symptoms of leaf injury.

Now, there are things that occur, the suppression of the photosynthesis process and the stimulation of respiration that cuts down on the amount of photosynthate that is available for the plants to grow and develop.

Then there are many biochemical and anatomical changes that take place. We have a great deal of information on the acute type of symptoms from these controlled fumigations, but we are now concerned with the more chronic effects.

In the field of ozone effects, as with many other air pollutants, it occurs sporadically; sometimes it comes consecutively, but many times it is a day now and another one in a week.

Some of the studies that were started back in the early 1960's in California with citrus showed that there was some 35 to 50 percent reduction in fruit production. This was with lemons and oranges with very, very little leaf symptoms. If you went into the orchard, you would not see evidence of air pollution injury.

Yet, when these trees were placed in chambers in the field and excluded pollutants from one group of chambers and allow the smog into another type, then we got this type of crop production.

This was one of the first experiments to demonstrate this type of impact in the field. Since that time, there have been a number of other studies in California and other parts of the country that have been conducted.

On grapes in the south coast air basin, similar studies we found there was about a 50-percent reduction in fruit production due to the smog.

In the Great Central Valley, studies with cotton have shown a 20- to 30-percent reduction in lint production, and this occurred with no, or very, very little, visible symptoms on the leaves.

Other studies along the east coast have shown similar results with soybeans and other types of crops.

The agroecosystem is quite a simple system relative to the ecosystem of a natural community in that where we are practicing agriculture, we have usually a single or very few cultivators of other crops, and usually these are all alike and the culture of this crop is very uniform.

In this—if you want to call it a monoculture—we have a setup here that is quite vulnerable to air pollution effects, a destruction from a severe stress such as the air pollution can be catastropic in some areas.

There have been a few studies in the past that have attempted to measure the air pollutant impact on a crop in this natural ecosystem or natural system that the row crop is growing in. We have done relatively little work with the natural ecosystems, and a very large amount of our land in the United States lies in such systems—rangelands, forests, and the like.

One study that has been going on in southern California for some 8 years now is an attempt to determine the long-term impact of oxidant air pollutions from the south coast air basin in the Greater Los Angeles area on a coniferous forest ecosystem. It has been exposed to air pollutants as the marine air drifts in, and it has done so for the past 40 years, but with a very pronounced increase in the pollutants in the last 25 or 30 years.

The data on this study is not yet complete and we cannot report the full results yet, but some of the things we have noted in there are that there is a significant number of the ponderosa pine and Jeffrie pine that have died from the exposure to oxidant air pollutants over a period of time. This is evident from the foliage symptoms.

Also, many trees have been weakened to the point that they are targets for such things as the western pine bark beetle and other insects that have caused death of the major plant species. So tree mortality is serious there.

Also, with the defoliation caused by the smog, there is a buildup of an excess amount of litter on the ground, and some of the studies are showing that this buildup of litter prevents the germination of pine seed and some of the other tree species.

Consequently, we have a change in specie makeup of that community. In other words, a leaning toward more cedar and white fir which is very susceptible to forest fires.

We are gradually setting up a disaster situation when a wildfire gets away in this area. Measurement of the growth of the ponderosa trees have shown over the past 40 years compared with the 1920–40 period there has been at least a 50-percent reduction in rate of growth; that is, production of boardfeet of lumber.

I hasten to say this is not a lumber-producing area. It is not noted for that. It is a recreational-residence area in the mountains, but this could be something that would be occurring in other areas.

There is damage to the watershed and certainly damage to the recreational areas in that region and causing increased cost of the forest management. We are hoping when this data is all produced during this year that we are in right now, and we anticipate this will provide a great deal of information for predictive modeling of other areas; for example, the High Sierras and some of the Eastern areas to predict what may happen there with the apparent increase or continued increase in air pollution effects.

The changing of energy sources in California as I mentioned awhile ago is causing a great deal of concern. There are already efforts by several of the powerplants to locate electrical powerplants in California fueled with coal from the West, and there is a great deal of pressure from many groups to keep these from locating in agricultural areas or even near the mountains. This makes it very difficult to site a plant because the only thing that is left is the desert which we feel is quite fragile or along the seacoast and then the marine air carries the pollutants inward and causes damage there.

It has already been shown that there are synergistic responses from the sulfur dioxide and oxidant air polluants. In most of California we are already struggling with the oxidant pollutants so it is serious then if we impose another type of pollutant on top of this one.

Much work is going to have to be done. I think it will have to be done even perhaps at the expense of duplicating some of the work

that has been done in the Eastern United States because of our difference in climatic changes, or conditions and species composition of our agriculture and our native areas in California to find what we might expect from these powerplants coming in.

We are told that if a 1,400- to 1,600-megawatt powerplant is located in California equipped with the best available scrubbing system may emit 30 to 40 tons of sulfur dioxide per day. This emission may in itself not affect plant communities but many questions may be asked.

What will this do in a region where photochemical oxidants already exceed plant damaging levels?

Will changes in agricultural practices be required?

How much additional industry and urban development can be tolerated in the region before unaccetable agricultural losses are encountered?

Some preliminary work in California and some in other States have indicated that some of the practices that farmers must go through, must carry out, increase the susceptibility of crops to some of the air pollutants.

There are several of the insecticides when applied to crops have been shown that they increase susceptibility of those crops to ozone injury. We know that there are inneractions with some of the fungicides that some of these will make the crops less susceptible.

We need more information along these lines on the use of fertilizers, pesticides, cultivaries, and others and their susceptibility if we are going to set standards that will protect agriculture.

Mr. Chairman, we could make a long list of the needs as I see them, but one of the things that is foremost I believe now is that we need an effective testing of the acceptibility of the present air pollution standards in protecting crops and native species from injury.

We have set these standards and recently the standards were increased, and we still do not know whether these will be absolutely safe for the crops. We must improve the assessment techniques because ultimately there is a payoff of cost benefit in implementing any of the control techniques on industry or on the automobile.

We must be able to improve our assessment area from the regional and national standpoint.

We must have more information on the effects of pollutant mixtures and we must study the plant communities. I do not want to do this in exclusion of the greenhouse controlled environments, but very often the response of vegetation in its natural habitat takes, or I should say, is much different than that in a controlled atmosphere.

We must have more information on these natural communities, or ecosystem-type studies, and then a great deal of work needs to be done on the interactions not only with the chemical additives the farmer uses, but with microorganisms.

There has been evidence that exposure to the oxidant air pollutant or ozone has reduced the activity of nitrogen fixing bacteria on legumes which could be extremely important.

There is also evidence that mycorrhizae, that fungi that infects the foots of plants, is beneficial and helps the plant absorb nutrients. If the plants are exposed to ozone, then this decreases the infection of mycorrhizae and could have an impact.

Mr. Chairman, we must get into all of this because there is strong evidence that not only oxidant pollutants, but many of the air pollu-

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tants interfere with many of the predatory insects that are so essential in controlling other pests.

Thank you.

Mr. BROWN [presiding]. Thank you very much. I meant to comment before you started on my own personal knowledge of the long history of research in this area, the air pollution on the ecosystem and on agriculture associated with the laboratory there which I am proud to say is in my own congressional district, and I am hopeful that we can expand some of the areas of research that you have indicated.

Dr. TAYLOR. Thank you.

Mr. BROWN. Preceding our panelists will be Dr. Jay S. Jacobson.

Dr. JACOBSON. Thank you very much.

Mr. BROWN. Before you begin, Doctor, I do not know if Mr. Ambro inserted Dr. Taylor's statement into our hearing record.

If not, his statement will be printed in full in the record at this point.

[The prepared statement of Dr. Taylor is as follows:]

OVERVIEW—AIR POLLUTANT IMPACTS

(Prepared by O. Clifton Taylor, Statewide Air Pollution Research Center, University of California, Riverside)

Several review articles and chapters are available to provide detailed discussions of plant response to air pollutants. An excellent example of such publications is the series of review publications prepared by the Committee on Medical and Biologic Effects of Environmental Pollutants of the National Academy of Sciences. These publications contain excellent discussions of plant response characteristics, critical concentrations and dosages of the pollutants, and of all of the cultural, environmental, meteorological and genetic factors known to influence plant response. No attempt will be made here to repeat or expand upon this information.

An attempt will be made in this brief report to focus on three of the many important aspects of air pollutant-plant community interactions. These three areas include: 1) need for effects assessment; 2) impact of changing energy sources; and 3) interaction of pollutants and agricultural practices.

PHOTOCHEMICALLY GENERATED POLLUTANTS

Air pollutant damage to vegetation was first reported well over a century ago. The compounds responsible for this injury were emitted largely from industrial operations but during the last 30 years it has become evident that the automobile contributions are equally or in many regions even more detrimental to atmospheric quality than industry. Although there are two broad categories of pollutant sources (stationary and mobile) there is considerable over-lap of the types of pollutants they produce; as an example, nitrogen oxides are major primary pollutants emitted by both mobile and stationary sources. Therefore, the characteristics of pollutants in a given air basin are greatly influenced by man's activities in that area. The automobile is the principal source of photochemically generated pollutants in areas such as the Los Angeles Basin; consequently, the oxidants are generally widely distributed throughout the air basin and conversely, pollutants from the stationary source usually affect agriculture and other vegetation most severely in a rather restricted region adjacent to the source.

Since about 1950, a very large amount of scientific information has been compiled to demonstrate that photochemical oxidants (ozone, nitrogen dioxide and the peroxyacyl nitrates), at current ambient levels, can be highly destructive to agricultural crops, ornamentals, natural vegetation and forests. During the past 15 years, interest in photochemical oxidants has increased markedly and numerous scientific articles have been published on the subject. Much of this work has been done with short-duration, high-concentration exposures. Acute injury from such studies has been well documented on a wide variety of vegetation. The acute injury is usually confined to the development of necrotic and/or cholorotic injury symptoms on foliage. The impact on growth and flower and fruit production is

largely a secondary reaction to the loss of leaf area. Injury also stimulates development of the abscission zones and ultimately promotes premature and excessive drop of leaves, flowers and fruits. Abortion of the reproductive structures directly reduce production. The effect of photochemical oxidants may be restricted to aesthetic deterioration when the marketed portion of the plant is foliage but the economic loss can be equally significant when yields and quality of fruit, grain and vegetable crops is reduced. A single pollutant episode can be catastrophic and repeated episodes during the growing season is almost assured to result in very large crop losses.

The impact of chronic injury, resulting from continuous or intermittent exposure to low concentrations of the oxidants, is often more difficult to detect and measure than the acute injury. However, there is considerable evidence that such chronic effects are responsible for serious reductions in growth and production. Studies in California and at several locations along the eastern coast have revealed sizable crop losses of citrus, grapes, cotton, soybean and other crops with little if any of the acute injury.

In the future emphasis must be focused on long term studies of plant response to low concentrations of pollutant mixtures and to the more realistic intermittant exposures which represent natural conditions. Information on full seasonal and/or multi-year exposures is critical if reliable loss assessments for agriculture, forests and range lands are to be made and if proper support is to be provided for acceptable national and regional air quality standards.

EFFECTS ASSESSMENT

The agroecosystem is a relatively simple system in that large areas are devoted to a single crop and frequently to a single cultivar of a crop. Such a monoculture is highly vulnerable to destruction by a single severe stress such as an air pollutant episode. It is also vulnerable to chronic injury effects of repeated-intermittant exposures to low levels of pollutants.

Attempts have been made to estimate economic loss to agriculture due to oxidant air pollutants but such estimates on a national, state or even a regional basis can be misleading. Crop losses are frequently large in the proximity of large urban and industrial complexes and diminish significantly in the more remote rural areas where the oxidant levels are low. This variation in pollutant dosage complicates efforts to make reliable measurements of crop response.

Natural ecosystem of forests, parks, rangeland, etc., are more complex and diverse plant communities than the farmed areas. They are composed of numerous species of plants and animals with a wide range of tolerances to the pollutants. An eight year study of a coniferous forest in southern California, which is being completed this year, has revealed that some rather drastic changes have occurred during the past 40 years as a result of exposure to ozone. Ozone levels which have increased markedly in the South Coast Air Basin, as urbanization and industry has expanded, and these pollutants have invaded the forests in the mountains on a regular basis. The oxidants have caused premature loss of needles thus reducing growth, weakening the trees and increasing susceptibility to their natural enemies. The pollutant is a link in the chain of events leading to subtle changes in vegetation stand composition, tree mortality, damage to an important watershed, decreased recreational potential, and increased management costs.

Assessment of losses in either the agricultural or natural ecosystem is difficult to attain but such assessments are essential for a cost-benefit justification of pollutant control regulations. The current ability to estimate dollar losses or to predict air pollutant losses is complicated by the fact that we are working with a dynamic biological system. It is virtually impossible to simulate field growing conditions with our present research techniques and still adequately control air pollutant exposures to produce reliable measurement of growth and production response. A real need is to develop accurate dose response patterns for a wide variety of agricultural crops and native vegetation under field conditions. The best features of modeling, regression analysis, field chambers, survey techniques and any new approaches must be incorporated into a complete systems approach to develop the kind of data that is needed.

CHANGING ENERGY SOURCES

In highly industrialized regions the potential for serious vegetation damage from such gases as sulfur dioxide, hydrogen fluoride, and chlorides has long been recognized. Significant crop losses have been associated with each of these pol-

lutants at one time or another. Destruction of foliage, yield loss and reduced quality of the marketable produce can be disastrous for growers unfortunate enough to be operating in a high impact zone. A great deal of research has been done to better understand the response of a wide variety of plants to these air pollutants.

Most of the sulfur oxide problems have been in the eastern states; but now with the energy crises facing the western states, it seems inevitable that sulfur containing fuels will be used more extensively. Coal fired power plants and industry will no doubt intensify problems with air pollutants in California. Some researchers have reported synergistic responses when plants were exposed to mixtures of photochemical oxidants and sulfur dioxide. In an area where the oxidants are already causing extensive damage to crops and native vegetation, the addition of sulfur dioxide may significantly intensify the problems. Synergistic response from nitrogen dioxide and sulfur dioxide mixtures have also been reported. Further studes will no doubt reveal other synergistic, additive and antagonistic reactions from the gaseous components of the complex mixtures in the polluted ambient atmosphere. Variability in tolerance of vegetation is influenced by a dozen or more genetic, pollutant mixture and environmental factors. Consequently, it is difficult to extrapolate results from greenhouse or growth chamber experiments to evaluate the response of field grown crops. It is therefore essential that field conditions be used while studying the effects of pollutant mixtures complicated by the inevitable changes in fuel sources.

Research must be designed and funded for field studies of pollutant mixtures in ambient air if we are to make wise decisions on air quality standards, pollutant control regulations, industrial siting permits and general land use planning. Predictions of the impact of a coal fired power plant on an agricultural or native vegetation ecosystem can be made only if there is a data base from which to work. A 1400 to 1600 megawatt power plant equipped with the best available scrubbing system may emit 30 to 40 tons of sulfur dioxide per day. This emission may in itself not affect plant communities but many questions may be asked. What will this do in a region where photochemical oxidants already exceed plant damaging levels? Will changes in agricultural practices be required? How much additional industry and urban development can be tolerated in the region before unacceptable agricultural losses are encountered?

Over the past 40 years photochemical oxidants and other air pollutants from the South Coast Air Basin of California have impacted the forests in the San Bernardino mountains on a regular basis. Many changes in the forest characteristics have been recorded but it is difficult to determine the full importance of these changes relative to recreation, productivity, watershed quality and other factors. If coal is introduced into the basin as a major fuel source this will introduce another important factor threatening the future of the forest. It would appear we are approaching a new era in the air pollution in the west.

AGRICULTURAL OPERATIONS—POLLUTANT INTERACTIONS

The use of large amounts of chemicals in the form of sprays, dusts and soil treatments are essential for a profitable agricultural operation. Are there interactions involving these chemical additives and ambient air pollutants that may inhance the detrimental effects of pollutants. Few studies have been made in the area but there are indications that the use of certain insecticides may significantly increase the effects of ozone. Some fungicides and other agricultural chemicals have been demonstrated to reduce ozone injury. As an aid to the very important agricultural industry of the country it is critical that such relationships be fully investigated.

Mr. BROWN. You may proceed, Dr. Jacobson.

Dr. JACOBSON. Thank you, very much.

This country is faced with the increasingly urgent need to achieve goals that appear irreconcilable. The rise in industrial productivity and the effort to mantain a high standard of living produce residues which pollute the air, water, and soil. Virtual elimination of these residues is difficult, expensive, and perhaps inflationary. Rapid development of new energy sources to diminish dependence on foreign fuels also will produce residual contaminants. Reconciliation of these competing objectives requires the fullest possible understanding of the

scientific information and an interpretive process that makes assumptions explicit, is free of contradictions, and leads to valid conclusions.

This statement examines the state of knowledge concerning the air pollutant known to cause the largest losses to agriculture, namely ozone; it describes differing interpretations of this knowledge; and provides a series of recommendations concerning policies designed to protect agriculture and forestry from the effects of urban and industrial emissions.

Is ozone an urban or rural air pollution problem?

Data on atmospheric pollutant concentrations from the National Air Monitoring Network demonstrate that ozone concentrations exceed the secondary ambient air quality standard in most areas of the United States where ozone is measured. These measuring sites are largely in urban areas, consequently ozone has been identified as an urban problem. Other evidence seems to contradict this conclusion, however.

Detailed case studies performed both in the Western and Eastern United States have shown that ozone concentrations are higher in rural sites downwind of highly urbanized or industrialized locations. The explanation for this phenomenon is that ozone is produced in moving air masses by photochemical reactions involving nitrogen oxides and hydrocarbon compounds, pollutants emitted from the combustion of fossil fuels. These precursor compounds are emitted largely in cities and industrial locations. Air movement and atmospheric reactions, dependent on sunlight and time, lead to increases in ozone concentrations with distance from emission sources. In fact, the highest concentrations of ozone often occur as much as hundreds of kilometers downwind of urban/industrial sources of precursor compounds. Thus, the effects of ozone are definitely a rural problem.

The general consequences for agriculture and forestry of photochemically produced ozone have been known for decades. Far more injury to crops has been produced by ozone than any other air pollutant. The specific consequences for crops, however, are not known precisely for several reasons:

1. Ozone concentrations have not been adequately described in farming areas;
2. Long-term field experiments on crop yields are lacking, and
3. Variation in plant response with season, location, cultivar, and environmental and cultural conditions makes extrapolation highly uncertain from one year, site, and variety to another.

Is the ozone problem becoming more serious with time?

Data on ozone concentrations during the 1970's have exhibited both increases and decreases at different locations and no nationwide trend has been observed.

A reasonable conclusion is that, although the ozone problem is far from solved, at least it is not becoming more serious. However, studies have suggested that increasing development of emission sources in nonurban areas and increasing suburbanization have resulted in the spread of ozone to areas which formerly were relatively unpolluted. This suggests that the problem is becoming more serious for rural areas, although the lack of data for rural locations prevents the development of a completely convincing argument.

Are the effects of ozone on crops significant to agriculture?

Numerous estimates of direct monetary damage to crops by air pollutants have been made, and the most recent of these suggests

that economic losses may reach one-half of $1 billion per year. Recently, the secondary ambient air quality standard for ozone was relaxed by about 50 percent. The EPA justified this relaxation by concluding that evidence was insufficient to prove a significant effect on crops. The reasoning which led to this conclusion apparently contained two major elements, which are:

1. Estimates of losses to agriculture are imprecise and may be exaggerated, and

2. This loss amounts to only 1 percent of the total value of agricultural crops in the United States.

This argument disregards several important factors, namely:

1. Indirect effects also may occur but these cannot be estimated in monetary terms—delayed maturation of crops, increased susceptibility to other environmental stresses, increased cost of production, increased cost of marketing, et cetera;

2. No consideration was given to effects on forests;

3. The problem of equity—or who suffers—was not considered;

4. There was no discussion of the value system by which significance was determined; and,

5. The nature of the problem precludes precise estimates.

Let us take an example to clarify some of these factors. Suppose that a 50-percent reduction in the yield of an ozone-susceptible crop such as beans occurs in California or New York. This loss is entirely insignificant when compared to our gross national product and is trivial in relation to the value of all agricultural crops. But this loss is significant to the agriculture of the affected State and has a devastating impact on bean farmers in that State.

An examination of the arguments used to relax the secondary ozone standard reveals several assumptions that were not made explicit. One assumption is that losses occurring in a few sections of the country due to ozone should be compared to agricultural productivity of the Nation as a whole.

Another assumption is that virtually every dollar spent for pollution control must save at least $1 of direct monetary losses to agriculture by pollutants. Are we prepared to accept the concept that $1 spent for controls is equivalent to $1 of direct monetary losses to agriculture? Continued use of this value system will lead to the relaxation of many other pollution standards and a substantial reduction in environmental quality in future years.

Can individual States adequately control emissions of pollutants which are transported to agricultural and forested regions?

Regions of the country differ markedly in pollution emission intensities and in their potential for atmospheric conditions which limit dispersion of pollutants. Consequently, Congress empowered the EPA, through the Clean Air Act, to develop nationwide criteria and standards for air pollutants and assigned to the States the responsibility to implement pollution control regulations.

This policy developed before full recognition was available of the extent to which pollutants are transported across State and national boundaries. We now know that air masses transport contaminants far from their emission sources before dilution and deposition cleanse the air and reduce the risk of effects on vegetation. The emission of pollutants in one legal jurisdiction that affects susceptible crops or

trees in another jurisdiction pose a difficult problem for effective pollution control policies.

How can pollution control efforts in one State prevent damage to agriculture and forestry in that State when pollutants, such as ozone, are transported to that area from other regions of the country? It is not even possible to point to one particular source as the culprit. The multiplicity of sources and the distance between emissions and receptors require a critical reevaluation of current strategies for pollution control.

We have had information on the transport of pollutants from urban and industrial areas to agriculture locations for many decades. Future efforts to resolve the energy crisis by intensive utilization of fossil fuels will add more pollutants to the atmosphere. Based on these considerations and the difficulties encountered in controlling nitrogen oxide emissions, the following predictions can be made.

1. In the next 20 years, nationwide emissions of nitrogen and, perhaps, sulfur oxides will increase and long-range transport of pollutants to agricultural and forested areas will continue. The ozone problem will spread over larger portions of the United States and it will remain a significant problem for agriculture and forestry into the next century.

2. Long-range transport of pollutants from urban/industrial areas also produces acid rain, a problem which apparently has been occurring in the Northeastern United States for several decades but has been recognized too recently for sufficient information to have developed concerning effects on agriculture and forestry. The problem of acid rain also will spread and continue to pose problems to agriculture and forestry into the next century.

The foregoing analysis of the effect of current pollution control policies on agriculture suggest five directions that require special attention:

1. Determine the present existence and anticipated occurrence of atmospheric pollutants and their change in concentrations with time in major farming and forested areas of the country.

2. Perform long-term investigations on the response of field-grown crops and trees to pollutants now occurring or expected to occur in agricultural regions.

3. Examine carefully the location and design of new pollution sources to avoid enhancing the long-range transport of pollutants to agricultural areas.

4. Make explicit the assumptions used in revisions of air quality standards concerning the significance of scientific data for effects of pollutants on agriculture.

5. Analyze the problem of unequal geographic distribution of air pollutants and the inequities involved in pollution damage in order to develop new pollution control policies that will resolve or mitigate these problems.

6. The final recommendation is not to wait until new energy sources are developed to formulate policies for the protection of farm and forest lands from pollutants transported from urban/industrial locations. These policies should be developed simultaneously and in conjunction with the growth of domestic energy supplies so that we can reconcile agricultural production and environmental quality with our energy and economic requirements.

Thank you, very much.

Mr. BROWN. Thank you, Dr. Jacobson.

Now for our last panelist, Professor Ellis B. Cowling.

Professor COWLING. Thank you, Mr. Chairman. Mr. Chairman, I would like to commend both Congressmen, Dr. Taylor and Dr. Jacobson, for this presentation.

It was 4 years ago, Mr. Brown, that I first met you at a hearing very much like this one. The first recommendation that I made in that testimony, given on July 9, 1975, was essentially the same as Dr. Jacobson's first recommendation today and Congressman Jefford's recommendation in his statement as these hearings opened.

We need to establish in this country a network of sampling sites to provide a continuous record of temporal and spacial trends in the disposition of substances from the atmosphere into ecosystems. The sampling sites should be positioned so we can obtain reliable information about changes in the chemistry of both dry and wet deposition. A uniform system should be used throughout the Nation so that data for one State or region can be compared directly with that for other States and regions.

I also recommended to you in July 1975, that the USEPA should not operate this proposed network and that the State agricultural experiment stations should play a leading role in the development of this Network. That is the course that we followed during the past 4 years developing the regional project that is now called the national atmospheric deposition program.

One of the things that goes on in congressional hearings is that scientists not only speak to their Congressmen but they themselves become better educated and stimulated to fulfill the requirements of their own recommendations. I left the hearing room that July and have spent about half of my professional time ever since working with a group of other scientists from many institutions and agencies around this country to build the kind of a monitoring network that we recommended to you at that time.

That program, Mr. Brown, is aimed at the very things that Congressman Jeffords and Jay Jacobson called to your attention today. As this country undergoes all sorts of changes—in energy policy, in industrial development, in regulating systems in social attitudes towards regulations and so on—a baseline monitoring system, needs to go on providing objective data about changes in the chemistry of atmospheric deposition. We need a thin and inexpensive network that can be sustained over a very long period of time to give us insight into how governmental policy, how industrial development, and social attitudes affect the quality of the air in this country.

When we speak about air pollution, we generally are talking about the gases in the air, but it is very obvious that it is not just gases in the air that affect plants and animals and human beings, but also substances that come down in precipitation; substances that settle out of the air as particulate matter and the aerosol particles that are too light and too tiny to fall out of their own mass.

In the written testimony which I wish to have included in the record at this point, I have attempted to summarize some of the things that are known about acid precipitation and its effect upon crops.

Mr. BROWN. Your statement will appear in the record at this point.

[The statement of Professor Cowling follows:]

STATEMENT BY DR. ELLIS B. COWLING, ASSOCIATE DEAN FOR RESEARCH AND PROFESSOR OF PLANT PATHOLOGY AND FOREST RESOURCES, NORTH CAROLINA STATE UNIVERSITY, RALEIGH, N.C.

My name is Ellis B. Cowling. I am currently Dean for Research in the School of Forest Resources and Assistant Director of the North Carolina Agricultural Research Service at North Carolina State University. For the past 14 years I have been a Professor of Plant Pathology and have guided the dissertation researches of some 60 graduate students and postdoctoral fellows in the field of forest pathology. Six of these students completed their research or are currently engaged in research on the effects of acid precipitation and other air pollutants on agricultural crops or forest vegetation.

I am a member of the National Academy of Sciences and Vice-Chairman of the NAS' Board on Agriculture and Renewable Resources (BARR). The BARR is currently engaged in a major analysis of the exchange of matter between the atmosphere and the biosphere of the earth. I am also chairman of the National Atmospheric Deposition Program—a regional program sponsored by the State Agricultural Experiment Stations and several other state and federal research agencies including the Department of Agriculture, the U. S. Geological Survey, the National Atmospheric and Oceanic Administration, the U.S. Environmental Protection Agency, and others. The objectives of the National Atmospheric Deposition Program (NADP) are as follows:

(1) to organizze and coordinate research on the effects of atmospheric deposition on the productivity of agricultural crops, forests, range lands, wet lands, and surface waters; and

(2) to determine spatial and temporal trends in the deposition of beneficial and injurious substances into ecosystems in various regions of the United States.

In December of 1978, the NADP submitted a report to the President's Council on Environmental Quality entitled: "A National Program for Assessing the Problem of Atmospheric Deposition (Acid Rain)." In this report the NADP provided two things:

(1) an assessment of the present scope of available knowledge about atmospheric deposition and its effects on agricultural lands, forests, ranges, parks, surface waters, and aquatic life in the United States; and

(2) recommendations for a coordinated program of research and monitoring necessary to serve as a basis for the intelligent management of atmospheric emissions and for the amelioration of the adverse effects of atmospheric deposition on plant and animal life.

Many of the facts and recommendations presented later in this written testimony are developed more fully within the pages of this report which is provided for reference by the staff and members of the Congressional sponsors of these Joint Hearings.

The major points of my testimony may be summarized briefly as follows:

Acid rain is becoming a dominant feature of man-induced change in the chemical climate of the earth. But the increasing acidity of rain is only part of the changing chemistry of precipitation, dry particulate matter, aerosols, and gases. Recent research has demonstrated that (1) atmospheric deposition contains both beneficial nutrients and injurious substances; (2) plants, animals, and ecosystems vary greatly in susceptibility, tolerance, and adaptability to changes in atmospheric deposition; (3) injury is most likely when rapid changes in the chemical climate coincide with a vulnerable life form or life stage; (4) increasing acidity of precipitation has caused extinction of fish and other changes in species composition at all tropic levels in oligotrophic lakes in northern Europe and eastern North America; and (5) simulated acid rain has caused leaching of nutrients from soil and both direct and indirect injury to terrestrial vegetation; with rare exceptions, however, economic damage to crops by naturally occurring acid rains has not been demonstrated to date. These results show why a National Atmospheric Deposition Program is currently being developed to determine spatial and temporal trends in the amount, chemical form, and geographical distribution of atmospheric deposition and its effects on vegetation, soils, and aquatic ecosystems.

ACID PRECIPITATION AS PART OF A GENERAL PHENOMENON OF ATMOSPHERIC DEPOSITION

Precipitation formed in an atmosphere relatively free from natural or anthropogenic sources of contamination would have a pH of about 5.6 due to dissolution of gaseous CO_2. Thus, acid precipitation has been defined operationally as rain or snow with a pH value below 5.6. But acidity in precipitation must be understood as a reflection not only of the amounts of substances yielding hydrogen ions (such as sulfuric, nitric, hydrochloric, and organic acids) but also of the total ionic balance between all the cations and anions in precipitation.

Most of the substances dispersed in the atmosphere are at least partially soluable in water. These dissolved substances can be absorbed or assimilated by plants when precipitation is intercepted by vegetation. Since some of the substances dissolved in precipitation are beneficial while others are injurious to plants and animals, the net effect of atmospheric deposition can be beneficial or injurious depending on the chemical composition of the deposited matter, the duration and intensity of deposition episodes, the species and genetic characteristics of the organisms on which the substances are deposited, and the physiological condition, structure, phenology, and stage of maturity of the organisms.

Direct injury to living organisms by acid precipitation is most likely when a particularly vulnerable life form (for example, lichens or fish) is exposed at a particularly vulnerable life stage (for example, the early stages of reproduction), and are growing in a poorly buffered environment (for example, sandy soils or oligotrophic lakes or bogs) during a season of the year when acid precipitation is most likely (for example, spring rains).

Rain and snow change in chemical composition within as well as between precipitation events. In cold climates, acid substances accumulate in the snowpak where they are released in concentrated form with the first melt water and thus cause very sudden increases in acidity of soils, vegetation, and surface waters. Thus, a given organism or ecosystem may be subject to beneficial atmospheric influences at one time and to negative influences at another time within a given day, month, growing season, or the years of its development in the case of perennial plants and animals. Even a given molecular species such as SO_2 or NO_2, may be absorbed and utilized as a beneficial nutrient at one concentration; at another, higher concentration, even on the same day, however, the same substance may be absorbed and found to be toxic or even injurious to the very same plant, animal, or microorganism.

Herbaceous and perennial plants are subject to changes to atmospheric deposition within a given growing season. Trees and fish, on the other hand, persist for many years (or even decades in the base of trees); they are subject to long-term as well as episodic changes in the chemistry of the atmosphere and precipitation.

DIRECT AND INDIRECT EFFECTS OF ACID PRECIPITATION ON VEGETATION

A partial list of theoretical effects of acid precipitation on vegetation was developed earlier by Tamm and Cowling and is reproduced in Table 1. The effects are classified as either direct or indirect although most direct effects will have many indirect consequences as well. A decreased rate of growth would be the expected consequence of most of the effects postulated in Table 1 but unequivocal evidence of significant growth effects has yet to be demonstrated in agricultural, forest, or range ecosystems. Specific biological effects which have been proven to occur in at least one experimental plant are marked with an asterisk (*) next to the numbers in Table 1.

TABLE 1.—*Potential Effects of Acid Precipitation on Vegetation*

DIRECT EFFECTS

**1. Damage to protective surface structures such as cuticle*

Damage to surface structures may occur due to accelerated erosion of the cuticular layer that protects most foliar organs. It also could result from direct injury to surface cells by high concentrations of sulfuric acid and other harmful substances that are concentrated by evaporation or adherence of soot particles on plant surfaces.

*2. *Interference with normal functioning of guard cells*

Malfunction of guard cells will lead to loss of control of stomata and thus altered rates of transpiration and gas-exchange processes and possibly increased susceptibility to penetration by foliar plant pathogens.

*3. *Poisoning of plant cells after diffusion of acidic substances through stomata or cuticle*

This could lead to development of deep necrotic or senescent spots on foliar organs including leaves, flowers, twigs, and branches.

*4. *Disturbance of normal metabolism or growth processes without necrosis of plant cells*

Such disturbances may lead to decreased photosynthetic efficiency, altered respiratory patterns and intermediary metabolism, as well as abnormal development or premature senescence of leaves or other organs.

*5. *Alteration of leaf- and root-exudation processes*

Such alternations may lead to changes in populations of foliar-surface and root-surface microflora and microfauna, including nitrogen-fixing organisms.

*6. *Interference with reproduction processes*

Such interference may be achieved by decreasing the viability of pollen, interference with fertilization, decreased fruit or seed production, decreased germinability of seeds, etc.

*7. *Synergistic interaction with other environmental stress factors*

Such reinforcing interactions may occur with gaseous sulfur dioxide, ozone, fluoride, soot particles, and other air pollutants as well as drought, flooding, etc.

INDIRECT EFFECTS

*1. *Accelerated leaching of substances from foliar organs*

Damage to cuticle and surface cells may lead to accelerated leaching of mineral elements and organic substances from leaves, twigs, branches, and stems.

*2. *Increased susceptibiilty to drought and other environmental stress factors*

Erosion of cuticle, interference with normal functioning of guard cells, and direct injury to surface cells may lead to increased evapotranspiration from foliar organs and vulnerability to drought, air pollutants, and other environmental stress factors.

*3. *Alteration of symbiotic associations*

Changes in leaf- and root-exudation processes and accelerated leaching of organic and inorganic substances from plants may affect the formation, development, balance, and function of symbiotic associations such as mycorrhizae, nitrogen-fixing organisms, lichens, etc.

*4. *Alteration of host-parasite interactions*

Resistances and/or susceptibility to biotic pathogens, parasites, and insects may be altered by subjecting plants to any environmental stress. Acid precipitation may increase the susceptibility of plants to these injurious agents, alter their capacity to tolerate disease or injury, or alter the virulence of pathogens. The effects of acid precipiation may vary with the following: the nature of the pathogen involved (whether a fungus, bacterium, mycoplasma, virus nematode, parasitic seed plant, insect, or multiple-pathogen complex); the species, age, and physiological status of the host; and the stage in the disease cycle in which the acidic stress is applied. For example, acid rain might decrease the infective capacity of bacteria before infection and increase the susceptibility of the host to disease development after infection.

Many scientists believe that acid rain and snow are deposited only onto soils where acid substances could be neutralized in well-buffered soils or by applications of lime. This is true on some agricultural lands, especially after harvesting of crops. But it is not true in forests, rangelands, or even on most agricultural lands during the growing season. Most raindrops are intercepted by the foliage of plants where substances dissolved in the rain can induce various physiological changes before reaching the soil. These early effects include erosion of epicuticular waxes and leaching of essential elements and various metabolites from foliar

organs. In a mature forest, for example, rain will wash over three tiers of foliage before reaching the soil. Most forests and rangelands in the United States are rarely fertilized and have almost never been limed to neutralize soil acidity.

SOURCES, AMOUNTS, AND DISTANCE OF TRANSPORT OF BENEFICIAL AND INJURIOUS SUBSTANCES IN THE ATMOSPHERE

There are three major reasons why agricultural, range, forest, and aquatic biologists are becoming increasingly concerned about atmospheric transport and deposition of both nutritionally beneficial and potentially injurious substances: (1) vegetation, soils, and surface waters are the primary deposition sites for precipitation and airborne particulate matter of all types; (2) atmospheric deposition constitutes an important source of nutrients and potentially injurious substances that effect the productivity and stability of agricultural, forest, and aquatic ecosystems; and (3) human activities are steadily increasing the amounts and variety of substances dispersed in the atmosphere.

Previously, it was believed that most anthropogenic emissions were removed from the atmosphere near the site of emission. Now it is recognized, particularly with increased use of tall stacks in power plants, that atmospheric processes can lead to extensive mixing which leads to both chemical and physical interactions and transformations of atmospheric particles, aerosols, and gases. Furthermore, these substances and their reaction products are dispersed by meteorological processes and finally enter the biosphere in fields of deposition that extend hundreds or even thousands of kilometers from the original sources of emission. The fallout of radioactive materials all over the northern hemisphere since the early 1950's as the result of atomic bomb tests provides a dramatic and continuing reminder of the long-distance transport and deposition of pollutants.

If the United States is to so greatly augment the amounts of substance dispersed in the atmosphere and deposited into the biosphere of the earth, it is essential that we should measure the amount and chemical form of the deposited matter and understand the biological consequences of that deposition in our country and abroad. Regretably, our understanding of these processes in North America is very fragmentary. Fortunately, however, more extensive measurements of atmospheric deposition and its biological consequences have been made in Europe where an atmospheric deposition network has been maintained since the late 1940's.

EFFECTS OF ACID PRECIPITATION ON ECOSYSTEMS

Research on the effects of change in the chemistry of precipitation on terrestrial and aquatic ecosystems has been conducted in Europe since about 1955 and in North America mainly since about 1966.

A. Effects on Aquatic Ecosystems

The effects of acid precipitation on fish populations and aquatic ecosystems have been very pronounced in various regions of northern Europe and eastern North America. The most important of these effects were summarized at the First International Symposium on Acid Precipitation and the Forest Ecosystem and at the International Congress on the Effects of Acid Precipitation held at Telemark, Norway in June 1976. The latter report reads in part:

"Water quality has changed during the last decades in numerous lakes and rivers in southern Scandinavia and eastern North America, pH often falling below 5, with sulfate becoming the most important anion. There is strong evidence that this change is due to acid precipitation. It is associated with the loss of buffering capacity, and the occurrence of additional short-term decreases in pH, related to meltwater from snow or episodic inputs of acid precipitation from polluted air masses.

The acidification of freshwater ecosystems leads to many changes, most of which involve decreases in biological activity and important changes in nutrient cycling. For example, decomposed organisms are less active in acid waters, resulting in increased accumulations of organic matter. When the pH drops below 6, numbers of species in several groups of organisms (phytoplankton and zooplankton, bottom fauna and several other groups of invertebrates), decrease considerably, thus affecting the variety of food for fish and other animals depending on freshwater ecosystems. Shifts have been observed from higher aquatic plants toward mosses, and this will influence not only the bottom fauna but also nutrient exchange with the sediments.

High acidity (pH <5.5) seriously affects fish populations, particularly when occurring in waters of low ionic strength. Rapid extinction rates of fish popula-

tions inhabiting acidified waters have been observed during the past few decades in southern Scandinavia as well as in parts of eastern North America.

Case studies of several fish populations and experiments clearly indicate that the elimination of fish is often a result of chronic reproductive failure in acid conditions and of damage done to sensitive stages, especially the newly hatched larvae. Such a process is insidious and not readily evident in terms of fishery yield until extinction is imminent.

In lakes and streams with soft waters, acid stress has also been shown both experimentally and in field studies to cause mortality among adult fish as a result of interference with physiological mechanisms regulating active ion exchange across gill membranes. In this case factors such as size, age, acclimation history, genetic background and ionic strength of the water interact in complex ways to determine the relative acid tolerance of the fish.

There is strong evidence that the increased acidity of precipitation is now the main cause of these extensive losses of salmonid fish stocks as well as other populations of economic importance both in southern Scandinavia and the northeastern part of the United States and parts of southeastern Canada.

Sensitivity is related to the tolerance of the differing species (reflecting their genetic diversity), to the timing of episodic acid precipitation in relation to the stage in the life cycle, and to the influence of the geological environment, e.g., lakes and rivers on bedrock, overburden and soils highly resistant to chemical weathering. This may also be the case in geological areas of this type elsewhere in the world. Special consideration should be given to the preservation of unique gene pools and habitats.

There may be complex interactions with other environmental factors, including some organic compounds. In waters of low pH the adverse effects of heavy metals on fish and other organisms can be enhanced, whereas at pH values near neutrality these substances would have been tolerated."

B. Effects on Terrestrial Ecosystems

Effects on terrestrial ecosystems generally have been less well documented than those on populations of fresh water fish and other aquatic organisms. Nevertheless, certain definite effects have been reported. The most striking of these effects was development of peat moss (*Sphagnum* sp.) as a submarine rather than a terrestrial plant in acidified lakes and streams in Sweden. Dense mats of *Sphagnum* and an apparently parasitic aquatic fungus develop on the bottom of these lakes in water as deep as 18 meters. This growth induces oligotrophication (opposite of eutrophication)—a self-accelerating process that leads to a substantial nutrient impoverishment of lake waters.

Analyses of forest growth in southern Sweden from 1896 to 1965 showed a 2- to 7-percent decrease in growth between 1950 and 1965. Johnsson and Sundberg "found no good reason for attributing (this) reduction in growth to any cause other than acidification." Similar attempts to quantify possible effects on growth of forests in the United States have been inconclusive.

Other reports given at the meetings in Columbus, Ohio and Telemark, Norway indicated that:

1. Forest canopies filter out sulfur and hydrogen ions from precipitation;
2. Acidity of bark and development of cuticular features such as frequency and size of stomata can be used as biological indicators of sulfur pollution and acidification; for example, pH values of 2.2 to 4.7 were reported in bark of several species of trees in Poland;
3. Vegetation developing in recently formed sandy soils or glacial outwash areas is more vulnerable to the effects of acid precipitation than vegetation growing in older, well-buffered soils of high clay content and consequently large base exchange capacity;
4. Before reaching the soil, acidic substances in precipitation can induce changes in the physiology of foliar organs;
5. After reaching the soil, these substances also can induce changes in root function and the availability of essential cations;
6. Ammonia and other cations combine with sulfate ions in the atmosphere and tend to neutralize and thus hide the atmospheric acidity—when the cations are absorbed by plants, however, additional hydrogen ions are released by the plants and contribute to the further acidification of agricultural and forest ecosystems;
7. Acid rains increase the leaching of nutrient cations from the root zone of plants;
8. Acid precipitation also increases the solubility (and therefore the toxicity of metal in soil such as Al, Pb, tnd Hg.

Simulated "rain" acidified with sulfuric acid has been reported to:

1. induce direct injury to foliage of pines, birch, and mosses;
2. induce symptoms similar to those caused by certain other pollutants and biotic pathogens;
3. induce poorer germination of spruce seeds;
4. accelerate leaching of nutrients from foliage and from soil;
5. inhibit decomposition of leaf litter from the forest floor;
6. increase erosion of epicuticular waxes on oak and bean leaves;
7. decrease uptake of nitrogen by endomycorrhizae of sweetgum seedlings;
8. inhibit reproduction of root-knot nematodes;
9. inhibit development of bean rust and production of telia by the oak-leaf-rust fungus, *Cronartum fusiforme;*
10. inhibit or stimulate development of halo blight in bean seedlings depending on the time in the disease cycle during which the simulated "rain" was applied;
11. inhibit modulation and fixation of nitrogen by *Rhizobium* in bean and soybean seedlings.

As yet unknown constituents of precipitation have been shown to induce "russetting"—brown blemishes that cause degrade in the marketing of Yellow Delicious apples (Kender, personal communication).

With the exception of this latter effect on apples, the possible economic consequences of the various biological effects listed above are not known. Nevertheless, the variety of biological influences that have been observed suggests that: (1) much more research is needed to evaluate the ecological and possible economic influences of changes in the acidity and other chemical properties of precipitation; and (2) a well coordinated network to measure long-term changes in the chemistry of air and precipitation is needed in rural and urban areas throughout North America.

Based on a general analysis of effects reported to date, Heck et al. offered the following generalizations about the relative vulnerability of various organisms and ecosystems to acid precipitation: (1) fresh water fish are more vulnerable to acute acid shock than fresh water vegetation; (2) aquatic vegetation is more vulnerable than terrestrial vegetation; (3) herbaceous vegetation is more vulnerable than woody vegetation; (4) plants growing in recently formed sandy soils or glacial outwash areas are more vulnerable than plants growing in well-buffered soils of high clay content and consequently large base exchange capacity; (5) reproductive stages are more vulnerable than vegetative stages; (6) plants growing in natural ecosystems are more vulnerable than plants growing in agroecosystems where liming and other fertilization practice are common; (7) coniferous forests are more vulnerable than hardwood forests; and (8) plants growing in regions of high rainfall are more vulnerable than desert plants.

DEVELOPMENT OF A NATIONAL ATMOSPHERIC DEPOSITION PROGRAM FOR THE UNITED STATES

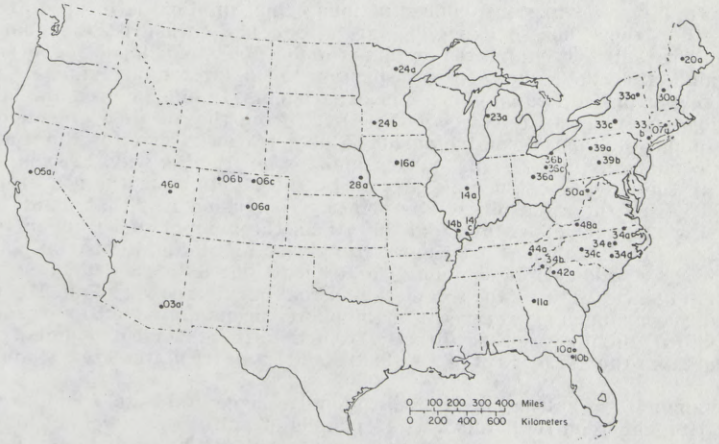
In 1975 the National Academy of Sciences Committee on Atmospheric Sciences published its report on Atmospheric Chemistry: Problems and Scope. In May of 1975, a workshop to define future needs for research on acid precipitation was held immediately following the First International Symposium on Acid Precipitation and the Forest Ecosystem. The recommendations of this workshop were published By Dochinger and Seliga. In May 1977 the Director of the Norwegian Special Project on Acid Precipitation—Effects on Forests and Fish provided an updated analysis of research needs on acid precipitation as perceived from the standpoint of knowledge of acid precipitation effects in Scandinavia. In September 1978, the Federal Interagency Advisory Committee on Water Data completed its report on "Research and Monitoring of Chemistry in the United States: Present Status and Future Needs." In September 1977, the congressionally mandated "Committee of Nine" responsible for regional research in the Agricultural Experiment Stations of the United States approved plans for establishment of a long term interagency research project designated NC–141—"Chemical Changes in Atmospheric Deposition and Effects on Agricultural and Forested Land Surface Waters in the United States." In March of 1978, the Fish and Wildlife Service published their extensive analysis of impacts of coal-fired power plants (including acid precipitation) on fish, wildlife, and their habitats. In November 1978, the name of the NC–141 program was changed to the National Atmospheric Deposition Program (NADP) and in December 1978, a subcommittee of NADP completed a report to the President's Council on Environmental Quality on "A National Program to Assess the Problem of Atmospheric Deposition (Acid Rain)" in the United States.

In each of these major studies, the needs for action to increase research on the changing chemistry of precipitation and its ecological effects were described. A remarkable degree of similarity in research recommendations is evident in all of these reports: (1) establish a permanent network to continuously monitor changes in the chemistry of precipitation and (2) coordinate this long-term monitoring program with research to determine the sources, transport, and transformation of pollutants; the meteorology of their dispersal and deposition; and the nature and magnitude of their ecological effects on agricultural land, forested land, range land, urban lands, and aquatic ecosystems.

An adequate program of monitoring and research should ideally include the various State Agricultural Experiment Stations, the regional Forest Experiment Stations of the Forest Service and the Agricultural Research Division of the Department of Agriculture, pertinent units of the United States Geological Survey, the Department of Energy, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Tennessee Valley Authority, the National Center for Atmospheric Research, the National Science Foundation and the National Aeronautic and Space Administration. An effective program will also require the interest and expertise of many scientists in a diverse array of publically and privately supported colleges and universities in the United States and Canada.

The design for such integrated, multinational, multidisciplinary, and multiagency program of research and monitoring has been developed. It should include each of the following elements: (1) quantitative analysis of emissions, chemical transformations and transport and deposition processes; (2) measurement of spatial and temporal trends in atmospheric deposition in various regions of North America; (3) analysis of the effects of atmospheric deposition on water quality, vegetation, soils, fish, microorganisms, and simple synthetic ecosystems; (4) calibrated watershed studies to provide an understanding of the chemical linkages between the atmosphere and both terrestrial and aquatic natural ecosystems; and (5) economic assessment and criteria development.

As Galloway and his colleagues have emphasized: "The time has come to stop talking and to implement a comprehensive and well coordinated program of research and monitoring. The United States already lags well behind other nations (including Canada, Norway, and Sweden) despite the severe threat posed by acid precipitation to large areas of this country."



Collection sites of the National Atmospheric Deposition Program - June 1979

[From Science, vol. 205, July 27, 1979]

SO_2 Pollution May Be Good for Plants

As man has reduced the amount of sulfur applied as fertilizer, sulfur-starved plants have adapted by extracting it from the air

Agricultural crops throughout the United States have become dependent on air pollution, according to J. C. Noggle of the Tennessee Valley Authority (TVA). Without their daily dose of sulfur compounds from the atmosphere, he says,

many common agricultural species would be markedly less productive. And if sulfur emission from coal-burning power plants and other facilities are curbed by new pollution abatement procedures, he contends, the plants' withdrawal symptoms could reduce the total value of crops in the Tennessee Valley by more than $300 million per year unless steps are taken to incorporate sulfur compounds into fertilizers.

Atmosphereic sulfur dioxide is, of course, toxic to plants above certain concentrations. Experiments at TVA and other laboratories have shown that exposure to as little as 0.5 part per million for 3 hours can cause visible injury to the foliage of sensitive vegetation. The importance of such damage is still a matter of some dispute, but it is clear that exposure to higher concentrations for longer periods of time can stunt plant growth. The toxicity is believed to be due to the accumulation of either sulfur trioxide or sulfates within plant tissues. Acid rain, produced when relatively high concentrations of sulfur dioxide and sulfates are washed out of the atmosphere by rain, damages forests, crops, and even fish. But at concentrations below those at which toxicity develops, sulfur in the air can apparently be beneficial to plants. The importance of this pollutant to plants has arisen from a combination of technological changes in farming and the adapta bility of plants.

Sulfur, says Noggle, a plant nutritionist, is the fourth most important plant nutrient, ranking behind only nitrogen, phosphorus, and potassium. It has a major role in the synthesis of both proteins and chlorophyll. Historically, plants received more than adequate amounts of sulfur from the degradation of manure and other organic matter in the soil. Later, farmers shifted to fertilization with ammonium sulfate, potassium sulfate, and superphosphates, all of which supplied sufficient quantities of sulfur. Since the 1950's, though, the trend has been toward fertilizers with high nitrogen, phosphorus, and potassium contents, but little or no sulfur. While farmers have been reducing the amount of sulfur applied to their fields, however, power plants have been burning increased amounts of sulfur-containing fuels. Many types of plants have apparently compensated for the decreased quantity of sulfur in the soil by increasing their intake of sulfur dioxide and hydrogen sulfide from the air.

In the early 1950's, Maurice Fried, now with the International Atomic Energy Agency, used isotopically labeled sulfur dioxide to show that plants can absorb the gas directly from the atmosphere and incorporate it into organic compounds in the plant tissues. Several other investigators have subsequently demonstrated that plants exposed to small concentrations of sulfur dioxide incorporate more sulfur than those not so exposed. But no one had measured the amount of atmospheric sulfur accumulated by plants under field conditions, Noggle says, or determined the importance of the absorption to the growth of plants.

Noggle performed two main types of experiments. In one, he used an elaborate filtration apparatus to remove all the sulfur from the air in a greenhouse. In the second, he used radioactive sulfur-35 as a tracer to monitor the uptake of sulfur compounds in soybeans, cotton, and fescue. In this way, he was able to separate the amount of sulfur taken up by the plants from the soil from that absorbed from the atmosphere. His primary conclusion was that plants absorb increasing amounts of sulfur from the air as the amount of sulfur in the soil decreases. Plants grown at locations distant from urban and industrial pollution, furthermore, produced less biomass and accumulated less sulfur than plants grown in identical low-sulfur soil close to a coal-burning power plant. His results showed that as much as 40 percent of the plants' accumulated sulfur was derived from sulfur dioxide absorbed directly from the air. Sulfur compounds that are washed from the air by rain or that settle out as particulates are an additional source.

The amounts of sulfur involved can be quite large. Cabbage, turnips, alfalfa, and cotton can require as much as 45 pounds of sulfur per acre (40 kilograms per hectare) per year, while corn and wheat can require as little as 11 pounds per acre (10 kilograms per hectare). Forests require even less. Calculations show, Noggle says, that coal-burning plants in the Tennessee Valley are emitting an amount of sulfur that is roughly equivalent to the amount required by crops in the region. If the output of sulfur is reduced by installation of emission controls, he argues, sulfur supply in the soils will be a limiting factor in crop growth. Cotton will be the first to be affected, but even those crops with relatively low sulfur requirements will eventually feel the pinch. After a period of several years, during which output would decrease slowly unless additional sulfur is added to the soil, crop production could decrease by a minimum of 10 percent, which

amounts to about $306.8 million per year in the seven Tennessee Valley states. Application of sufficient amounts of sulfur to maintain present crop yields could increase fertilizer bills in the region by $6.7 million per year, he calculates.

Noggle makes it clear that he does not intend that his research be used as part of the argument against cleaning up emissions from TVA's own plants and from others in the area. He does think it important, though, that the cost of supplying additional fertilizer be considered in estimating the costs of the cleanup. It is also crucial, he says, that farmers in the region be alerted to the need for sulfur fertilizers before crop production falls off significantly and earnings drop. If crops in the region do not get their fix, he says, farmers could find themselves in one.—THOMAS H. MAUGH II

Mr. BROWN. Please continue.

Professor COWLING. Attached to my testimony is a document that several of us in the national atmospheric deposition program developed for the CEQ. That report has been provided to your staff and for your personal examination as well.

Mr. BROWN. I appreciate that. We will put it in the committee's files.

Professor COWLING. If you look at page 2 of my written testimony there is a major point that I should like to stress with a brief additional comment: Acid rain is becoming a dominant feature of man-induced change in the chemical climate of the Earth. But the increasing acidity of rain is only part of the changing chemistry of precipitation, dry particulate matter, aerosols, and gases. The only other major impact of our pollution on the climate of the Earth that we observe today is the so-called CO_2 problem.

The increasing acidity of rain should be understood as a part of the general changes that are taking place in the chemical climate of the Earth. These changes include four major elements: In the chemistry of precipitation, chemistry of atmosphere aerosols, the chemistry of dry particulate matter, and the chemistry of gases.

Recent research has demonstrated that atmospheric deposits of all four types contain both beneficial nutrient elements and injurious substances that can affect the growth of plants both positively and negatively.

Since plants can take up nutrients through their leaves as well as through their roots, the emissions from combustion of fossil fuels can be beneficial to plants under certain circumstances but also detrimental to plants under other circumstances.

Mr. BROWN. I have a copy of that article which is entitled SO_2 pollution may be good for plants. I suppose you saw that article.

Professor COWLING. I have it with me.

Mr. BROWN. We will also put that in the committee files.

Professor COWLING. The point made in that paper must be understood as part of the truth. Forest trees do indeed derive a substantial part of their total nutrients requirements from atmospheric deposition. Thus, it is true that man is augmenting the supply of both beneficial substances and injurious substances in the atmosphere. The fact is another part of the array of factors that Jay addressed in his testimony. Rational regulation of air quality must involve a weighing of both the beneficial and the detrimental effects of substances in the air.

Now, the same pollutant, SO_2. At low concentrations this pollutant can be absorbed by plants and incorporated into the protein of those plants. In this way it helps the plant grow. And yet, at a higher concentration, on the very same day, the very same molecule may enter

the very same leaf and destroy the metabolic capacity of the very same cells that took it up earlier in the day and used it as a nutrient.

We must come to understand the basic physiology of uptake of substances from the atmosphere. And we must recognize that not everything in the air is bad.

It is also important to realize how different plants and animals and ecosystems are in their susceptibility, in their tolerance, and in their adaptability to changes in atmospheric deposition.

Injury to plants, or animals, or whole ecosystem is most likely when rapid changes take place in the chemical climate—especially when those changes correspond with a vulnerable life form, or a vulnerable stage. It is very clear that increasing acidity of precipitation has caused much damage to aquatic ecosystems both in Europe and North America. It has also been shown experimentally that simulated rain that has been acidified artifically causes leaching of nutrients from soil and causes both direct and indirect injury to plants. And yet, with rare exceptions, we have only limited data about the economic impact of acid precipitation upon terresterial plants or terresterial ecosystems.

Now, that is all that I should like to say by way of reference to the written testimony but I would like to address the questions that were a part of the hearing charter: How and to what extent is agricultural production threatened by acid rain?

First let me say a few words about how acid precipitation affects agriculture and forest production. First of all, acid precipitation accelerates the erosion of the protective waxes that cover the leaves of all plants. Erosion of these waxes has the potential of increasing the susceptibility to drought of all plants in which wax erosion is accelerated.

Second, acid precipitation can accelerate the natural processes of acidication of soils and thus increases the amounts of lime that must be applied to agricultural soils in order to maintain a pH-balance that is favorable for rapid plant growth.

Third, acid precipitation can inhibit the formation of nitrogen fixing nodules on the roots of leguminous plants such as soybeans. This will have the effect of increasing our dependence on energy-requiring fertilization practices.

Fourth, acid precipitation can accelerate the leaching of beneficial nutrient elements from leaves and from leaves and from soils into the ground water below the root zone so that the plants cannot reach the nutrients.

Fifth, acid precipitation can predispose plants to diseases induced by fungi, bacteria, and other disease-reducing agents.

Now, let us deal with the second part of that question. To what extent do these various effects occur and how important are they?

Except in the case of the rusting of Yellow Delicious apples, which is a serious problem to growers in various States we simply do not know the extent of damage to crops by acid precipitation and other types of atmospheric deposition. We know a lot about the biology but we do not know the magnitude of their impact in nature. Dr. Taylor spoke about that problem of these effects which can be demonstrated in controlled experiments in his testimony. Another thing that he mentioned is the evidence for synergistic interactions among pollutants. I think this has very important implications for regulatory policy.

Synergistic interactions among pollutants have been detected in numerous cases and may also occur in the case of acid precipitation. Despite the scientific evidence for synergistic interactions, among pollutants essentially all air pollution regulations deal with the concentration of only a single pollutant. Such regulations are based upon a false assumption. The impacts of pollutants cannot be regulated by dealing with pollutants one at a time.

It is necessary that we understand that synergistic interactions occur and take this into account in the design of regulations.

Now, the second question on the hearing charter is: "What more do we need to know to make sound judgments about setting air quality standards that will protect agriculture?"

The people of the United States are fairly well convinced that air pollution is bad for our health. But we as a nation, are not yet a nation adequately conscious that air pollution is bad for the health of the cosystems on which our good life depends.

It is interesting to compare the attitudes of Canadians and Europeans with Americans in this respect. Air quality standards in the United States are primarily related to effects on human health much greater public awareness of ecological effects of air pollutants on ecosystems exists both in Canada and in Europe.

In answer to the question what more do we need to know—we need to know almost everything. We have much to learn about the impacts that occur in foresting and in agriculture—both in a real economic sense and in a real ecosystem sense.

Most of the experimentation that has been done to date has been done by exposing plants to single pollutants. Some trials with multipollutants have been done. But in general, our knowledge is provisional and incomplete. This is the thing that Dr. Taylor spoke about. We need to have a much larger research effort designed to understand impacts upon ecosystems as such—the complex groups of organisms, including the microorganisms in the soil that Dr. Taylor spoke about.

We need to recognize that the investments that are necessary in research must extend beyond the toxic gases and that must include the aerosol particles, precipitation, and particulate matter.

As you are probably aware, the CEQ has recommended that there should be created a multiagency, coordinated program to achieve the kind of effects of research and the kind of monitoring of atmospheric deposition that needs to be done.

On page 5 of the CEQ report which you have, or will have, you will find a suggested budget for what we believe is an adequate program, considering the scope of the problem.

As part of testimony today, I should like to say thanks again to those of the Congress and your staff who have shown such a direct interest in the national atmospheric deposition program. It is an enormous challenge to create a program that emphasizes effects research in a broad sense, including precipitation and the deposition of dry particulate matter as well as gases. In the last several months there has been a substantial increase in the willingness of Government agencies to work together. I know you have that on your mind a good deal, Mr. Brown, and I remember your conversation about that at a dinner table at the National Academy of Sciences a few months ago.

In that connection, please look at the map which was the cover sheet of my written testimony. There you will see where the sites are located

that are now affiliated with the national atmospheric program. In certain parts of the country, we now have adequate coverage. In other parts of the country, we have totally inadequate coverage.

We hope we can succeed in stimulating interest in the States that are not now participating. One of the things that would help immensely is further interest on the part of the Congress in the development of interagency consciousness. It is obvious that no one agency can do the job alone. It is beyond the competence of every single agency that is involved with this problem. Just think of all the agencies that have reason to be concerned about atmospheric deposition. The U.S. Geological Survey is responsible for drinking water quality; the Fish and Wildlife Service is responsible for fish populations in our country; the Department of Agriculture is responsible to provide food and fiber for all of us; the National Park Service is responsible for the attractiveness of our national parks; the EPA has the general charter for environmental protection; the National Oceanic and Atmospheric Administration has the meteorological competence that is needed; the Forest Service and the Bureau of Land Management have responsibility for the forests and for rangelands of this country. In recent months we have seen a significant increase in willingness on the part of these agencies to work together; to acknowledge the need for expertise of the other agencies; to form a truly cooperative interagency effort; to participate as equal partners in this national atmospheric deposition program which was developed originally as a regional project among the State agricultural experiment stations that are affiliated with the Department of Agriculture.

At present, this program is funded in an awkward but still effective voluntary way. It is not easy to get 26 different agricultural experiment station directors and their scientists agree to to do exactly the same thing. Something more than our present shoestring support and coordination system will be necessary to make the monitoring system more complete and durable. It is especially important to have associated with that monitoring effort a significant program of effects research.

Mr. Brown, it is impossible to separate these two things. It is not possible to do useful effects research without adequate monitoring data; it is also impossible to do adequate monitoring without a good understanding of the nature of the effects of the atmospheric deposition.

In closing, I should like to echo the same idea, the same refrain that Jay and Cliff and Congressman Jeffords said by reading a statement on page 9 of my written testimony. It is essentially the same thing as Jay's last statement:

> If the United States is to so greatly augment the amounts of substance dispersed in the atmosphere and deposited into the biosphere of the earth, it is essential that we should measure the amount and chemical form of the deposited matter and understand the biological consequences of that disposition in our country and abroad.
>
> Regrettably, our understanding of these processes in North America is very fragmentary. Fortunately, however, more tensive measurements of atmospheric deposition and its biological consequences have been made in Europe where an atmospheric deposition network has been maintained since the late 1940's.

Thank you, very much.

Mr. Brown. Thank you, Professor Cowling. Your statement is not only inclusive, factual, and pertinent but it is inspirational and it

serves as a needed reminder that we need to elevate our priority of attention to this matter so that we can get a little faster action than we have over the last several years.

Let me say that I am not unhappy with what has been done. I think everything that you have pointed out is necessary and constructive, but it is not yet sized to the magnitude of the task.

Professor COWLING. That is correct.

Mr. BROWN. Just by way of additional comment, I might point out that we are again experimenting with these sorts of multiagency cooperative projects and this committee has initiated several, including the earthquake hazard program and they have similar programs in that they require this kind of loosely knit networking kind of approach to a major problem.

While we are gaining this experience there has been some increase in the level of awareness of the importance of the problem that you have discussed and there has also been technological progress in the sense of improved and more economical instrumentation for carrying out the kind of measurements that are needed; better understanding of the processes; the revolution in electronics is giving us the capability to store and transmit data more effectively and more cheaply than we have before.

These things I am sure will come to a head hopefully in the near future. Most of these kinds of ideas require several years to determine or develop any major legislative development but I am inclined to feel we have reached the point where we can persuade a sufficient number of Members of the Congress of the importance of this and to move ahead.

As I said, your comments remind us of the importance of going ahead.

Gentleman, I would like to pursue a number of lines of questioning, but I am afraid, unfortunately, that the demands on your time and mine will preclude that.

I would like to ask if we could submit any necessary questions to you in writing and I think the chairman already mentioned that and I would like to apologize for our lack of proper timing on this so we would have more opportunity to question you, but I am sure you understand that.

Just to conclude this hearing this morning at this point, I thank you again for your very excellent contributions to the work of the two subcommittees that will be involved with this.

Again, thank you, very much.

The subcommittees will be in recess until 2 o'clock this afternoon when our subject will be Land Resources, Soil Erosion, and Non-Point Source Pollution and Ed Jones will chair that particular session.

Thanks again, gentlemen.

[Whereupon, at 12:45 p.m., the subcommittees recessed, to reconvene again at 2 p.m. of the same day.]

AFTERNOON SESSION

The subcommittees met, pursuant to recess, at 2 p.m. in room 2318, Rayburn House Office Building, Hon. Jerome Ambro, presiding.

Mr. AMBRO. I would like to open the last segment of these hearings.

I apologize as did Dr. Marceau by telling you that Mr. Brown, who was going to chair these hearings for Mr. Jones is on the floor, we are

in the process of a most heated debate on the Clinch Breeder reactor which emanates from a bill, a portion of which this Committee on Science and Technology has developed.

Mr. Jones, as I understand it, is in markup, in conference on food stamps.

One of the members on one of the subcommittees has kindly consented to come over and chair this segment for me, and he will be here shortly, as will Mr. Brown, who is up now on the floor debating Clinch River, so we are fond of saying you now know what Jack Kennedy characterized Washington as a city of southern efficiency and northern charm.

We apologize to the panelists. We will revert back to the format that we had yesterday as opposed to that which we had this morning, and call up each of the witnesses separately and ask them to withdraw, and have the next witness come up, and at the end of the testimony of all of the witnesses, ask them all to come back as a panel for the purpose of answering questions, so I would like first to call up Dr. John F. Timmons, Professor of Economics of the Iowa State University, for an overview of land resources, soil erosion and nonpoint source pollution.

While you are getting seated, Dr. Timmons, I would like to recognize Jimmie Budd of the American Society of Agricultural Engineers, for the purpose of presenting us with a report which we will install in the record.

Mr. BUDD. Thank you, Mr. Chairman.

I am Jimmie Budd, executive vice president of the American Society of Technical Engineers, whose members work in connection with agriculture.

Included among our members are agricultural engineers employed in industry, colleges, universities, government and private practice.

I am here today to present for the record this report prepared at the request of Chairman Brown relating to agriculture and environment.

The report was developed by an ad hoc committee on the American Society of Engineers and presents a consensus of that committee's membership.

We anticipate the report will also be presented to the board of directors of the society for possible adoption as a policy statement of this society as a whole.

Mr. Chairman, we in the American Society of Agricultural Engineers are pleased to have been invited to make available to this committee this information and expertise of our specialization on this subject.

We hope the information we have collected will help you and your effort to protect and preserve the productivity of American agriculture, as well as our Nation's environment.

Please call on us again, to provide further information, and we are happy to assist you in this all important task.

Mr. AMBRO. For Chairman Brown and the other subcommittees and myself, I appreciate it, and I thank you, and we will include the entire report in the record.

Mr. BUDD. Thank you.

[The report mentioned above appears in the appendix, page 448.]

Mr. AMBRO. Professor Timmons, as I say to all others, we will include all of your testimony in total in the record, and you may proceed in any way you feel most proper.

[The prepared statement of Dr. Timmons follows:]

TESTIMONY ON LAND RESOURCES, SOIL EROSION AND NON-POINT SOURCE POLLUTION: "AN OVERVIEW" BY DR. JOHN F. TIMMONS, PROFESSOR OF ECONOMICS, AND CHARLES F. CURTISS, DISTINGUISHED PROFESSOR OF AGRICULTURE, IOWA STATE UNIVERSITY, AMES, IOWA

Soil erosion is a double bladed sword which both reduces productivity of our cropland and pollutes our water courses and air. Both of these effects of soil erosion constitute serious problems confronting our Nation and are demanding solutions in the national interest. Currently and prospectively, soil erosion appears to be accelerating, thus worsening its adverse effects on agricultural productivity and environmental quality. There is little question about the need and urgency for controlling soil erosion. There remains many questions regarding (1) desired levels of permissible soil loss and of environmental quality, (2) precise causes of soil erosion and (3) how these causal factors can be modified in bringing soil erosion losses down to permissible levels using acceptable means.

NATURE AND SEVERITY OF SOIL EROSION

The nature of soil erosion can become better understood through contrast and comparison of soil and petroleum, two of our most important natural resources. Although petroleum presently is generating serious concerns and much debate, the use and misuse of soils are of greater long run concern to this Nation's future security and welfare. Soil erosion is deserving of much more understanding, debate, and action than it now receives.

Erosion of soil is somewhat analogous to the extraction of petroleum. Both soil and petroleum are important natural resources. Both were formed by geological processes over long periods of time. Through erosion, our soil is being exported in the form of food and feed grains similarly to petroleum exports from OPEC countries. Through erosion, soil becomes an exhaustible nonrenewable natural resource as is petroleum.

Beyond these similarities, soil and petroleum are very different. Petroleum currently provides people with their principal source of energy, but viewed in the total range of human experience, petroleum is destined to a brief and passing epoch. On the other hand, soil has always been, is now, and is likely to remain the major source of human sustenance. Petroleum is both a resource and a product while soil is a natural resource which creates food as one of its products. People cannot use petroleum's product of energy without exhausting the petroleum resource. But people can gain and consume the product of food from soil without exhausting the soil resource.

Unlike petroleum (and the entire fossil fuel energy base) which is exhaustible but nonrenewable, our soil resource base for food is exhaustible but can be made renewable for the most part if, and only if, the soil is used and managed carefully. This we are not now doing.

Recent food and feed grain demands (since 1972) for agricultural products are exacting serious soil and water quality losses through erosion and sedimentation of water courses. Thus, in effect we are exporting our soil, water and water quality in the form of food and feed grain exports.

CURRENT AND PROSPECTIVE SOIL EROSION LOSSES

Scientists, through their research results, are warning our citizens and public officials of this Nation that soil erosion losses are now excessive and increasing. Our soil erosion studies conducted periodically since 1947 in Western Iowa (Ida-Monona-Hamburg Soil Association), reveal that annual soil loss in tons per acre per year, decreased from 21.1 in 1949[1] to 19.5 in 1952,[2] and to 14.1 in

[1] John C. Frey, Some Obstacles to Soil Erosion Control in Western Iowa. Iowa Agriculture Experiment Station Research Bulletin 391. 1952.

[2] R. Burnell Held and John F. Timmons, Soil Erosion Control in Process in Western Iowa. Iowa Agriculture and Home Economics Experiment Station Research Bulletin 460. 1958.

1957.[3] However, in the early 1970's, annual soil losses reversed their downward trend and increased to 17.2 tons per acre per year in 1974,[4] a 22 percent increase compared to 1957.

Looking ahead, we have estimated soil erosion losses resulting from future increased agricultural production between a base period, 1969–1971, and 1985 in the 12 Corn Belt states under two future scenarios.[5] Scenario I which assumes continuation of historical trends, results in a 39 percent increase in soil erosion losses associated with a 17 percent increase in planted crops. These estimated soil losses vary from 68 percent in Iowa to 8 percent in Kansas. Scenario II featuring increased production because of higher exports, results in a 72 percent increase in soil erosion associated with a 29 percent increase in planted crop acres in the 12 Corn Belt states. The soil loss increases in this estimate vary from 106 percent in Iowa to 40 percent in Illinois.

These and other studies throughout the Nation demonstrate the damaging effects of soil erosion upon future productivity of U.S. agriculture and the correlative pollution of the Nation's watercourses and airsheds.

The need for taking action to reduce soil erosion losses appears imperative and well documented. However, the precise nature of actions to be taken remains less clear and debatable. Future action must necessarily be directed toward factors responsible for soil erosion losses as a basis for fashioning appropriate remedies.

CAUSES OF SOIL EROSION

Physically, soil erosion is caused by the natural forces of water and wind. Physically, the remedies for soil erosion consist of technological practices to lessen the erosion impacts of wind and water upon soil. But we know that the erosion control problem also depends upon the human element in terms of why people are motivated or forced to perform or not to perform soil conserving technological practices.

Therefore, we must search into the actions of people in terms of what they do and what they don't do in using technological practices to reduce soil erosion. More particularly, we must identify and examine reasons for people's actions and inactions in controlling soil erosion.

From our studies of obstacles to soil erosion control, primarily in Western Iowa, I conclude that people are most interested in increasing their net income over their respective planning horizons.[6] This involves minimizing costs and maximizing revenues associated with their production activities in using labor, capital, and land and their choice of technological practices. Compounding this motivation to maximize net income are institutions which affect people's behavior resulting in soil erosion. Such institutions include land tenure (including tenancy), credit, tax and market system.

These studies reveal how these obstacles rooted in institutions affect soil erosion control. Tenants possess short term planning horizons which motivate them to emphasize immediate income. Also, their rental arrangements do not usually encourage soil conservation investments with a long term payoff. Small size of farm frequently forces people to press the land for a living regardless of effects upon soil erosion. Landlords who are interested in short run returns on investment usually are not motivated to make long term soil conservation investments.

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[3] Melvin G. Blase and John F. Timmons, Soil Erosion Control in Western Iowa: Progress and Problems. Iowa Agriculture and Home Economics Experiment Station Research Bulletin 498, 1961; and Melvin G. Blase and John F. Timmons, Soil Erosion Control: Problems and Progress. Journal of Soil and Water Conservation, vol. 16, No. 4, July–August 1961.

[4] Wade Rodwell Hauser III, Soil Erosion Control in Western Iowa. Unpublished Thesis. Iowa State University. 1976.

[5] Dennis C. Cory and John F. Timmons, "Responsiveness of Soil Erosion Losses in the Corn Belt to Increased Demands for Agricultural Products." Journal of Soil and Water Conservation. vol. 33 No. 5, September–October 1978.

[6] Wade Rodwell Hauser III, Soil Erosion Control in Western Iowa. Unpublished Thesis. The Graduate College, Iowa State University, 1976. Melvin G. Blase and John F. Timmons, Soil Erosion Control in Western Iowa: Progress and Problems. Iowa Agriculture and Home Economics Experiment Station Research Bulletin 498, 1961. R. Burnell Held and John F. Timmons, Soil Erosion Control in Process in Western Iowa. Iowa Agriculture and Home Economics Experiment Station Research Bulletin 460, 1958. Loyd K. Fischer and John F. Timmons, Progress and Problems in the Iowa Soil Conservation Districts Program: A Pilot Study of the Jasper District. Iowa Agriculture and Home Economics Experiment Station Research Bulletin 466, 1959. John C. Frey, Some Obstacles to Soil Erosion Control in Western Iowa. Iowa Agriculture and Home Economics Experiment Station Research Bulletin 391, 1952. Mervin D. Dougal, E. Robert Baumann and John F. Timmons, Physical and Economic Factors Associated with the Establishment of Stream Water Quality Standards. Vols. 1 and 2. Iowa State University Engineering Research Institute, Ames, 1970.

Pressures of credit and tax payments dictate that sufficient income be generated to meet these obligations regardless of effects on soil erosion.

Frequently, farmers are not convinced that a particular level of soil loss goal, i.e. 5 tons per acre per year, is necessary to maintain soil productivity. Also, individual farmers may not be fully informed on acceptable erosion control technologies or the economic consequences of these practices and investments.

Prices and costs as determined in the market do not always reflect all the costs associated with cropland products. Soil erosion effects on offsite water quality deterioraton are seldom reflected in the costs and prices as determined in the market. Of course, the same is true of offsite benefits. If offsite costs of soil erosion are not included in producer costs or consumer prices, there is little incentive to reduce these excluded costs.

Considerable progress was achieved from the 1940's through the 1960's as evidenced in soil erosion losses estimated above. But serious intransigent obstacles remained.

Soil erosion remains a major factor in non-point pollution of water in terms both of suspended silt and of associated residuals for which silt serves as a transport agent through adsorption and absorption. A major problem in the establishment of water quality levels involves identification and inidence of costs in achieving the levels.[7]

EROSION TOLERANCES AND ENVIRONMENTAL STANDARDS

Some estimated effects of soil erosion on water quality as well as the estimated costs of reducing soil erosion to improve water quality are revealed in our recent studies of the Nishnabotna River Basin in Western Iowa.[8]

Presently, we estimated that about 10,600 mgs. of silt per liter becomes suspended in the water of the river. This estimated amount represents 25 percent of the eroded silt that reaches the river in the form of suspended sediment. This percentage is termed the delivery ratio" [9]

This level of suspended silt resulting from current cropping practices, is much greater than tolerance standards being set by Iowa's Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA).

Effects on farm income caused by direct outlays and reduced income (opportunity costs) from complying with specified water quality standards would range from $1,200 to $12,000 per farm per year, depending upon factor costs, product prices, technologies applied, delivery ratios and other variables. Eventually, these increased costs would be passed to consumers through higher product prices.

Therefore, there exists trade-offs between levels of environmental quality, farm income, consumer prices and volume of crop production. All of these factors should be taken into consideration when establshing enviornmental standards, but they seldom are.

Permitted soil erosion loss limits and environmental non-point pollution limits are becoming established throughout the Nation and are assuming the character of compliance tests for land use. However, present values for erosion tolerances and environmental standards are both provisional and imperfect and require further analysis and testing before being "set in concrete" as the final basis for compliance tests and penalties. In the process of further analysis, trade-offs will be required in terms of productivity and output of cropland and the cost and price of products from cropland.

Soil loss tolerance, termed T values, are based on estimated erosion losses. The T value specifies maximum annual soil loss that can be sustained short of adversely affecting land productivity. The T value is essentially a physical area on-site concept that does not connote economic approbation; nor does it include offsite effects of erosion in terms of what economists term externalities.

Thus, T values require validation in terms of offsite effects as well as productivity, and output, and price and cost effects as well. Results of such valida-

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[7] John F. Timmons, "Identification and Achievement of Environmental Quality Levels in Managing the Use of Natural Resources." Chapter 10 in Economics and Decision Making for Environmental Quality. Florida State University Press, Gainesville, Florida, 1974.

[8] James E. Jacobs and John F. Timmons, "An Economic Analysis of Agricultural Land Use Practice to Control Water Quality." American Journal of Agriculture Economics, vol. 56. No. 4. November 1974. Also, see David Kerry Webb, "Energy Environment and Agricultural Product Interrelationships: A Parametric Linear Programing Case Study of the Nisnabotna River Basin." Unpublished Thesis. Iowa State University, Ames, Iowa.

[9] In the analysis, we varied the delivery ratio from 15 to 30 which demonstrated that results of the analysis were very sensitive to the size of delivery ratio.

tion will probably mean a wider range in T values to reflect offsite effects as well as onsite soil productivity. As T values become policy and program goals, (and some such type of value must be developed) which is happening and is likely to expand in practice, great care must be exercised in their development and use. The forthcoming annual meeting of the Soil Science Society of America in Ft. Collins, Colorado, next month, includes a Symposium on Determinants of Soil Loss Tolerance composed of eleven invited papers prepared by physical and social scientists.

Despite the probability that more is known about setting soil erosion limits than environmental non-point pollution limits (albeit the two are related) policies and programs are proceeding with pollution limits that probably should be considered provisional awaiting further facts and analysis.

Non-point pollution control standards are considerably more complex than soil erosion T values because in addition to T values, pollution control standards must embrace the amounts of suspended sediment and the residuals for which sediment serves as a transport agent in water and possibly air.

BROADER ISSUES AFFECTING SOIL LOSSES

After about five decades of agricultural surpluses and low farm prices, interrupted briefly by events of the World War II period, abrupt and important changes arose in the early 1970s. These changes whose causal roots run deep into the past appear likely to persist well into the future. They bring with them a higher priority for agriculture in the Nation's domestic well being. They also bring stronger public sentiment to maintain a viable and productive agricultural industry. Increased soil erosion with its deteriorating effects upon land productivity and environmental quality is an inherent result of these changes. These effects exacerbate the long term obstacles to soil erosion control discussed earlier.

In 1972 and 1973, a diverse and complex mix of domestic and international developments coalesced which substantially increases the demand for agricultural products and at the same time reduces agriculture's capacity to respond to their demands.

Two sets of development are involved. One set brings increased demand. The other sets limits agriculture's response to these demands.

Among the factors associated with increased demand for agricultural products is increased per capita income in developed and developing countries. Increased per capita income with its effect upon kind and amount of food demanded has derived largely from increased national income and/or improved income distribution within industrial nations and the OPEC countries plus the countries they assist with grants and loans. Of course, increased population as propounded by Malthus and his long line of successors continues to put pressure on demand for agricultural products but per capita income presently appears to be more important. Also, food and feed grain exports to the Communist countries exert important influences on increased demand for agricultural products.

Another demand increasing factor is the need for foreign exchange by the United States to purchase petroleum, vehicles, electronics, textiles and other products which until recently were produced domestically. Agricultural exports are being relied upon increasingly by the U.S. as a matter of public policy to help balance our international payments and have quadrupled in dollars value during the past decade and will most likely exceed $32 billion during 1979. The continuing imbalance of payments, however, puts pressure on the United States to increase further and substantially the export of agricultural products in the national interest of integrity of the dollar and inflation control. At the same time, the continuing excess of imports over exports reduces the value of the dollar in terms of other currencies benefiting from our trade imbalance and therefore adds to the demand of our relatively low priced U.S. agricultural products in terms of these other currencies.

Another set of concommitant factors of natural and man made origins adversely affects the ability of U.S. agriculture to respond to increased demands for its products. One of these factors, weather conditions, particularly inadequate moisture during the middle 1970's, interfered with crops production throughout large sections of the nation and of the world. Second, petroleum based inputs, particularly fertilizers, pesticides and energy, responsible for much of the increase in crop yields in recent decades, are becoming increasingly expensive and scarce. Third, environmental quality constraints, especially non-profit water pollution including suspended silt and chemical residuals, discourage continuation of some of our more productive agricultural practices. Fourth, interferences

with agricultural production emanating from expanding urban and industrial development into productive farming areas frequently conflict with and aggravate crop production practices because of noise, odors, chemicals, and tractor machinery traffic on rural roads affecting recent urban settlers. Fifth, there appears to be a leveling off of per acre productivity increases due to the above factors and possibly due also to inadequate production research of basic and applied nature.

Sixth, reduction in yield increases per acre resulting from the above factors necessitates bringing additional acres into cultivation. These additional acres usually are less productive than current cropland, hence per acre output is less, particularly in terms of net value productivity. Also, additional acres converted to cropland frequently are more fragile and susceptible to water and wind erosion with adverse effects on environmental quality and continuing productivity of soil.

Soil erosion loss increases arising from these two sets of factors are being exacerbated by other deeply imbedded factors discussed earlier which have remained unmitigated during decades. Future behavior of all these factors would appear to bring continuing pressures on our soils with further erosion increasing consequences.

A NOTE ON WHO PAYS THE COSTS FOR SOIL EROSION CONTROL AND ENVIRONMENTAL ENHANCEMENT

Achievement of reduced soil erosion losses and more stringent non-point water quality standards will tend to increase production costs to farmers. Ultimately these costs will be passed on to consumers through higher prices of farm products. This occurs because of the relatively competitive conditions of agricultural production and the production response (reduced) to increasing costs. Price elasticity of demand will tend to place limits on product prices since the demand for cropland products is less than perfectly inelastic.

Thus, agricultural production may be expected to decline in the short run with increasing costs generated through compliance with decreasing soil erosion loss limits and more stringent water quality standards. Concomitantly, consumers will pay relatively higher prices and may experience some shortages of agricultural products. Of course, in the long run, consumers may expect to receive benefits of higher water quality and lower prices for agricultural products than they would have paid with decreased productivity due to continued and increasing soil erosion losses.

Hence, one might reason that consumers pay the costs and realize the effects resulting from either erosion control or the lack of it. This reasoning may be used as an argument for public erosion control payments for erosion control costs beyond what the farmer can pay short of reducing his production. Thus, citizens would participate in paying soil erosion and environmental quality control costs either as taxpayers contributing to public erosion control payments to private land owners and operators or as consumers paying higher food prices caused by declining land productivity and environmental quality without soil erosion control. This policy choice remains to be made.

In the event National stability of the dollar and inflation necessitates increasing exports of agricultural products to improve our balance of payments with other countries, and if such increased exports are depending upon soil erosion control, citizens would share in these benefit stabilities and consequently would be eligible to share in the erosion control costs.

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STATEMENT OF DR. JOHN F. TIMMONS, PROFESSOR OF ECONOMICS, IOWA STATE UNIVERSITY

Dr. TIMMONS. Thank you, Mr. Chairman.

Soil erosion is a double-bladed sword which both reduces productivity of our cropland and pollutes our water courses and air.

As you well know, both of these effects of soil erosion constitute serious problems confronting our Nation and are demanding solutions in the national interest.

Currently and prospectively, soil erosion appears to be accelerating, thus worsening its adverse effects on agricultural productivity and environmental quality.

There is little question about the need and urgency for controlling soil erosion.

However, there remain many questions regarding:

1. Desired levels of permissible soil loss and of environmental quality.

2. Precise causes of soil erosion and,

3. How these causal factors can be modified in bringing soil erosion losses down to permissible levels using acceptable means.

Now, we are getting much tension and discussion on petroleum, which is an important resource in the production of energy. But it seems to me that our soil resource is actually much more important than petroleum in the long run. There are other energy substitutes for petroleum, but we do not know, nor have we experienced, nor do we have any evidence that we will have another resource that will take the place of soil in the production of food.

The nature of soil erosion can become better understood through contrast and comparison of soil and petroleum, two of our most important natural resources.

Although petroleum presently is generating serious concerns and much debate, the use and misuse of soils are of greater longrun concern to this Nation's future security and welfare.

Soil erosion is deserving of much more understanding, debate, and action than it now receives.

Erosion of soil is somewhat analogous to the extraction of petroleum.

Both soil and petroleum are important natural resources.

Both were formed by geological processes over long periods of time.

Through erosion, our soil is being exported in the form of food and feed grains similarly to petroleum exports from OPEC countries.

Through erosion, soil becomes an exhaustible nonrenewable natural resource as is petroleum.

Beyond these similarities, soil and petroleum are very different.

Petroleum currently provides people with their principal source of energy, but viewed in the total range of human experience, petroleum is destined to a brief and passing epoch.

On the other hand, soil has always been, is now, and is likely to remain the major source of human sustenance.

Petroleum is both a resource and a product while soil is a natural resource which creates food as one of its products.

People cannot use petroleum's product of energy without exhausting the petroleum resource.

But people can gain and consume the product of food from soil without exhausting the soil resource.

Unlike petroleum (and the entire fossil fuel energy base) which is exhaustible but nonrenewable, our soil resource base for food is exhaustible but can be made renewable for the most part if and only if the soil is used and managed carefully.

This we are not now doing.

Recent food and feed grain demands, particularly in 1972, for agricultural products are exacting serious soil and water quality losses through erosion and sedimentation of water courses.

Thus, in effect we are exporting our soil, water, and water quality in the form of food and feed grain exports.

Scientists, through their research results, are warning our citizens and public officials of this Nation that soil erosion losses are now excessive and increasing.

Our soil erosion studies conducted periodically since 1947 in western Iowa (Ida-Monona-Hamburg Soil Association), reveal that annual soil loss in tons per acre per year, decreased from 21.1 in 1949 to 19.5 in 1952, and to 14.1 in 1957.

But, in the early 1970's, annual soil losses reversed their downward trend and increased to 17.2 tons per acre per year in 1974, which represents a 22-percent increase compared to 1957.

Looking ahead, we have estimated soil erosion losses resulting from future increased agricultural production between a base period, 1969–71, and 1985 in the 12 Corn Belt States under two future scenarios.

Scenario I which assumes continuation of historical trends, results in a 39-percent increase in soil erosion losses associated with a 17-percent increase in planted crops.

These estimated increases in soil losses vary from 68 percent in Iowa to 8 percent in Kansas.

Scenario II featuring increased production because of higher exports, results in estimates of 72 percent increase in soil erosion, associated with a 29-percent increase in planted crop acres in the 12 Corn Belt States through 1985.

Soil loss increases in this estimate vary from 106 percent in Iowa to 40 percent in Illinois.

Now I think these and other studies throughout the Nation demonstrate the damaging effects of soil erosion upon future productivity of U.S. agriculture and the correlative pollution of the Nation's watercourses and air sheds.

The need for taking action to reduce soil erosion losses appears imperative and well documented.

Future action must necessarily be directed toward factors responsible for soil erosion losses as a basis for fashioning appropirate remedies.

Physically, soil erosion is caused by the natural forces of water and wind.

Physically, the remedies for soil erosion consist of technological practices to lessen the erosion impacts of wind and water upon soil.

But we know that the erosion control problem also depends upon the human element in terms of why people are motivated or forced to perform or not to perform soil conserving technological practices.

Therefore, we must search into the actions of people in terms of what they do and what they don't do in using technological practices to reduce soil erosion.

More particularly, we must identify and examine reasons for people's actions and inactions in controlling soil erosion.

From our studies of obstacles to soil erosion control, primarily in western Iowa, I conclude that people are most interested in increasing their net income over their respective planning horizons.

This involves minimizing costs and maximizing revenues associated with their production activities using their land, labor, capital, and land and their choice of technological practices.

Compounding this motivation to maximize net income are institutions which affect people's behavior resulting in soil erosion.

Such institutions include land tenure (including tenancy), credit, tax, and market systems.

These studies reveal how these obstacles rooted in institutions affect soil erosion control.

Tenants possess short-term planning horizons which motivate them to emphasize immediate income. Also, their rental arrangements do not usually encourage soil conservation investments with a long-term payoff.

Small size of form frequently forces people to press the land for a living regardless of effects upon soil erosion. Landlords who are interested in shortrun returns on investment usually are not motivated to make long-term soil conservation investments.

Pressures of credit and taxpayments dictate that sufficient time be generated to meet these obligations regardless of effects on soil erosion. Frequently, farmers are not convinced that a particular level of soil loss goal—that is, 5 tons per acre per year—is necessary to maintain soil productivity.

Also, individual farmers may not be fully informed on acceptable erosion control technologies or the economic consequences of these practices and investments.

Prices and costs as determined in the market do not always reflect all the costs associated with cropland products.

Soil erosion effects on offsite water quality deterioration are seldom reflected in the costs and prices as determined in the market.

Of course, the same is true of offsite benefits.

If offsite costs of soil erosion are not included in producer costs or consumer prices, there is little incentive to reduce these excluded costs.

Considerable progress was achieved from the 1940's through the 1960's as evidence in soil erosion losses estimated above. But serious intransigent obstacles remained.

Soil erosion remains a major factor in nonpoint pollution of water in terms both of suspended silt and of associated residuals for which silt serves as a transport agent through adsorption and absorption.

A major problem in the establishment of water quality levels involves identification and incidence of costs in achieving the levels.

Some estimated effects of soil erosion on water quality as well as the estimated costs of reducing soil erosion to improve water quality are revealed in our recent studies of the Nishnabotna River Basin in western Iowa.

Presently, we estimate that about 10,600 mgs of silt per liter become suspended in the water of the river. This estimated amount represents 25 percent of the eroded silt that reaches the river in the form of suspended sediment. This percentage is termed the "delivery ration."

This level of suspended silt resulting from current cropping practices, is much greater than tolerance standards being set by Iowa's Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA).

Effects on farm income caused by direct outlays and reduced income (opportunity costs) from complying with specified water quality standards would range from $1,200 to $12,000 per farm per year, depending upon factor costs, product prices, technologies applied, delivery rations, and other variables.

Eventually, these increased costs would be passed to consumers through higher product prices.

Therefore, there exists tradeoffs between levels of environmental quality, farm income, consumer prices, and volume of crop production.

All of these factors should be taken into consideration when establishing environmental standards, but they seldom are.

Permitted soil erosion loss limits and environmental nonpoint pollution limits are becoming established throughout the Nation and are assuming the character of compliance tests for land use.

However, present values for erosion tolerances and environmental standards are both provisional and imperfect, and require further analysis and testing before being "set in concrete" as the final basis for compliance tests and for penalties.

Soil loss tolerance, termed "T values," are based on estimated erosion losses. The T value specifies maximum annual soil loss that can be sustained short of adversely affecting land productivity.

Thus, T values require validation in terms of offsite effects as well as productivity, and output, and price and cost effects as well.

Results of such validation will probably mean a wider range in T values to reflect offsite effect as well as onsite soil productivity.

As T values become policy and program goals—and we have to have some kind of value to enable our programs to function, which is happening and is likely to expand in practice—great care must be exercised in their development and use.

The forthcoming annual meeting of the Soil Science Society of American in Fort Collins, Colo., next month, includes a Symposium

on Determinants of Soil Loss Tolerance composed of 11 invited papers prepared by physical and social scientists.

Despite the probability that more is known about setting soil erosion limits than environmental nonpoint pollution limits (albeit the two are related), policies and programs are proceeding with pollution limits that probably should be considered provisional awaiting further facts and analysis.

Now, there are some broader issues I want to mention before I close with respect to erosion losses.

After about five decades of agricultural surpluses and low farm prices, interrupted briefly by events of the World War II period, abrupt and important changes arose in the early 1970's.

These changes whose casual roots run deep into the past appear likely to persist well into the future. They bring with them a higher priority for agriculture in the Nation's domestic well-being. They also bring stronger public sentiment to maintain a viable and productive agricultural industry.

If this is not done, I would predict the public sentiment will become increasingly stronger.

Increased soil erosion with its deteriorating effects upon land productivity and environmental quality is an inherent result of these charges.

These changes exacerbate the long-term obstacles to soil erosion control mentioned earlier. But these changes also complicate erosion control measures and threaten our agricultural production potential.

In 1972 and 1973, a diverse and complex mix of domestic and international developments coalesced which substantially increases the demand for agricultural products and at the same time reduces agriculture's capacity to respond to these demands.

Two sets of development are involved.

One set brings increased demand.

The second set limits agriculture's response capacity to meet these demands.

Among the major factors associated with increased demand for agricultural products is increased per capita income in developed and developing countries.

This is something we have to realize, the increase in per capita income both domestically and foreignwise is one of the main factors affecting demand. It is not so much the number of people, it is the increase in per capita income.

For example, the United States consumes about one-third of the petroleum resources of the world, and it has only 4 percent of the world's population. This results from per capita purchasing power based on high per capita income. The same reasoning applies to food and other agricultural product demands emanating from other industrial nations and the OPEC countries.

In addition to these two factors from the demand side, also are exports we have been making to the Communist countries, which is a recent phenomenon. Now that Russia has decided they want to develop a protein industry, and they have to have the grains to do that, it means they will have to buy more and more of our feed grains for that purpose.

Another demand increasing factor is the need for foreign exchange by the United States to purchase petroleum, vehicles, electronics,

textiles, and other products which until recently were produced domestically.

Agricultural exports are being relied upon increasingly by the United States as a matter of public policy to help balance our international payments and have quadrupled in dollar value during the past decade and will most likely exceed $32 billion during the current years

Because of the diminishing value of the dollar, these foreign investors are buying land over here, and this certainly applies to food and feed grains.

The continuing imbalance of payments, however, puts pressure on the United States to increase further and substantially the exports of agricultural products in the national interest of achieving integrity of the dollar and inflation control.

At the same time, the continuing excess of imports over exports reduces the value of the dollar in terms of other currencies benefiting from our trade imbalance and therefore adds to the demand of our relatively low prices U.S. agricultural products in terms of these other currencies.

Another set of concommitant factors of natural and man made origins adversely affects the ability of U.S. agriculture to respond to increased demands for its products.

Petroleum based inputs, particularly fertilizers, pesticides and energy, responsible for much of the increase in crop yields in recent decades, are becoming increasingly expensive and scarce.

Environmental quality constraints, especially non-point water pollution including suspended silt and chemical residuals, discourage continuation of some of our more productive agricultural practices.

Interferences with agricultural production emanating from expanding urban and industrial development into productive farming areas frequently conflict with and aggravate crop production practices because of noise, odors, chemicals, and machinery traffic on rural roads affecting recent urban settlers. All of these factors exert pressure on agricultural practices. People moving into rural areas, and then objecting to the odors, or to the dust, or to the noise from machinery, proceed to get ordinances passed that depress the carrying out of top agricultural practices which reduces our agricultural productivity.

Also, there appears to be a leveling off of per-acre productivity increases due to the above factors and possibly due also to inadequate production research of basic and applied nature that would enable agriculture to meet potential world demands.

This could be serious.

We are not getting the rates of increase that we enjoyed two or three decades ago in terms of increased productivity in agriculture. I think we will have to look very carefully in terms of research, whether or not we are doing the kind of applied and basic research we ought to be doing, that will generate the yield increases we are going to need in the 1980's and 1990's, and beyond the turn of the century.

I think all of these factors call for very innovative and complex remedies for soil erosion and production problems.

I think these remedies will be quite different from what we have been interested in and doing in the past, particularly with Govern-

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ment payments that have been used for production practices rather than conservation practices.

Achievement of reduced soil erosion losses and more stringent non-point water quality standards will tend to increase production costs to farmers.

Ultimately these costs will be passed on to consumers through higher prices of farm products.

This occurs because of the relatively competitive conditions of agricultural production and the production response—reduced—to increasing costs.

Price elasticity of demand will tend to place limits on product prices since the demand for agricultural products is less than perfectly inelastic.

Thus, agricultural production may be expected to decline in the short run with increasing costs generated through compliance with decreasing soil erosion loss limits and more stringent water quality standards.

Concomitantly, consumers will pay relatively higher prices and may experience some shortages of agricultural products.

Of course, in the long run, consumers may expect to receive benefits of higher water quality and lower prices for agricultural products than they would have paid with decreased productivity due to continued and increasing soil erosion losses.

Hence, one might reason that consumers pay the costs and realize the effects resulting from either soil erosion control or the lack of it.

This reasoning may be used as an argument for public erosion control payments for erosion control costs beyond what the farmer can pay short of reducing his production.

When we force the farmer to bear costs that are greater than his production, he will go out of production, and this will reduce supply, which means consumers will pay more for their products, and the products will be more scarce, both for export and domestically.

Now, if the U.S. Government really values the stability of the dollar and inflation control that is endangered by our imbalance of payments, then we will probably embark on a more direct policy to increase agricultural products, because that is about the only major group of products that we have that we can export to pay for the increased imports of petroleum, and I might add there are a lot of other resources even more scarce than petroleum, that the United States does not now have that are concentrated in a few other countries.

It would be easy for them to set up a new OPEC-type cartel. We will have to rely on agriculture probably more and more to take care of these imbalances.

If that is the case, it seems to me it is a matter of national interest, and of national security to proceed with the control of soil erosion to maintain the productivity of the agricultural plant so it will continue to serve the Nation in the capacity of firming up our balances of payments.

Thus, citizens would participate in paying soil erosion and environmental quality control costs either as taxpayers contributing to public erosion control payments to private landowners and operators or as consumers paying higher food prices caused by declining land productivity and environmental quality without soil erosion control.

This policy choice remains to be made.

In the event national stability of the dollar and inflation necessitates increasing exports of agricultural products to improve our balance of payments with other countries, and if such increased exports are depending upon soil erosion control, citizens would share in these benefit stabilities and consequently would be eligible to share in the erosion control costs.

Thank you, Mr. Chairman, for the opportunity to testify, and as I understand it, later on we will have the opportunity to answer any questions.

Mr. HANCE [presiding]. Yes.

We will have a panel of all of the witnesses at the conclusion of the testimony, and we will have questions at that time.

Dr. TIMMONS. Thank you.

Mr. HANCE. The next witness is Mr. Norman A. Berg, Associate Administrator of the Soil Conservation Service of the U.S. Department of Agriculture.

Please proceed, Mr. Berg.

STATEMENT OF NORMAN A. BERG, ASSOCIATE ADMINISTRATOR OF THE SOIL CONSERVATION SERVICE OF THE U.S. DEPARTMENT OF AGRICULTURE

Mr. BERG. Thank you Mr. Chairman.

Mr. Chairman, it is a pleasure to appear before this joint committee to discuss a most important issue, "Land and Soil Resources."

I am pleased to join the panel that you have assembled here, because these are distinguished colleagues who have spent many, many years in this particular field.

My particular background, as the Associate Administrator of the Soil Conservation Service, goes back over three decades, and what you are doing here is something that we have been looking forward to.

It is very timely. It is especially timely in that Congress, in 1977, enacted Public Law 95–192, which we refer to as RCA.

The Soil and Water Resources Conservation Act of 1977, calls for a more comprehensive appraisal than has ever been made of the kinds of resources we are talking about today, and looking at what has been done over the past 40 or 50 years. We have incrementally added about 30 authorities for soil and water conservation work in the Department of Agriculture, and one question is whether they can deal with the problems we are talking about here, as we look far into the future.

Our studies project forward 50 years in to the future and it is impossible in the short time we have here to highlight all aspects of the study, but we can touch on those with the highest priority.

Therefore, with your permission. I would request that the material we have prepared be made a part of the record.

Mr. HANCE. Without objection, so ordered.

[The additional documentation appears on p. 247].

Mr. BERG. I am also pleased to represent an agency in the Department of Agriculture that has conservation men and women who are working at the field level, every day of the year, all across this great land, in harmony with the conservation districts of the country, something that I think has been going on longer than in any other Nation

in the world in terms of the cooperative effort of Federal, State and local government working with the private sector.

Conservation districts have in their roles more than 2 million land users as cooperators, and we have helped these land users develop nearly 2 million conservation plans. The people working in the field representing both the Department of Agriculture and the conservation districts, are out doing something about these problems each and every day, and that is gratifying.

We have a large list of accomplishments, and we have made great progress, and if you fly over this country, you can see the results from the air, but there is still an awful lot of work to be done, because it is a big country and conditions keep changing.

Demands on our resources have never been higher, and they continue to escalate, and we are coming close to the limits on some of our resource supplies. This situation is truly testing the will and skill of our decisionmakers to make the proper critical choices for the future.

We are reminded, as you know, during this decade, that the world's population has increased on an average of 72 million people a year, and our country still grows at the rate of nearly 2 million people per year.

We have just recently completed the national resources inventory (NRI) which we started in 1977, as an early step in gathering information in response to the RCA Act.

The inventories were designed to update 10-year old conservation needs and soil erosion estimates and provide data for other purposes including the appraisal which was called for in the RCA.

We also updated some of our data which we gathered in the mid-1970's, related to potential cropland.

We were being pressed by the U.S. Senate Committee on Agriculture, Nutrition, and Forestry to respond to their oversight inquiries. Now that we are implementing the Resources Conservation Act, that will be the way in which we respond to that oversight activity to both Houses.

We also found that the data from the National Resources Inventory is immensely useful for the appraisal, which is a section of the RCA.

This data is also being used for State conservation programing and planning, and by decisionmakers in many agencies beyond the Department of Agriculture. Private industry as well will find current resource information useful.

The inventories are designed to provide statistical data for non-Federal lands in each of the States and the Caribbean area. We have a very well-tested sampling system worked out with Iowa State University in Ames which includes storage and the analysis of the data.

The first phase of the inventory is completed and includes updated data on land capability classes that relate to what we have identified as high quality farmland, land use, conservation needs of the land in flood-prone areas, identification of wetland areas types 3 through 20 as defined in Interior Circular 29, wind erosion in the 10 Plains States, and new information on what is happening to some of our prime farmlands.

The appraisal we are conducting under the RCA will be available in draft form this fall, along with the conservation program that was called for in the act. The draft document will be circulated widely

for public review and comment before it is agreed to in the Department and sent to the President to transmit to Congress.

Some of the data we have gathered on soil quality is going to be very valuable.

For instance, rural land available for agricultural, forestry, and other uses in the United States declined by nearly 37 million acres in the 1967 to 1977 period. Yet the percentage of good, fair, and poor land available remained about the same. We rated the quality of land on the basis of our soil capability classes—44 percent was rated good, 13 percent fair and 43 percent is identified as land that would be poor for most of the agricultural purposes that we are concerned about here.

These lands are valuable for other uses, such as forestry, watershed areas, wildlife habitat, and many others.

Of the total nonfederal rural land, over 400 million acres occurs on level to nearly level topography, and about a billion acres occurs on slopes ranging from gentle to very steep.

Over 260 million acres of these soils have a natural wetness condition, and over 400 million acres have problems of drought, lacking sufficient water during some periods for growing good agricultural, or forestry crops.

Some of these lands are both sloping and wet, while others may be level and droughty. Many of these conditions limit the use of land.

We have a lot of figures and material which we submitted for the record.

About half of the soils of the United States have a high natural fertility. This means that they may be fertile enough for growing crops successfully without applying fertilizers, although yields may be below the potential with fertilizers. Highly fertile soils are abundant in the Great Plains, dry areas of the Mountain States, and the Corn Belt.

There are some serious resource problems associated with the 413-million acre cropland base in the United States:

1. 207 million acres are susceptible to erosion;
2. 40 million acres are affected by stoniness, shallowness, or draughtness;
3. 105 million acres have excess water; and
4. 27 million acres have a climatic limitation.

Many cropland acres have two or more of these problems.

Some 892 million acres of agricultural and forest land need conservation treatment in 1977.

This total did not change significantly over the 10-year period, but the kind of treatment needed—and the kinds of land requiring treatment—did change.

In 1967, 64 percent (272 million acres) of the cropland needed treatment; 58 percent (241 million acres) required treatment in 1977, a decrease of 6 percent for cropland.

Total acres in pastureland and rangeland increased, as did the treatment needs. In 1967, 71 percent (346 million acres) needed treatment; this increased to 75 percent (404 million acres) in 1977.

Surprisingly, the percentage of forest land needing treatment increased from 62 percent to 67 percent in the 10-year period while the total acreage of forest land decreased.

Estimated average annual sheet and rill erosion for all cropland is 4.8 tons per acre. Cropland erosion rates range from less than 1 ton in some States to more than 41 tons per acre for the Caribbean area. Estimates in 1967 showed annual cropland erosion rates of 5.9 tons per acre and a total of 2.6 billion tons of soil eroded. In 1977, the amount was down to 2 billion tons annually.

This bright picture is dimmed by the fact that 22 States, mainly in the central and eastern part of the United States and the Caribbean area, have average annual erosion rates for cropland of 4 tons or more per acre. Seven States and the Caribbean area have erosion rates of more than 8 tons.

Erosion on sloping croplands varies from one to nearly four times their permissible rates. Surprisingly, some nearly level wet soils in the delta region are eroding at above permissible rates.

Pastureland and native pasture in 11 States and the Caribbean area have average annual erosion rates of more than 4 tons per acre. Rangeland erosion rates in five States and the Caribbean area are over 4 tons per acre.

Except for three States and the Caribbean area, erosion rates for forest land are not high; but grazed forest land is eroding three times as much as nongrazed forest land.

These problems have an effect on long-range sustained commodity output, environmental quality, and energy consumption.

Cultivated cropland with soil erosion as the dominant problem averaged 7.8 tons of soil loss per acre in 1977. Some soils averaged losses in excess of 75 tons per acre in the South, 80 tons per acre in the West, and 30 tons in the Northeast and Appalachian States. Overall, 50 percent of the cropland contributed 65 percent of all cropland erosion.

The Great Plains States have a significant problem of wind erosion on cropland.

The most damage usually occurs in eastern Colorado, New Mexico, and west Texas with losses averaging 8.9 tons, 11.5 tons, and 14.9 tons tons per acre per year, respectively.

Twenty-five percent of the Nation's cropland is on wet soils requiring some special treatment for sustained production.

About 175 million acres lie in flood prone areas and have a 1 percent or higher chance of flooding within a given year. About 54 million acres of prime farmland are in flood prone areas and nearly 33 million acres are used for cropland.

One hundred and thirty-five million acres of land in uses other than cropland have high or medium potential for conversion to cropland, if needed. Most of this acreage is currently in pasture or range.

The conversion to cropland could be costly and cause tradeoffs of concern to a quality environment.

Forty million acres have high potential for use as cropland. Just over one-half is prime farmland.

Most high potential land can be converted without special treatment or large investment.

About 95 million acres have only medium potential for use as cropland, of which approximately one-third is prime farmland. Most of this land has one or more soil limitations that must be considered before converting.

The greatest potential for conversion of noncropland areas to cropland exists in the Corn Belt, southern plains, northern plains.

The potential is lowest in the Caribbean area and in the Northeast and Pacific States.

The U.S. Department of Agriculture had the leadership for the study and gathered most of the data but many others were involved, and we hope widespread use will be made of the information.

These will aid local and State governments as well as Federal agencies in many kinds of program decisions that may affect farmlands. The Soil Conservation Service has been preparing countywide and statewide maps showing the location of prime and unique farmlands as well as other farmlands that may be of statewide or local importance.

We already have completed about 400 of these maps, and should have them available by the end of 1985 for about 1,600 counties that have the most pressure on farmlands.

The SCS–NRI shows that the use of the non-Federal land in the United States continues to change, especially as it relates to agricultural production. These shifts, particularly from agriculture to nonagricultural uses, have serious implications for the continued production of food and fiber products needed to meet needs at home and abroad.

Changes in the use of our Nation's lands do result from efforts to stimulate economic development, sustain agricultural and forest production capabilities, produce and conserve energy, provide community services and living space, maintain open space, and preserve the natural environment—our natural life-support system. Each of these uses provides public benefits. They also are interrelated; some compete for the limited supply of suitable and available land while others are complementary.

Well-managed farm and forest lands often play environmentally beneficial roles by assimilating the residues resulting from other economic activities, by serving as buffer zones, and by offering relative environmental stability when compared with some other land uses. They also provide open space, relative freedom from air pollutants, and recreation opportunities, thus enhancing the quality of living for many persons.

Maintaining existing farm and forest helps insure a stable economic base in rural communities.

At the same time, retention of productive farm and forest lands in order to assure adequate supplies of food, fiber, wood, and water means that other natural systems such as forests, grasslands, wetlands, and flood plains can be preserved and improved as natural areas.

Yet U.S. Public policy to hold the best land for agriculture is either absent or not working.

It is the conventional wisdom that agricultural land use conversion is the result of "market forces."

This generalization holds no one responsible and is too simple an answer.

Questions need to be raised in the policy arena:

How serious is the problem?

What is the proper role for the various levels of government?

What changes are needed and where?

Many people have long shared an assumption that the Earth is infinitely generous. The perception of scarcity, now rearing its head, is an unwelcome one; it is transforming relationships among Nations, among regions within countries, and among classes of people.

The demand for food, fiber, and timber from United States production lands is expected to increase to the point where the production capability of the Nation will be tested, although it is not certain when or with what degree of urgency this will occur.

Public interest will be served by maintaining maximum flexibility of options with respect to future land use needs in a changing and uncertain world.

USDA should be concerned with any actions that will diminish the Nation's ability to produce food, fiber, and timber.

[The prepared statement of Mr. Berg, plus a summary of the RCA Process and National Resources Inventory highlights follow:]

STATEMENT OF NORMAN A. BERG, ASSOCIATE ADMINISTRATOR, SOIL CONSERVATION SERVICE

Mr. Chairman, it is a pleasure to appear before this joint committee to discuss a most important issue, "Land and Soil Resources."

It is timely and appropriate that this subject be discussed because the Department of Agriculture is now conducting a major study of our land and water resources and programs for their conservation and protection. This study is being carried out pursuant to the Soil and Water Resources Conservation Act of 1977 (Public Law 95–192), commonly referred to as RCA.

Mr. Chairman, it would be impossible to provide you in these few minutes the total results we expect to come from this major effort called for in the law. I would like to highlight some of our findings and discuss with you the RCA effort and our schedule for bringing this comprehensive report to Congress in 1980.

The RCA process calls for an appraisal of the soil, water, and related resources. This appraisal now being conducted includes the most comprehensive, statistically accurate and reliable inventory and analysis of our Nation's soil and water resources ever made. Our National Resources Inventory (NRI) is one of several data sources used in the study and allows us to take an indepth look at the quality and quantity of soil, water, and related resources of the 1.5 billion acres of privately owned land and 99 million acres of large water areas in the United States and the Caribbean area (excluding Alaska).

Some very interesting things have surfaced during this analysis. Among these are:

1. 614 million (44 percent) of the 1.5 billion acres are comprised of soils suitable for cultivated crops and for a wide range of other uses.
2. 189 million acres (13 percent) are considered to be marginal for cultivated crops because of unfavorable soil properties.
3. 599 million acres (43 percent) consist of soils that are generally not suited for cultivated crops but can be used for pasture, range, woodland, wildlife habitat, or recreation.
4. Areas having the largest acreage of high quality soils for agricultural purposes are the: Corn Belt, 76 percent; Lake States, 58 percent; Northern Plains, 58 percent; and Delta States, 55 percent.

About half of the soils in the United States have high natural fertility. This means that they may be fertile enough for growing crops successfully without applying fertilizers, although yields may be below the potential with fertilizers. Highly fertile soils are found in the Great Plains, dry areas of the Mountain States, and the Corn Belt.

MAJOR PROBLEMS

There are some serious resource problems associated with the 413 million acre cropland base in the United States:

1. 207 million acres are susceptible to erosion,
2. 40 million acres are affected by stoniness or shallowness,
3. 105 million acres have excess water, and
4. 27 million acres have a climatic limitation.

Some acres have two or more of these problems.

These problems have an affect on long range sustained commodity output, environmental quality, and energy consumption.

Cropland with soil erosion as the dominant problem averaged 6.7 tons of soil loss per acre in 1977. Some soils averaged losses in excess of 75 tons per acre in the South, 80 tons per acre in the West, and 30 tons in the Northeast and Appalachian States. Overall, 50 percent of the cropland contributed 65 percent of all cropland erosion.

The Great Plains States have a significant problem of wind erosion on cropland. The most damage usually occurs in eastern Colorado, New Mexico, and Texas with losses averaging 8.9 tons, and 14.9 tons per acre per year, respectively.

Twenty-five percent of the Nation's cropland is on wet soils requiring some special treatment for sustained production. Forty-nine million acres lie in flood-prone areas and have a 1 percent or higher chance of flooding within a given year. About 54 million acres of prime farmland are in flood-prone areas.

POTENTIAL CROPLAND

One hundred thirty-five (135) million acres of land in uses other than cropland have high or medium potential for use if needed as cropland. Most of this acreage is currently in pasture or range. The conversion to cropland could be costly and cause trade-offs of concern to a quality environment.

Forty (40) million acres have high potential for use as cropland. Just over one-half is prime farmland. Most of it can be converted without special treatment or large investment.

About 95 million acres have only medium potential for use as cropland, of which approximately one-third is prime farmland. Most of this land has one or more soil limitations that must be considered before converting.

The greatest potential for conversion of noncropland areas to cropland exists in the Corn Belt, Southern Plains, and the Northern Plains. The potential is lowest in the Caribbean Area and in the Northeast and Pacific States.

PRIME FARMLAND

Farmland classified as prime is land that has the best combination of physical and chemical characteristics for the production of food and fiber and is available for that use, although it may currently be in other uses.

In 1977, there were about 346 million acres of prime farmland in the United States. Most of this land is in the Corn Belt, followed by the Northern Plains, the Lake States, and the Southern Plains.

Two hundred and thirty (230) million acres, or 67 percent of the prime farmland and more than one-half of the total cropland, was cropped in 1977. Of the remainder of prime farmland, 42 million acres (12 percent) are forestland, 40 million acres (11 percent) are native pasture and pastureland, 23 million acres (7 percent) are rangeland, and 11 million acres (3 percent) are farmsteads, farm roads, feedlots, or similar uses.

States using more than 90 percent of their prime farmland for crops include Arizona, Colorado, New Mexico, North Dakota, and Utah. States using less than 50 percent of their prime farmland for crops include Alabama, Connecticut, Florida, Georgia, Maine, Massachusetts, New Jersey, North Carolina, Rhode Island, South Carolina, Tennessee, Texas, Vermont, Virginia, and Wyoming.

From 1967 to 1975, about 8 million acres of prime farmland was lost to other uses. Of this 8 million acre loss, 6.5 million acres were converted to urban and built-up areas and about 1.5 million acres to water areas.

From this and other appraisal data, we are analyzing the capability of the soil and water resources to meet seven broad areas of concern (Potential Problem Areas) :

First: The quality and quantity of soil resources available to meet the food and fiber demands through the year 2030. In this area, we are determining if the present cultivated lands can produce the needed food and fiber with projected technology and appropriate conservation measures.

Is the permanent conversion of agricultural lands to other uses a major concern to the Department and to the Nation? There has been established, in addition to efforts in RCA, an interagency "National Agricultural Land Availability Study." They will make an in depth review of prime and other agricultural lands and report to the President their findings by January 1981. The study will address both agricultural land availability for the future and the allocation of

agricultural lands among competing demands. It will show not only how much land is being lost, but the consequences in terms of having to use less productive lands resulting in more energy usage and possible less yield per acre. It will also show both positive and negative aspects of changing land uses on the well-being and stability of both rural and urban communities as well as its implications for energy and natural resource development.

Second: The ways agricultural, silvicultural, and land conversion activities may be influenced through soil and water conservation programs to help meet State and national water quality objectives. We are examining nonpoint sources of sediment, nutrients, pesticides, animal waste, salinity, despoiled lands, acid rains, and toxic substances in relation to water quality. We are receiving assistance from EPA in this effort.

Third: How can we increase water supply and water conservation through efficient use of water. Our main study here is in the efficiencies needed in irrigation.

Fourth: How we can provide or improve fish and wildlife habitat through a soil and water conservation program. The U.S. Fish and Wildlife Service is assisting us in this study effort.

Fifth: A study of how upstream flood damages can be reduced through use of land treatment, structural, and nonstructural methods.

Sixth: The conservation of energy is one area most prominent at this time. We are examining:

(*a*) Ways of reducing energy consumption on the farms and ranches of the country through reduced or conservation tillage, improved crop drying techniques, control of soil erosion that wastes nutrients and energy, retention of prime agricultural lands, and improved agricultural water management.

(*b*) Ways of generating energy through uses of organic wastes, biomass (including the land and water resource needs for the production of alcohol and gasohol), and alternative ways of producing energy on the farms and ranches, i.e., solar, windmills, etc.

A major part of this RCA study is an analysis of the impacts on food and fiber production that would result from portions of our present croplands being used for energy production or the impacts on soil erosion should new marginal lands be brought into production. This is a new field of consideration in agriculture, but one needing much study and research.

Seventh: Other related resources, such as urbanizing areas and rural communities with their soil and water-associated problems—sediment, erosion, soil stability, stormwater, waste disposal, and loss of prime agricultural lands to other uses.

The RCA Process will include the selection of quantifiable objective levels for each of these seven major areas of concern to be addressed by future soil and water conservation programs.

RCA requires that the President send to Congress—based on the appraisal—a national soil and water conservation program. This document will set forth future direction for soil and water conservation programs and is probably the most exciting and challenging part of the total job. Secretary Bergland told us when he launched this Departmental effort that nothing is sacred. What he meant was don't abandon the "old and tried" if it is applicable in the future, but examine new ways to carry out soil conservation on the private lands more effectively and efficiently. Is the present way of doing business, developed over 40 years, the way to do it in the next 40?

In October of 1978, the Secretary asked that the RCA Process include all agencies in the Department concerned with soil and water conservation. This includes eight agencies: Agricultural Stabilization and Conservation Service (ASCS); Office of Budget Planning and Evaluation (OBPE); Economics, Statistics, and Cooperatives Services (ESCS); Farmers Home Administration (FmHA); Forest Service (FS); Rural Electrification Administration (REA); Science and Education Administration (SEA); and Soil Conservation Service (SCS).

The Secretary established a USDA Coordinating Committee chaired by the Deputy Assistant Secretary for Conservation, Research, and Education to direct this effort. He also invited the Council on Environmental Quality (CEQ) and Office of Management and Budget (OMB) to be represented on this committee which has been meeting regularly and frequently since its inception. The agencies involved are cooperating. We can report that this truly is now a Departmental effort.

With this charge, USDA is examining Alternative Strategies or alternative ways of carrying out a future conservation program to meet the objectives previously discussed. I would like to briefly list these alternatives under consideration.

Status quo

The present approach in the USDA consists of over 34 separate programs (research, financing, technical help, etc.) directly relating to soil and water conservation administered by seven agencies. This present strategy has evolved over many years and responds primarily to landowners seeking assistance. Questions have been raised as to the cost-effectiveness of this approach and our ability to meet varying conditions and needs, set national priorities, and target on the problems.

Regional priority conservation projects

This strategy is to focus on problems of similar nature on a geographic basis. The problem area could be a watershed, county, or multicounty region. In this approach, a multidisciplinary analysis would be made to identify the problems and most cost-effective solutions. Various program elements would be established in close cooperation with the local people and would reflect a blend of national and local priorities.

A national priority conservation program

This strategy will focus on solving those soil and water conservation problems identified at the national level as being most important. National resources would be directed to those areas identified by national data and analysis that would give the greatest return for the effort. National modeling would be used in a systems analysis approach to identify the problems which are to be addressed.

Non-Federal activities

The possibility of expanding the State role in soil and water conservation programs is also being explored. Some States have already assumed a major role in soil and water conservation with financial expenditures exceeding the Federal input.

Incentives

The use of additional incentives is being examined. These possible areas include the "Green Ticket" concept of rewarding those landowners and operators who practice conservation. A "Cross Compliance" concept where soil conservation is a requirement to receiving assistance under other USDA programs, along with tax incentives are other ways to approach the issue.

Any new strategies will be tested against the following suggested criteria to see how well they stand up:

Ability to meet the natural resources objectives within specified timeframes,
Targeting on the resource problems,
Cost-effectiveness,
Reasonableness and practicability,
Compatibility with other authorities,
Degree of nonfederal involvement,
Social distribution of cost and benefits,
Land use implications,
Avoidance of internal USDA duplication,
Response to market changes,
Environmental and regulatory impacts,
Maintenance of soil and water conservation, and
Political viability.

Mr. Chairman, we were also directed by Congress to carry out the RCA Process in an open and objective manner with a high level of public participation. We believe this is being accomplished. A major concern is that this not just become another academic exercise, but rather a study in which the issues are laid on the table for all to see—and from which the best solutions for the complex conservation problems can be selected. Your understanding the issues and weighing the alternatives will be needed to make this the meaningful exercise intended in the Act.

Congress also requested in the Act that all levels of government be involved in both the Appraisal and Program development. We have already involved the public in more than 6,000 local, State, and national meetings. This fall,

USDA will go to the public for comments on the draft Appraisal and Soil and Water Conservation Program documents. They will be asked to respond to several alternative strategies to be used to accomplish the objectives in soil and water conservation. A National Public Opinion Survey contract with Lou Harris and Associates will also be conducted this fall. It will determine public perceptions of soil and water conservation along with the alternative strategy(ies) they feel would best meet the needs. We will also use this survey as a baseline for future surveys and plan to compare this survey with the other public participation activities to determine if our method of public participation is valid.

Attached for your information is a summary of the RCA Process and National Resources Inventory highlights. I will respond to any questions you may have.



United States
Department of
Agriculture

RCA

Soil and Water Resources Conservation Act

PROCESS Summary

Development of the 1980 Appraisal, USDA Soil and Water Conservation Program and Statement of Policy

R C A P R O C E S S

The Soil and Water Resources Conservation Act (RCA), Public Law 95-192, states that the soil and water conservation programs of the United States Department of Agriculture shall be responsive to the long-term needs of the Nation. In carrying out RCA responsibilities for nonfederal land, the Department is to --

- o Appraise the current status and condition of the soil, water, and related resources on nonfederal land.
- o Determine the particular problems in meeting the projected production of food and fiber and environmental demands.
- o Determine which of those problems that can be and should be addressed by a USDA Soil and Water Conservation Program.
- o Recognize and utilize information and data available from Federal, State, and local governments, private organizations, and other sources.
- o Coordinate the resource appraisal efforts in RCA and the resource assessment effort in the Forest and Rangeland Renewable Resources Planning Act (RPA).
- o Link USDA's RCA and RPA program development with the Renewable Resources Extension Program.

GENERAL DESCRIPTION OF PROCESS

The process is one of --

(1) Appraising the resources.

(2) Projecting demands and the resources required to meet the demands.

(3) Analyzing the appraisal, demands, and needed resources and identifying areas of concern as basis for determining objectives.

(4) Establishing feasible soil and water conservation objectives.

(5) Developing and comparing alternative strategies to meet the objectives.

(6) Selecting the alternative strategy in order to establish the recommended USDA Soil and Water Conservation Program.

After this process is completed, two draft documents--an "Appraisal Report" and a "Program Report"--will be provided to the public for review and comment.

APPRAISAL DEVELOPMENT

The major components of the appraisal will be --

- The status, condition, and trends of soil, water, and the following related natural resources:
  - -- Fish and wildlife habitat
  - -- Wetlands
  - -- Vegetation
  - -- Outdoor recreation
  - -- Strippable mineral resources
  - -- Organic waste
  - -- Snow and icefields
  - -- Flood plains
  - -- Prime and unique lands
- The capabilities of soil and water resources to meet future needs
- The effect technology will have on these resources
- An inventory of legislative authorities affecting these resources
- Alternative irrigation techniques
- A history to date of the past soil and water conservation efforts and accomplishments and the institutional arrangements
- The assumptions and projections considered in establishing the future long-range USDA Soil and Water Conservation Program
- A description of the public participation activities conducted to date and planned for the future.

PROGRAM DEVELOPMENT

The USDA Soil and Water Conservation Program is to be developed according to the Appraisal and the data available from many other sources. In the fall of 1978, the Secretary of Agriculture directed that the RCA Process address all soil and water conservation efforts of USDA. These efforts are directed through 28 programs in seven agencies--ASCS, ESCS, FmHA, FS, REA, SEA, and SCS.

Potential Problem Areas

The process for developing this program began with the establishment of broad areas of concern, called Potential Problem Areas (PPA). Each PPA will be examined in detail in order to determine the specific problems and the extent to which they can be addressed through a soil and water conservation program. The Potential Problem Areas are --

(1) Providing an adequate supply of food and fiber through conservation, use, and development of soil and water resources (through year 2030).

(2) Influencing agricultural, silvicultural, and land conversion activities to help meet state and national water quality objectives.

(3) Increasing water conservation through efficient use of water.

(4) Providing fish and wildlife habitat.

(5) Reducing flood damage in upstream areas.

(6) Increasing conservation of energy.

Other problem areas may be identified and analyzed.

Resource Analysis

Analysis of the soil and water resource data available in the appraisal can help determine the capability of the resources to meet present and projected demands or requirements for each of the six broad areas covered by the Potential Problem Areas.

In this analysis, all legislative and policy constraints are removed. Removing these constraints provides an unbiased manipulation of the various resources to meet the projected demands. As decisions are made, constraints can be reintroduced.

Following is a brief discussion of the analysis on each of the six Potential Problem Areas. Examples of questions that are being examined in the analysis concerning the Potential Problem Areas are:

1. Food and fiber --

   - o What will future demands be?
   - o Will existing cropland be able to meet the demands?
   - o What will be the impact of technology on meeting the demands?
   - o What effect will a national conservation program have on food and fiber?
   - o What lands--dry, wet, or irrigated--can be brought into production?

2. Water quality --

   - o What is the extent of nonpoint-source pollution?
   - o What part of nonpoint-source pollution is due to agricultural and silvicultural activities?
   - o What will a national conservation program be able to do to lessen the amount of sediment, pesticides, excess nutrients, salinity, pathogens, and toxic substances in water?

3. Water conservation --

   - o What irrigation systems are more efficient?
   - o How much water can be saved through the use of more efficient irrigation systems?

4. Fish and wildlife habitat --

   - o How do conservation systems diminish the amount of fish and wildlife habitat?
   - o What conservation systems improve or create wildlife habitat?

5. Flood damage in upstream areas --

   - o What is the magnitude and extent of floodwater damage in upstream areas of less than 250,000 acres?

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- What structural or nonstructural methods can be used to reduce damage to certain levels?

6. Energy conservation --

- What energy can be saved through improved irrigation efficiency, conservation tillage systems, and drainage of poorly drained land presently in cultivation?

- What energy can be produced through organic waste and biomass?

- What will be the effect of energy production through organic waste and biomass on soil and water resources?

An example of other specific problem areas to be analyzed is to determine the impact on urbanization and the needs in rural communities.

The analysis for the 1980 reports is based on existing data. This process will also identify the type of analysis and data needed for the 1985 effort.

Objectives

After specific problems have been identified, objectives will be established by the Coordinating Committee. The objectives will represent quantifiable levels of the specific problems to be addressed by a USDA Soil and Water Conservation Program.

Alternative Strategies

In this stage of the process, alternative ways of meeting the objectives will be developed. Constraints will be reintroduced to the decisionmaking process. Delivery mechanisms, such as level of education, technical assistance, loans, and cost-sharing tax incentives will be established.

Once the level of delivery mechanism is established for each alternative approach, the legislative authority will be examined to determine whether or not it can meet the need as it exists, or whether it should be modified or new legislation enacted.

Comparative Analysis

The alternative strategies derived will be analyzed and compared for practicability, feasibility, and general acceptance.

Selection of Alternative Strategies

USDA will select from the alternative strategies perhaps three to five strategies to be included in the Program Report for further consideration by the public and others.

Circulated Drafts

The Appraisal Report will be prepared as a draft report and made available to the public for review and comment.

The Draft Program Report, which contains the selected alternative strategies, will be provided to the public for review and comment.

Field meetings will be held to provide information on the alternative strategies and to answer questions.

Consider Comments

After the public review period, all comments received will be analyzed and considered in determining the alternative strategy the administration recommends to Congress.

It is possible that the selected alternative strategies proposed will be modified, because of public concern, and become the recommended program. The Appraisal Report and Soil and Water Conservation Report will be prepared in final form and presented to the Congress by the President.

General RCA Flow Chart and Schedule of Activities

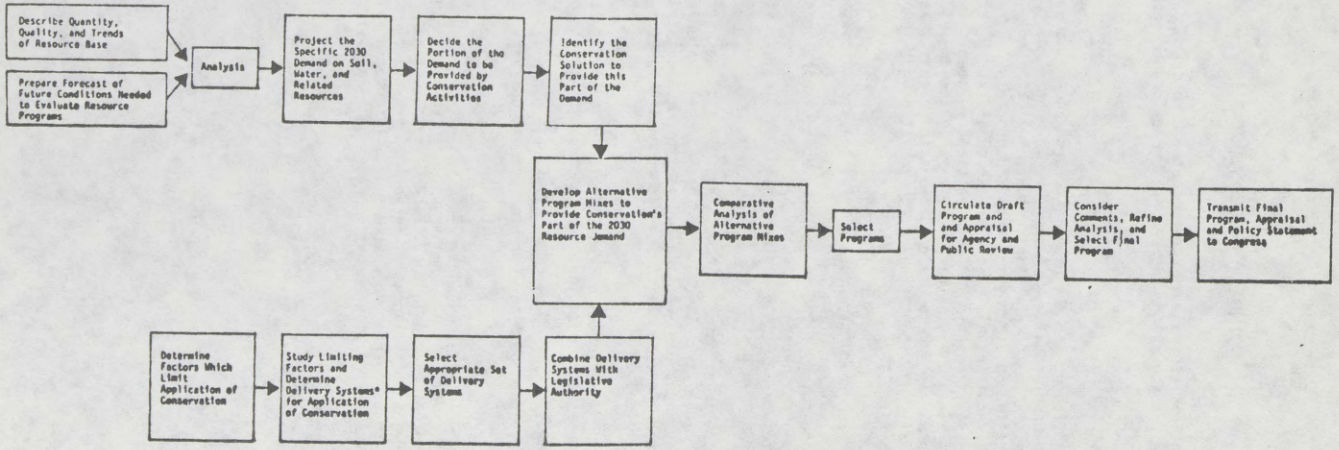
The enclosed flow chart should help you understand how the RCA Process will work. The Schedule of Activities provides dates of major events.

RCA SCHEDULE OF ACTIVITIES

		Public Participation	CC[1] Decisions	Other Events
1.	Briefing of national organizations[2]	1/19/79		
2.	Briefing of USDA Field Level Agencies involved in RCA	1/25-2/15/79		
3.	Concurrence in "RCA Process" and schedule		2/1/79	
4.	Provide to USDA Field Agencies "RCA Update Report" (including RCA Process schedule)	2/8/79		
5.	Provide information and notice of RCA Process availablity to all organizations	2/8/79		
6.	Concurrent in Appraisal Report outline		2/15/79	
7.	Concurrence in RCA Assumption and Projections and Program Report Outline		3/1/79	
8.	USDA State level RCA briefing held	3/5/79		
9.	Complete first draft of Appraisal Report			3/15/79
10.	Concurrence in final draft of Appraisal Report		4/16/79	
11.	Selection of specific problem areas and extent of short-falls and concurrence in initial objectives by Cooridinating Committee		6/1/79	
12.	Complete analysis of resource data			7/2/79
13.	Determine alternative program mixes to reach objectives		7/10/79	
14.	Selection of final alternative program mix		7/20/79	
15.	Concurrence in final draft of Program Report		8/3/79	
16.	Draft Appraisal and Program Reports to public			8/20/79
17.	Begin Draft Report Public Participation Process	8/21/79		
18.	Hold National Public Opinion Poll on draft appraisal and report	9/21/79		
19.	End of Public Review	10/22/79		
20.	Incorporate public input and select program		12/3/79	
21.	CompleteAppraisal, Program and send to printer			12/14/79
22.	Report to Congress			1/1/80

1/ CC - USDA Coordinating Committee
2/ Keep National Organizations informed and involved as appropriate.

GENERAL RCA PROCESS



* Technical assistance, education, loans, cost-share, research, etc.

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Soil Conservation Service
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20013

NATIONAL RESOURCE INVENTORIES

What: This paper highlights some of the new natural resource data and results from the first phase of the National Resource Inventories (SCS-NRI).

Why: SCS began the inventories in March 1977, in order to provide current resource data to:

--Respond to findings of the USDA Task Force on Adequacy of Conservation Systems on Cropland.
--Answer Senate Committee on Agriculture, Nutrition and Forestry requests for information about program needs and progress.
--Meet recommendations of the task force on "Future Directions of SCS."
--Answer General Accounting Office questions related to an audit.
--Update 10-year-old estimates of conservation needs and soil erosion.
--Aid in appraisal of resource conditions and trends that would be called for in a Soil and Water Resources Conservation Act (RCA), which was enacted in fall 1977.

Where: The inventories were designed to provide statistical data for nonfederal lands in each State (except Alaska) in the U.S. and in the Caribbean Area. They used about one-third of the randomly selected sample areas that were used in the 1967 national inventory of soil and water conservation needs (CNI). Data were collected by SCS field employees at 70,000 primary sample units and more than 200,000 sample points.

When: Phase 1 of the inventories is completed. It includes data on land capability classes (soil quality); land use and use of small water areas; conservation needs; floodprone areas; wetland types 3 to 20; sheet and rill erosion; wind erosion in the 10 Great Plains States; potential for new cropland; irrigation; and prime farmlands.

Phase 2 of the inventories will be completed in 1979. It will include data on gully, streambank, roadside, and construction-site erosion.

Phase 3, the final one, will be completed in 1980. It will include using new data in a computer model to estimate sediment delivery for major river basins (hydrologic units).

Who: SCS-NRI data will be used by SCS State offices for long-range soil and water conservation programing and planning. These data and other current information also are being used in the first RCA appraisal and program now underway. Decisionmakers in other agencies as well as private firms, groups and organizations that need current natural resource information will find the data useful for selecting resource-oriented research, activities, and evaluations.

THE FINDINGS:

Soil Quality

Rural land available for agricultural, forestry and other uses declined by nearly 37 million acres in the 1967-to-1977 period. Yet the percentage of good, fair, and poor land remained about the same. That is, 44 percent of the rural land (613 million acres) is in land capability classes I-III, 13 percent is in class IV (189 million acres), and 43 percent is in classes V-VIII (599 million acres).

Of the total rural nonfederal land, 414 million acres occur on level to nearly level topography and over 1 billion acres occur on gentle to very steep slopes. At least 269 million acres have a natural wetness condition, while nearly 402 million acres are droughty or lack sufficient water to grow agricultural or forestry crops. Some lands are sloping and wet, others may be level and droughty. Many of these conditions, singly or in combination, limit the use of land.

Land Use

Cropland: There is a continuing decline in the acreage of nonfederal land used for growing crops in the U.S. During the 10-year period from 1967 to 1977, acres in cropland decreased by 18 million, from 431 million to 413 million. This represents a decrease of 1.8 million acres a year. The rate is considerably less than the decline of the 1950's, but about the same as the decline of the 1960's. The 1977 SCS-NRI data show that land users retained the better land for cropland. Since 1950, there has been a 3-percent increase in the use of good land (capability classes I-III) for cropland and a 4-percent decrease in cropping of poor land. Use of fair (marginal) lands increased by 1 percent.

Grassland and forest land: Land available for grazing has increased greatly; it accounted for 541 million acres in 1977. Now, over half of the nonfederal agricultural land is used for native pasture, pastureland and rangeland. The SCS-NRI data show an overall decline in nonfederal forest land. In 1967, there were 444 million acres of nonfederal forest land. The total decreased to 370 million acres in 1977, a change of 74 million acres.

Urban and built-up: The 1977 data confirmed previous estimates that homes, factories, roads and other similar uses are absorbing rural land at a rapid pace. Some 90 million acres now are in these uses or committed to these uses. Another 4 million acres are in very small built-up areas and are considered part of the other rural land uses. Nearly 95 percent of the rural land shifted from agricultural, forestry and other uses is related to urban development. The remaining 5 percent of land changed to small water areas. The data suggest that land is converted to these irreversible uses at a rate of about 3 million acres a year. About 10 percent of the land converted to small water areas and 30 percent of the urban and built-up area come from land formerly used for cropland.

Use of Small Water Areas

Small water areas increased by more than 1 million acres in the 1967-to-1977 period. SCS-NRI data show that the total 9 million acres of small water is evenly divided between small streams (less than 1/8 mile wide) and water bodies (less than 40 acres). About 4 million acres of small water are used primarily for recreation, including fish and wildlife. Nearly 3 million acres are used for livestock water supply.

Conservation Needs

Some 892 million acres of agricultural and forest land needed conservation treatment in 1977. The total did not change significantly over the 10-year period, but the kind of treatment needed--and the kinds of land requiring treatment--did change distinctly. In 1967, 64 percent (272 million acres) of the cropland needed treatment; 58 percent (241 million acres) required treatment in 1977, a decrease of 6 percent for cropland. Total acres in pastureland and rangeland increased, as did the treatment needs. In 1967, 71 percent (346 million acres) needed treatment; this increased to 75 percent (404 million acres) in 1977. Surprisingly, the percentage of forest land needing treatment increased from 62 percent to 67 percent in the 10-year period while the acreage of forest land decreased.

Floodprone Areas

SCS-NRI data specifically identified the acreage of floodprone areas and furnished valuable new information on the use and quality of this fragile resource. There are 175 million acres of floodprone areas in the nonfederal land area of the U.S. (excluding Alaska). About 32 percent (54 million acres) is pastureland, native pasture and rangeland. Another 30 percent (52 million acres) is forest land. Another 27 percent (48 million acres) is cropland. The remaining 11 percent is in other land uses. About 46 percent of the floodprone land is of good quality (capability classes I-III) and 54 percent is fair to poor (classes IV-VIII).

Wetlands

New data are available on the use, composition, and potential of wet soils and wetland types 3 to 20. There are 42 million acres of wetlands in the U.S., of which 40 million acres (97 percent) are in noncropland uses. Forested wetlands account for 50 percent of the acreage. None of the wetlands has potential or is available for conversion to cropland. By contrast, the U.S. (except Alaska) has 269 million acres of wet soils on nonfederal lands. Nearly 105 million of these acres are now cropped; of the other 164 million, only 31 million have potential for conversion to new cropland.

Sheet and Rill Erosion

Estimated average annual sheet and rill erosion for all cropland is 4.8 tons per acre. Cropland erosion rates range from less than 1 ton in some States to more than 41 tons per acre for the Caribbean Area. Estimates in 1967 showed annual cropland erosion rates of 5.9 tons per acre and a total of 2.6 billion tons eroded. In 1977, the amount was down to 2 billion tons annually.

This bright picture is dimmed by the fact that 22 States, mainly in the central and eastern part of the U.S. and the Caribbean Area, have average annual erosion rates for cropland of 4 tons or more per acre. Seven States and the Caribbean Area have more than 8 tons. Sloping croplands are eroding at 1 to nearly 4 times their permissible rates. Some nearly level wet soils in the Delta region are eroding at above permissible rates. Pastureland and native pasture in 11 States and the Caribbean Area have average annual erosion rates of more than 4 tons per acre. Rangeland erosion rates in 5 States and the Caribbean Area are over 4 tons per acre. Except for 3 States and the Caribbean Area, erosion rates for forest land are not high; but grazed forest land is eroding three times as much as nongrazed forest land.

Wind Erosion in the Great Plains

Average annual soil loss on cropland in the 10 Great Plains States from erosion by wind is 5.3 tons per acre. Annual rates for each State range from 1.3 tons per acre to 14.9 tons per acre. Three of the States have rates above 8 tons per acre. Annual erosion by wind on rangeland varies from none in two Great Plains States to 6.2 tons per acre for one State.

Potential for New Cropland

A 1975 SCS inventory--that estimated how much pastureland, rangeland, forest land, and land in other uses could be converted to cropland--created much interest and debate. New data were collected for the 1977 SCS-NRI, based on 1976 prices and costs. Although the total cropland acreage with high or medium potential for conversion was estimated at 135 million acres in 1977 compared to 111 million acres in 1975, the acreage with high potential was down by nearly 50 percent. The acreage of land with medium potential for conversion was up to 95 million acres, suggesting that (1) conversion problems were thought to be more complex in 1977 than in 1975 or (2) prices received versus the cost to produce a crop were such that more land with conservation problems might be brought into production in 1977.

Irrigated Land

The acreage of irrigated land has increased sharply. In 1967, 47 million acres of cropland and pasture were irrigated; in 1977, the total was 62 million acres. Irrigation is no longer confined to the dry areas of the west--SCS-NRI data show that all but 2 States now irrigate some lands. Three States irrigate more than 5 million acres each and 14 States irrigate 1 to 5 million acres each. Most of the land (63 percent) is irrigated by use of gravity systems. Another 32 percent is irrigated by use of pressure systems. The remaining 5 percent uses a combination of both.

Prime Farmlands

The 1975 estimates showed 384 million acres of prime farmlands in the U.S. and Caribbean Area; the 1977 SCS-NRI data showed 346 million acres. The latter figure is a more accurate measure of these important farmlands. Three States have more than 20 million acres each of prime farmland, 4 States have 15 to 20 millio acres each, 7 States have 10 to 15 million acres each, and 9 States have 5 to 10 million acres each. Some 67 percent of the prime farmland already is being used for cropland. Only 116 million acres of prime farmland are in other uses. Of these, 1977 SCS-NRI data showed that only about 45 (52 million acres) could practicably be shifted to cropland production.

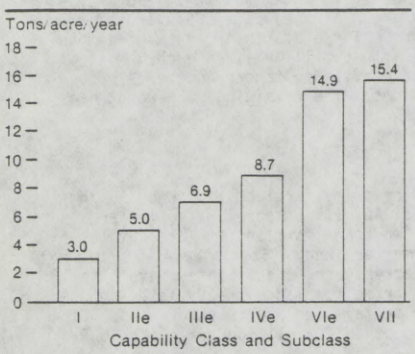
Conservation Treatment Needs in 1967 and 1977—National Summary

	Cropland		Pastureland and Rangeland		Forestland	
	Acres (Millions)	Percent	Acres (Millions)	Percent	Acres (Millions)	Percent
1967						
Treatment Needed	272	64%	346	71%	271	62%
Treatment Not Needed	159	36%	161	29%	174	38%
1977						
Treatment Needed	241	58%	404	75%	247	67%
Treatment Not Needed	172	42%	137	25%	123	33%

Use of Flood Plains in 1977, National Summary of Non Federal Land

Land Use	Acres (millions)	Percent
Cropland	48.2	27
Pastureland and Native Pasture	19.8	11
Rangeland	34.7	21
Forest Land	51.6	30
Other Land	20.7	11
Total	175.0	100

Estimated Average Annual Sheet and Rill Erosion on Cropland in the United States in 1977, by Capability Class



Use of Prime Farmland in 1977

Land Use	Acres (millions)	Percent
Cropland	231	67
Native Pasture and Pastureland	39	11
Rangeland	23	7
Forest Land	42	12
Other Land	11	3
Total	346	100

Soil Quality — Non Federal Rural Land (Excluding Alaska)

Condition*	Million Acres	Percent
Level	414	29
Sloping	1,021	71
Wet	269	19
Droughty	402	29
Flood Prone	179	12

*Some soils are sloping but wet, level but droughty, etc.

Trends in Use of Nonfederal Land for Cropland by Capability Classes (percent)

Use of Cropland by Capability Class	Year			
	1950	1958	1967	1977
I-III	82%	83%	84%	85%
IV	10%	11%	11%	11%
V-VIII	8%	6%	5%	4%
Total	100%	100%	100%	100%

National Summary of Trends in Use of Non Federal Land

(Millions of Acres)

Land Use	1958	1967*	1977
Agricultural Land:			
Cropland	448	431	413
Pastureland, Native Pasture, and Rangeland	485	507	541
Forest Land	453	444	370
Urban and Built-Up	51	61	90
Small Water	7	7	9
Other Land Uses	60	50	77
Total	1,504	1,500	1,500

*Unadjusted

Mr. HANCE. Mr. Berg, thank you for your testimony. I know personally of the good the Soil Conservation Service has done throughout the years.

The first contact I had with them was when I was about 8 years old, one of its representatives came to our farm, and the wind that day was a little above average, about 45 or 50 miles per hour, his hat blew off, and my father said not to worry, there was a fence a mile on the other side of the farm, that we would go over and pick up his hat at a later time.

I do not know if he was ever reimbursed, but he did do a good job.

Mr. BERG. Thank you.

Mr. HANCE. Our next witness will be Mr. Neil Sampson, executive vice president, National Association of Conservation Districts.

Mr. Sampson, the message we just received from the floor is there will probably be a vote within the next 30 minutes.

If you could, and all of the remaining witnesses, just give a summation of your testimony, your entire testimony will be entered as a part of the record, and try to make that a 5- to 10-minute summation, so that we can get as close as possible to getting through before the vote comes up.

STATEMENT OF NEIL SAMPSON, EXECUTIVE VICE PRESIDENT OF THE NATIONAL ASSOCIATION OF CONSERVATION DISTRICTS

Mr. SAMPSON. Thank you. Due to some other meetings that we have in town today, I have with me today three of our national officers, and I would like to take a couple of seconds to introduce them.

We have Mr. Lyle Bauer of Kansas, our national president, Mr. George Bagley, your immediate past president, and Director Steve Brunson of Tennessee, the chairman of our district outlook committee, and we are pleased to have them with us.

Mr. HANCE. We appreciate your being here. I have had some similar paying jobs in the past, and I can offer my condolences as well as my congratulations in the job that you do.

Mr. SAMPSON. I would like to skim through some of the material I did bring today.

It basically concerns itself with agricultural land, farmland resource base, and if you will just sort of track through it rather quickly with me, I think you will see there are some charts in there that you may want to come back to at some later time.

The first table I have on page two shows that the really good lands. we are already using most of those for croplands.

Eighty-two percent of the Class I and 65 percent of the Class II is being used.

The American farmers know where the good lands are, and they are plowing it.

At the same time, they have been gradually improving.

Table 2 shows the percentage of the good land has gone up a little bit. While the percentage of the really bad land has been going down over the years, so economically, American agriculture has been slowly shifting to those better lands.

We are using our farmlands a great deal more intensively, and that is not news to anybody who has been out in the country, but the 1977 data shows in table 3 that there is more than 27 percent more row crop than 10 years ago, and 40 percent less rotation in pasture, and of course the acreage reserve in effect in 1957, which you will see in that other cropland is virtually gone, so that the crop land resource is used very intensively.

At the same time the total amount of crop land has been going down.

Mr. Berg mentioned this, in table 4, we show we only really got about 13 million acres we call crop land in 1977, and this is a decline as you see across the table.

You might look and notice the amount of irrigated crop land is almost double, which is a further evidence of how intensively we use those resources.

There is intense competition for the good lands of the country, about 3 million acres a year is being added to that urban and built-up land, whether it is airports, highways or other kinds of urbanization activities, and as you see, from table 5, the urban lands are up at 90, and other land uses are rising.

Those are net shifts, and I think you need to realize that.

Back in 1967, the potential crop land study allowed us to study what happened with what lands, and you found that 52 million acres of crop land was being shifted to grass, an additional 32 were being moved from grass into crops, so you have a net shift of 22 million acres, so it affects 80 million acres, so I think you need to recognize that, just looking at the net acreage changes, it hides an awful lot of turmoil within the base itself.

I guess my point comes down to this, we know the farmland base is large, that it is being used intensively, it is not inexhaustible.

It is being depleted to the tune of about 3 million acres a year for conversion, and if my interpretation of the erosion implications are accurate, about another 3 million acres of productive capacity, not acres, is being lost through that soil erosion process.

That is a total of some 6 million acres a year, which is a fairly significant piece.

We recently ran a survey that I would like to mention briefly with our district supervisors at the local level, and we asked them to respond. Is that a problem in your area?

Forty-one percent of the 1,900 that responded said it was indeed a serious or very serious problem, when you look at it from their local point of view, and they are looking at hundreds of acres instead of the millions.

The Federal actions that were taking place up there were causing a fair share—environmental impact statements were not seen as being very beneficial in preventing it—and so our survey showed that the problem of agricultural land conversion is no doubt a national problem.

It is not regional; it is spread all over—in the East and West, in the urban areas. In the North, it may be a wildlife refuge or some other thing taking farmland.

We do not know when and with what severity that diminishing will collide with those ever-increasing demands to give us a real problem, and a serious gap in our productive capacity.

The other major thing we do know is what should be done about this.

The USDA has moved with policy to help prevent some of this. EPA has had some policy. Representative Jeffords has been a key sponsor of a bill at the national level that will address the problem.

A lot of States and local levels are trying to do something about it.

One of the most innovative State programs going you will hear about, but I think at the national level, we have to say that all of that is not doing very much in terms of actually stopping the depletion of the agricultural resource bases. So I think it is safe to say we have a problem, and I think it is a problem that demands action.

In taking action, we urge you to remember our basic principles, to keep a solid perspective on where the conservation movement and institution of conservation has come in the last 4 years.

Our goal today is to work toward good conservation and wise use of the Nation's lands and waters. We believe this should be supported by the kinds of technical assistance and research and economic incentives as are required, and that this can be accomplished by a free people working together in a voluntary manner.

The policies and the funding for those programs, at least at the national level, must come largely through your leadership, and that is why we are pleased to see you back on this topic.

Thank you.

Mr. HANCE. Thank you, Mr. Sampson. We appreciate your officers being with us.

Mr. SAMPSON. Thank you.

[The prepared statement of Mr. Sampson follows:]

STATEMENT

of
Neil Sampson, Executive Vice President, NACD
to the
Joint Hearings of the
Conservation and Credit Subcommittee, Agriculture,
and
Natural Resources and Environment Subcommittee, Science and Technology,
House of Representatives

on
AGRICULTURAL PRODUCTIVITY AND ENVIRONMENTAL QUALITY
July 26, 1979

Mr. Chairman. Members of the Committee. I am Neil Sampson, Executive Vice President of the National Association of Conservation Districts. NACD, as we are commonly known, represents the nation's 2,924 conservation districts, the 50 state associations of conservation districts, and the 17,000 conservation district officials that serve them.

We are pleased to bring some of our opinions to this important hearing today. Our testimony will be brief, but we have attached two papers that we would respectfully ask be incorporated as part of the record, as they contain much of the background analysis on the estimates we will present today. One is a paper prepared for inclusion in a forthcoming book to be published by the Soil Conservation Society of America that combines the data on soil erosion and land conversion and estimates the magnitude of the current losses. The other is a preliminary report on an NACD survey of conservation district officials about the agricultural land conversion problem.

The protection of agricultural lands has been a major goal of conservation districts since the beginning of the district movement in the 1930's. When land is lost through the ravages of wind or water erosion, or being converted to another use, or irreversibly destroyed by man's actions, it is a serious matter. These issues concern conservation district officials and should, we feel, concern citizens in all walks of life.

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Let us begin with what we know about the farmland resource base today. Table 1, taken from the Soil Conservation Service's 1977 Natural Resource Inventories, gives some of the characteristics of the way in which we currently use the land. Note that 82 percent of the lands in Capability Class I are already used for cropland, while 65 percent of the Class II lands are cropped. In other words, of the very best lands for cropping, we already are cropping most of them.

Table 1. CAPABILITY AND USE OF RURAL NONFEDERAL LANDS IN 1977

	Capability Class							
Land Use	I	II	III	IV	V	VI	VII-VIII	Total
	(Millions of Acres)							
Non-Irrigated Cropland	23	166	114	36	2	11	3	355
Irrigated Cropland	9	21	17	7	1	2	1	58
Total Cropland	32	187	131	43	3	13	4	413
Pasture & Range	4	48	87	76	8	165	153	541
Forest Land	2	41	58	60	17	83	109	370
Other Land	1	10	11	9	2	6	72	111
Total	39	286	287	188	30	267	338	1,435

In terms of the recent trends, American farmers have been gradually shifting to the better lands. Table 2 shows that the amount of marginal land being cropped has dropped by 50 percent in the last 20 years, while the amount of Classes I-III land has gradually increased.

Table 2. Trends in Use of Nonfederal Land for Cropland by Capability Classes

Use of Cropland by Capability Class	Year		
	1958	1967	1977
Classes I-III	83%	84%	85%
IV	11%	11%	11%
V-VIII	6%	5%	4%
Totals	100%	100%	100%

We have been using our farmlands more intensively. As Table 3 indicates, there has been a 27 percent rise in the amount of row crop since 1967, accompanied by a 40 percent decline in the amount of rotation hay and pasture and a virtual disappearance of the acreage reserve that was shown in the "other cropland" category a decade ago.

Table 3. CROPLAND USE IN 1977 COMPARED TO THE 1967 CONSERVATION NEEDS INVENTORY

Cropland Type	1967 Cons. Needs Inv. Irr.	Nonirr.	Total	1977 National Res. Inv. Irr.	Nonirr.	Total	Change
			(millions of acres)				(%)
Row crops	19.0	141.4	160.4	29.7	173.5	203.2	+27%
Close-grown crops	8.1	92.5	100.6	11.0	93.9	104.9	+ 4%
Rotation hay & pasture	7.4	43.0	50.4	4.4	25.8	30.2	-40%
Hayland	5.6	21.6	27.2	7.3	25.8	33.1	+22%
Orchards, vinyards, etc.	2.6	2.5	5.1	3.3	2.2	5.5	+ 8%
Other cropland	1.5	60.4	61.9(a)	1.9	4.9	6.8	-89%
Summerfallow		32.0	32.0		29.3	29.3	- 8%
Total	44.3	393.3	437.6	57.6	355.4	413.0	-5.6%

(a) Other cropland in 1967 included conservation acres and idle cropland (set-aside) as well as "other" cropland.

At the same time, the total amount of land used for cropland has been declining at the rate of about 1.75 million acres per year. Table 4 shows that we were using 18 million less acres for cropland in 1977 than in 1967.

TABLE 4. TRENDS IN CROPLAND USE

Land Use	1958	1967	1977
		(Millions of Acres)	
Irrigated	37	44	58
Non-Irrigated	411	387	355
Total Cropland	448	431	413

There is intensive competition for the good lands of this country. During the period 1967-1977, the amount of urban land grew 29 million acres, while water areas grew 2 million acres and "other" land uses increased by 27 million acres. But the numbers you see in Table 5 don't tell the whole story, either. They reflect net changes in land use. In order to get some idea what is really happening to the nation's cropland, you must look at the 1975 Potential Cropland Study done by SCS.

There, for example, SCS found that 52 million acres of cropland had been shifted to grass between 1967 and 1975. A different 32 million acres had been changed from grass to crops. The net shift was 20 million acres going from crops to grass, but 84 million acres were affected in the process. We don't have similar comparative data in the 1977 study, but you should be aware that, while the net changes in land use are significant, they hide even more significant changes that have both regional and national significance.

Table 5. TRENDS IN USE OF NON FEDERAL LAND

Land Use	1958	1967(a)	1977
		(millions of acres)	
Agricultural Land			
Cropland	448	431	413
Pasture & Range	485	507	541
Forest Land	453	444	370
Urban and Built-up	51	61	90
Small Water Areas	7	7	9
Other Land Uses	60	50	77
Total	1,504	1,500	1,500

(a) Unadjusted CNI data

Summing up, then, we know that America's farmland base is being used as intensively, or more intensively, than ever before. It is large, but not inexhaustible. It is being reduced, in terms of total productive capacity, by the equivalent of some 3 million acres each year due to land use conversion.

To this loss must be added the loss of productivity due to soil erosion. I have estimated that loss to be in the same range as the conversion loss, when calculated in terms of the productive capacity represented by the current soil loss rates.

That loss of productive capability from the combination of soil erosion and land use conversion is not only large, but it will get larger, and at an increasing rate. Both processes are self-reinforcing, and also interactive.

Soil depletion is not just a steady loss. It accelerates as each increment of topsoil is washed away, leaving less absorbtive capacity, organic matter, and plant growth to protect the soil when rain strikes again. Farmland conversion, likewise, feeds on itself. Each plot of farmland lost breeds not only new houses to consume rural resources and services; it also creates another group of farmer-speculators who decide that the time is soon coming when the land will make more money by being sold than by being maintained as a producing farm.

The interaction between the two processes is more subtle, but no less real. As erosion eats away the productivity of the land--affecting the most marginal lands fastest--it forces more reliance on the prime farmlands of the nation. Yet these prime lands absorb a disproportionate share of the urbanization and build-up, so the competition for them grows from two directions. As good lands become urbanized and unavailable for food production, agriculture is forced onto more marginal lands, signalling a new round of soil erosion and new pressures on the land and water base.

The losses from the American farmland base are not insignificant. Of the 413 million acres currently in the cropland inventory, they represent some 1.5 percent annually. Of the 135 million acres estimated to remain as potential cropland for future use, they represent over 4 percent annually, meaning that the equivalent of the nation's reserve of cropland could be lost in a 25-year period.

We know that problems are being recognized on the local level. NACD has recently completed a survey of conservation district officials on the subject of agricultural land conversion. Of the 1900 responses we received, 41 percent categorized their local problem as serious or very serious.

Where district officials felt they had a serious problem with agricultural land conversion, over half identified the federal government and its actions as a significant or major factor. In other words, federal actions are seen as part of the problem.

The environmental impact statement is not helping local people make their views effectively known on these land use issues, according to the conservation district supervisors who answered our questions.

Finally, our survey showed without question that the problem of agricultural land conversion is a national problem, with areas experiencing loss of agricultural land, for many different reasons, in virtually every region. In some regions, such as the east and west coasts, urban growth is the major reason for agricultural land loss. But in many of the rural counties, particularly in the northern states, it is major additions to wildlife refuges, or changing policies on the management of federal lands, or wetlands purchases, or federal water projects, that is the cause of the problem.

What we do not know is when, and with what severity, those losses will collide with the ever-growing demand for agricultural products to create a serious gap in this nation's productive capacity. All observers agree that this is an inevitable outcome of the current trends, but forecasting that unpleasant event depends entirely on the assumptions one makes about future weather and technological advances. My own view is that we will, like the

petroleum shortages of the early 1970's, see the tip of the iceberg on this problem in a very few years, then see it in larger and larger dimension as succeeding years of poor crop weather illustrate the real losses we have suffered from total productive capacity.

The major thing we don't know is what should be done. USDA has moved forward with policy to help prevent their actions from contributing to the loss of farmland. The EPA has a similar policy. There is federal legislation in the Congress that would encourage state and local testing of new programs. You will hear about one of those innovative state programs today, but I think the national view must be that, while many states and local areas are trying to slow down the conversion and loss of farmland to other uses, there is little evidence on the national scale that it is having much effect as yet.

Right now, it is safe to say that we have a problem. It is getting worse, and will continue to do so, all current trends indicate. It appears to be the kind of program that warrants immediate attention from the Congress.

In taking action, we urge you to remember our basic principles, and keep a solid perspective on where the conservation movement, and the institutions such as conservation districts that are part of it, have come over the last 40 years. Our goals today, as they were at the start, are good conservation and wise use of the nation's lands and waters. We believe that goal can best be accomplished by a free people, working together in a voluntary manner, guided by a sensible land ethic, and supported by the kinds of research, technical assistance, and economic incentives that are required. The policies and the funding for those programs, at least at the national level, must come largely through your leadership leadership.

We would be pleased to answer any questions you may have.

Attachment I

THE CONVERSION OF AGRICULTURAL LAND

A Look at the Issues by Conservation District Officials

Preliminary Report

Compiled by

THE NATIONAL ASSOCIATION OF CONSERVATION DISTRICTS

July 6, 1979

National Association of Conservation Districts
Rm. 1105, 1025 Vermont Ave., N.W., Washington, D.C. 20005
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NACD AGRICULTURAL LAND SURVEY

NATIONAL SUMMARY (AS OF JULY 6, 1979)

1901 Conservation Districts reporting out of 2924. (65 Percent)

1. Thinking back over the past 5 years, and looking about 5 years ahead, how would you rate the agricultural land conversion problem in your district?

226 No problem
899 Slight problem
588 Serious problem
187 Very serious problem

2. To what extent did the actions of federal agencies contribute to the problem, if any?

Not Noticably 603
Not Significant 586
Significantly 453
The major cause 134
Don't know 58

3. Does your district generally see an environmental impact statement for these federal projects? Yes 403 No 929 Sometimes 375 Do you comment on them? Yes 418 No 421 At times 280 Do your comments get action? Yes 136 No 387 Sometimes 357

4. Which federal agencies are involved?

832 Farmer's Home Administration
597 Environmental Protection Agency
207 Economic Development Administration
762 Federal Highway Administration
263 Federal Airport Administration
546 Housing and Urban Development
[illegible] Bureau of Reclamation
[illegible] Corps of Engineers
343 Other (Bureau of Sports Fisheries, etc)

5. What kinds of federal programs?

Rural Housing 784
Sewer/waste treatment, etc. 658
Highways 845
Airports 315
Commercial/Industrial Dev. 458
Dams/Reservoirs, etc. 455
Other 222

6. Which of the following general problems, if any, do you think are affecting your district as a result of the conversion of agricultural land.

249 None
659 Conflict between farmers and rural housing occupants
740 Farms going out of business
1170 Prime farmlands being lost
875 Increased soil erosion
847 Increased water pollution
771 Cost of public services going up
288 Agricultural businesses closing
198 (Other)

7. Over the past 5 years, how many acres of farmland do you estimate have been converted to non-agricultural uses in your district? 6,968,517 Acres
How many acres do you think have been idled, or placed in a less intensive agricultural use, in addition to the acres actually converted? 5,905,160 Acres

8. Over the next 5 yrs, how many more farm acres do you expect to be converted? 8,034,527
How many more acres will have lower agricultural production as a result of this? 5,637,215

NOTE: This is the form sent to all 2924 conservation districts. The blanks have been filled with the tabulation of data received from 1901 returns. Responses total more than 1901 on questions 4-6 due to many districts listing more than one answer.

I. Background and Method

The National Association of Conservation Districts represents the nation's 2924 conservation districts, their 50 state associations, and the 17,000 district officials that serve them. NACD policy is the product of the membership, originating with district officials, enacted by state associations, then brought to the NACD Council where an elected member from each association serves in an annual policymaking session. For many years, NASCD policy has contained statements of concern about the avoidable damage to and unnecessary conversion of agricultural land.

Facts about the agricultural land conversion process have been slim. The surveys run by the Soil Conservation Service have been done by sampling methods that provide reliable data at the state, regional, or national level. This gives broad numbers, but doesn't always tell how those facts are viewed by the people most directly affected by land issues. In light of the limited information about local facts and perspectives, NACD undertook a survey of conservation district officials to elicit their views and estimates on the conversion of agricultural land in their home district.

Page 1 summarizes the responses received in that survey. Sixty-five percent of the districts in the nation have responded. The information has been tabulated by states, USDA Farm Production Regions (see map, page 10), and the nation.

There is still some additional work to be done on the data. Computer analysis will proceed in the next month to check the totals and provide additional cross-checking. A final report, carrying a summary page for each state, in addition to maps and further analysis, should be available by late summer, 1979.

II. The Problem is National in Scope

When asked the question: "Thinking back over the past 5 years, and looking about 5 years ahead, how would you rate the agricultural land conversion problem in your district"?, 41 percent of the districts called the problem serious or very serious. Many had a difficult time, making marginal notes to the effect that "it has only been slight in the past, but will be serious from now on". Nearly half of the districts called agricultural land conversion a "slight" problem, with only 12 percent calling it no problem.

No definitions of "slight" or "serious" were provided with the survey form. Few districts have actual acreage data or hard facts. The questionnaire asks for the opinion of district officials, and the numbers must be viewed in that light. In 41 percent of America's districts, knowledgeable local officials view agricultural land conversion as a serious problem.

An interesting comparison could be made between Question 1 and Question 7, ere districts estimated the amount of land that had been converted. Sometimes a district would say they had a "slight" problem, then list a fairly substantial acreage converted. Other districts would feel they had a "serious" problem with a far smaller acreage loss. The seriousness of agricultural land loss, when viewed from the local level, is inextricably tied to local perceptions of the land resource base. In a district with limited prime agricultural land, or a struggling agricultural economy, small losses are serious. In others, because of a larger base, they may not be seen as such. Added together in national aggregate, however, these small losses may contribute significantly to the total problem.

Regional tabulations show that there are substantial differences in the way districts responded to Question 1. Table 1, below, reveals that nearly 3/4 of the districts in Alaska, Hawaii and Puerto Rico call their problem serious, while nearly 2/3 of the districts in the Northeast feel the same way. At the other end of the scale, only 20 percent of the districts in the Northern Plains call their problem serious, while 24 percent see no problem at this time.

Table 1. Regional summary of responses to Question 1, NACD Agricultural Land Survey, in percent.

Region (1)	No Problem	Slight Problem	Serious Problem	Very Serious Problem
ortheast	7	30	49	14
Appalachian	7	48	35	10
Lake States	15	50	30	5
Southeastern	13	55	25	7
Delta States	16	55	20	9
Corn Belt	5	49	38	8
Northern Plains	24	56	16	4
Southern Plains	21	46	24	9
Mountain	9	42	31	18
Pacific	14	37	32	17
AK, HI, & P.R.	0	29	54	17
National Averages	12	47	31	10

(1) USDA Farm Production Regions. See map, page 10.

Most surprising, perhaps, is the high rate of concern in the Mountain states. This large and diverse region, containing much public land and lots of "wide open spaces", is not usually considered a region with agricultural land problems. But almost half of the conservation districts responding to NACD's question feel they have a serious problem, and 18 percent of them call their problem "very serious". Many reasons are given, including threats to irrigation water supplies, urban encroachment in irrigated valleys, coal mining, and the growth of recreational communities.

Another noteworthy region is the Corn Belt, where 46 percent of the districts felt their problem was serious and only 5 percent said they had no problem at all. The urban-to-rural migration of people noted by USDA in recent years may be having more effect on agricultural land in this region than might have been previously recognized. This region contains not only much of the Nation's prime farmland, but also much of its industrial production, and many agricultural areas within commuting distance of industrial jobs are feeling the impact of rural growth.

To get some idea of the distribution of the problem on a national basis, NACD placed the answers to Question 1 on a color-coded map of the United States. (No map is included with this preliminary evaluation, but one is planned for the final report.) That map shows one fact clearly: agricultural land conversion is not a regional issue. The districts with serious problems are scattered all over the nation. There are fewer problem areas in Kansas, Nebraska, and the Dakotas, but even in that rural region, one county out of every 5 has a serious problem.

The lasting impression gained from the map is that agricultural land conversion is, indeed, a national problem and, therefore, a national resource issue. This statement is made even more compelling when it is based on the local impressions of people who understand the circumstances surrounding land resources in a very personal way.

III. The Impact of Federal Actions

In 1976, when USDA issued its first policy statement on the retention of prime and unique farmlands, the focus of that policy was on the actions of federal agencies. It was felt within the Department that many of the major actions causing the conversion of agricultural land could be traced back to some kind of federal action such as funding, permitting, etc. It was also seen to be a legitimate and politically acceptable federal role in the agricultural land issue to focus first on the prevention of unnecessary or excessively adverse federal actions.

Two-thirds of the districts answering NACD's survey did not recognize federal actions as a significant part of the problem of agricultural land conversion. Responses from the 775 districts who characterize their farmland conversion problem as serious or very serious show a far different pattern, however.

Over half (54 percent) of these districts call federal actions either significant or a major cause of the farmland conversion (Table 2). Over 26 percent of the districts in the Southern Plains states felt federal actions to be the major cause of farmland loss. Only in the Southeastern region were federal actions felt to be fairly minor, with nearly half of the districts indicating that the problems they had identified locally did not stem significantly from federal actions.

The general impression gained is that the USDA policy is on the right course. Where farmland conversion is perceived as a local problem, federal actions are a significant contributor in over half the localities. This indicates that reducing the impact of federal actions on farmland conversion will have some beneficial effect, even if it will not address the problems identified in all conservation districts.

Table 2. Regional summary of responses to Question 2, NACD Agricultural Land Survey, in percent of districts indicating a serious or very serious problem with agricultural land conversion.

Region	Not Noticible	Not Significant	Significant	Major Cause	Don't Know
Northeast	12	34	41	6	7
Appalachian	16	31	40	11	2
Lake States	23	26	41	8	2
Southeastern	21	44	28	2	5
Delta States	12	26	53	9	0
Corn Belt	10	29	45	14	2
Northern Plains	13	21	43	21	2
Southern Plains	15	25	34	26	0
Mountain	15	23	44	15	3
Pacific	23	28	37	10	2
AK, HI, & P.R.	25	30	35	10	0
National Averages	15	28	41	13	3

IV. The Environmental Impact Statement

The federal environmental impact statement, along with similar efforts in some states, has been the major tool available to display the various impacts of a proposed development and let different points of view be heard on the alternatives. In 1976, the Council on Environmental Quality issued a memorandum to federal agencies instructing them to consider the impact of their actions on prime and unique farmlands and minimize those impacts wherever possible.

NACD wanted to know how well that advice was working in the field, so we asked a series of 3 questions concerning environmental impact statements (EIS's). Our conclusion is that the EIS process itself isn't working very well, at least in the view of conservation district officials.

When asked "Does your district generally see an environmental impact statement for these federal projects?", only 21 percent of the responses were affirmative. Nearly half said no, and 20 percent said sometimes. When asked "do you comment on them?", 22 percent said yes and 15 percent said sometimes. When asked, however, "do your comments get action?", only 7 percent of the respondents said yes. One-fifth felt that their comments got no action.

In general, it appears that EIS's do not regularly get to conservation districts, but that districts usually comment when they get an EIS of interest to them. If those comments get little, if any, action, however, it will not serve to enhance continued participation. The NACD study does not provide enough information to fairly evaluate this situation, but the indications warrant further investigation into the real value of the EIS process in affecting agency decisions.

V. Federal Agencies Involved in Agricultural Land Conversion

When asked which federal agencies were involved in agricultural land conversion, districts had plenty of answers. Leading the field was USDA's Farmer's Home Administration, named in 44 percent of the responding districts as a cause of agricultural land loss. Close behind was the Federal Highway Administration (41 percent), the Corps of Engineers (33 percent) and the Environmental Protection Agency (31 percent). Given the chance to mention other agencies, many districts pointed out the Fish and Wildlife Service, using wildlife refuge or wetland purchase or expansion programs as an example of agricultural land taking by federal action.

Table 3. Regional summary of responses to Question 4, NACD Agricultural Land Survey, in percent of districts responding.

Region	FmHA(1)	EPA	EDA	FHA	FAA	HUD	B/R	CoE	Other
Northeast	53	32	18	44	11	45	1	29	14
Appalachian	57	29	12	45	14	32	6	36	15
Lake States	44	20	10	43	15	15	1	25	14
Southeastern	54	37	16	30	14	35	2	29	14
Delta States	44	28	9	32	5	32	1	38	17
Corn Belt	43	34	5	50	16	28	4	38	14
Northern Plains	33	30	7	40	17	23	16	24	22
Southern Plains	34	27	17	35	18	27	10	34	17
Mountain	39	38	10	35	8	25	22	25	32
Pacific	32	36	12	29	11	26	21	39	23
AK, HI, & P.R.	64	46	36	29	14	50	0	29	21
National Averages	44	31	11	40	14	29	8	32	18

(1)Agency abbreviations used are: FmHA--Farmer's Home Administration; EPA--Environmental Protection Agency; EDA--Economic Development Administration; FHA--Federal Highway Administration; FAA--Federal Airport Administration; HUD--Dep't. of Housing and Urban Development; B/R--Bureau of Reclamation; and CoE--Corps of Engineers. Agencies identified under Other include Bureau of Sports Fisheries and Wildlife, Soil Conservation Service, Agricultural Stabilization and Conservation Service, and others.

Table 3 shows the percentage of responding districts that mentioned a particular agency. Since many districts mentioned several agencies, the percentages add to more than 100. Farmer's Home Administration was listed in over half of the districts in the Northeast, Appalachian, Southeastern, and AK, HI & PR regions. This may reflect the regional bias of the rural housing and rural sewer and water programs of that agency. In the Corn Belt, the Federal Highway Administration was listed by half of the districts, reflecting a concern in that region for the impact of highway programs.

In response to question 5, concerning the types of federal programs involved in agricultural land conversion, the answers appear to track the responses to question 4 fairly closely. A more careful analysis of this data will be made for the final report, but there appears little of unusual interest at this stage.

In addition to the survey form shown on page 1, districts were given the option of calling attention to a specific development that has recently affected or is now affecting their district. A substantial portion took advantage of this opportunity, and "case study" opportunities abound in the data collected by NACD.

VI. The Types of Problems Affecting Local Areas

When districts were asked what types of general problems were affecting their local area as a result of the conversion of agricultural land, only 13 percent said that there were none. Nearly 2/3 of the districts called the loss of prime farmlands a problem, with increased soil erosion, increased water pollution, and increased cost of local public services being the next most frequently mentioned. Table 4 shows the regional distribution of these responses.

Table 4. Regional summary of responses to Question 6, NACD Agricultural Land Survey, in percent of districts responding.

Region/Problem (1)	1	2	3	4	5	6	7	8	9
Northeast	7	47	68	75	53	40	44	33	16
Appalachian	8	32	47	74	65	60	49	15	5
Lake States	13	46	36	60	34	30	44	14	9
Southeastern	11	21	40	48	49	48	38	16	15
Delta States	21	15	23	48	43	37	27	4	6
Corn Belt	7	42	36	74	59	55	42	12	9
Northern Plains	27	19	23	47	28	31	26	7	6
Southern Plains	22	26	34	48	38	35	31	15	15
Mountain	12	47	43	56	35	43	52	19	17
Pacific	11	49	48	63	37	35	51	21	17
AK, HI, & P.R.	0	25	54	89	50	54	54	36	21
National Averages	13	35	39	62	46	45	41	15	10

(1) Problems identified were: 1 -- None
2 -- Conflict between farmers & others
3 -- Farms going out of business
4 -- Prime farmlands being lost
5 -- Increased soil erosion
6 -- Increased water pollution
7 -- Cost of public services going up
8 -- Agricultural businesses closing
9 -- Other

The intense concern over the loss of prime farmlands in Alaska, Hawaii, and Puerto Rico, as well as the Northeast, is clearly associated with the limited quantity of prime farmlands in those regions and the sense of loss felt when any of it is converted to other uses. The high response from the Corn Belt must be for a different reason, however. This region, where 70 percent of the cropland meets the USDA criteria for prime farmland, certainly suffers no shortage of good land. But development that converts agricultural land in the Corn Belt virtually always converts prime farmland, and this could explain that response.

Increased soil erosion is mentioned as a problem in the Appalachian, Corn Belt, and AK, HI & PR regions by over half of the conservation districts, with increased water pollution mentioned as a parallel problem. The cost of public services is seen as a problem of note in the Appalachian, Pacific and Mountain regions, while agricultural businesses closing is a concern to 1/3 of the districts in the Northeast.

VII. The Rate of Agricultural Land Conversion

A recent survey completed by the Soil Conservation Service (SCS) indicates that urban, built-up and other land uses take about 2.5 million acres each year. In addition, a significant acreage--possibly another 2.5 million acres--is idled in the process. About one-third of the land is cropland immediately prior to conversion. The SCS data were obtained by a national statistical sampling procedure.

Conservation districts were asked to estimate how many acres of farmland had been converted over the past 5 years, and how many additional acres might have been idled as a result. They were then asked to look ahead and guess what might happen in the next 5 years. Both questions call for some speculation. Little hard data exist in most districts to verify recent land use conversions, and many districts noted that their estimates were just that -- estimates. Looking ahead, of course, is always speculative. But district officials know what lands have just been sold, and who is planning what in the local area. When viewed at the local level, by local experts, land use changes in the short-term future can be fairly reliably estimated.

Based on a 65 percent return, and assuming that the remaining 35 percent would respond in a similar manner, the NACD survey indicates that around 10 million acres have been converted in the past 5 years, for a 2 million acre-per-year rate. Add to this another 9 million acres where agricultural production has been reduced or eliminated as a result, and the estimates produce a conversion rate not far different from the estimate derived from the SCS study. The acreages estimated from the NACD study are not based on adequate data, however, they do provide a comparison that seems to support the SCS estimates.

Looking into the future, district officials estimate that the next 5 years may see a 15 percent rise in the annual loss of agricultural land. This estimate, while speculative, indicates that the conversion of agricultural land may become more serious in the near future.

The regional tabulations reveal that virtually all of the anticipated increase in agricultural land conversion is expected by districts in the Mountain States. This region, containing many of the fastest-growing states in the nation today, estimates that over twice as much agricultural land will be lost in the next 5 years as has been lost in the past 5. The issues include urbanization, transportation, recreational home development, energy development, loss of irrigation water, and many others. In one conservation district in Montana, a new federal wildlife refuge plan will take nearly 1 million acres of prime rangeland. To that locality, that is a big issue. But whatever the cause, agricultural land loss is a serious problem apparently turning critical in many parts of the Mountain States.

Table 5. Regional summary of responses to Questions 7 and 8, NACD Agricultural Land Survey, in acres, from 1498 districts (51%).

	Land lost in past 5 years		Next 5 Years	
Region (1)	Converted	Idled	Conversion	Idling
Northeast	490,516	367,112	414,885	224,365
Appalachian	884,236	680,415	947,700	667,860
Lake States	456,042	344,300	431,715	256,030
Southeastern	685,944	554,831	610,635	249,755
Delta States	394,585	276,543	363,922	238,332
Corn Belt	1,225,027	762,169	1,212,389	613,578
Northern Plains	315,353	195,979	327,151	137,620
Southern Plains	1,237,487	1,115,353	1,351,755	919,640
Mountain	756,567	937,278	1,775,155	1,474,825
Pacific	462,625	582,600	542,495	798,495
, HI, & P.R.	60,135	88,580	56,725	34,300
National Averages	6,968,517	5,905,160	8,034,527	5,637,215

VIII. Completion of the Analysis

NACD plans to have the final responses prepared for computer analysis, then prepare a final evaluation and tabulation of the results. This will allow additional cross-checking of the data and should provide additional insight to the ways in which districts view both the federal role and the environmental impact statment process, depending on their local situation.

In addition, we will be able to run some statistical reliability on the data to see if the conclusions we have drawn are valid, and if there are other conclusions that may be drawn. This analysis has not been done in the short time (6 days) between the receipt of the final district response and the preparation of this interim report.

It is hoped, however, that this preliminary report will provide a useful insight into the feelings of conservation district officials around the nation. There has been considerable debate as to whether local people--and particularly farmers--see farmland conversion as a problem. With the majority of district officials coming from the farm community and rural areas, it appears that there is, indeed, widespread concern. We hope this insight is helpful in the important national debate on the issues surrounding agricultural lands.



FARM PRODUCTION REGIONS

NORTHEAST: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland • **LAKE STATES:** Michigan, Wisconsin, Minnesota • **CORN BELT:** Ohio, Indiana, Illinois, Iowa, Missouri • **NORTHERN PLAINS:** North Dakota, South Dakota, Nebraska, Kansas • **APPALACHIAN:** Virginia, West Virginia, North Carolina, Kentucky, Tennessee • **SOUTHEAST:** South Carolina, Georgia, Florida, Alabama • **DELTA STATES:** Mississippi, Arkansas, Louisiana • **SOUTHERN PLAINS:** Oklahoma, Texas • **MOUNTAIN:** Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada • **PACIFIC:** Washington, Oregon, California



PROTECTING FARMLAND: THE ETHICAL DIMENSION

by
Neil Sampson
Executive vice president

Problems amidst plenty

> The United States food system dependence on increasingly fewer farmers, who in turn are dependant on a series of factors beyond their control, raises a basic question of farm sector resiliency to withstand supply-demand fluctuations without increasing Government assistance.
>
> U. S. General Accounting Office
> September, 1978.(1)

In 1978, United States farmers reaped a bin-busting crop. The major grain commodities posted record levels of production despite government attempts to ld down crop acreage. Never before had American farmers produced so much, fed so many people per farmer, or talked so openly about an impending agricultural crisis.

Crisis? Impossible! Maybe. Maybe not. Let us examine some of the indicators, and see if they lend any credibility to the efforts to protect the Nation's farmlands. Can we have a farm land problem in the middle of a farm production boom? The evidence is that we not only can, we do. But that problem is not well recognized, and is masked by analyses that measure resource adequacy on the basis of annual--or average--production figures.

Americans must begin to think about land, land quality, and land adequacy in a way that will allow us to evaluate the land's needs irrespective of the current situation on agricultural commodity supplies and prices. To aid in that thinking process, we should start with a basic statement of the relationship of agriculture to land.

Agriculture is a man-made ecological system. Viewed through the eyes of an ecologist, agriculture can no more escape certain ecological laws than Newton's apple could ignore the law of gravity. Any ecosystem, whether man-made or natural, must in the long run achieve a steady state in regard to both energy and terials. Fertility, organic matter, energy and water must flow into the system in relationship to outflow, or the system is depleting. The soil is a living resource reservoir of constantly shifting dimensions. If the size and capability

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of that soil reservoir is shrinking, it is certain that, if this trend continues, it will lead to problems.

Agriculture is, to that soil reservoir, like a pump on a well. The food produced can be increased, as can the water from the well, by speeding up or improving the pump. But that will only be profitable so long as the level in the reservoir is maintained. If we begin depleting the reservoir, improvements in the pump and ever-increasing energy inputs become essential in order to maintain current levels of production.

American agriculture is in precisely that position today. Past productivity increases have come through the adoption of new technology and a huge increase in the amount of capital used, during a period when climatic conditions may have been unusually favorable. This has enabled a steadily dwindling number of farmers in America to stay in business by growing larger in size, adopting the latest in techniques, and absorbing narrow (or non-existent) profit margins. But how much more of this trend are we able to absorb? Is the pump speeded up about as fast as it will go? All the evidence indicates that the water level in the well is continuing to drop.

Unless we turn to the land that makes up the "reservoir" from which agriculture "pumps" food, and find ways to reverse the damage and loss that is steadily depleting it, serious agricultural problems seem certain, and in the not-too-distant future. And those problems, because they will affect the Nation's most basic economic industry, will reverberate throughout the entire economy, undermining every effort to slow inflation and imperilling our ability to produce enough export goods to pay for increasingly costly imported oil. The strength of the Nation comes from the land, and the land is in trouble.

Stress on the Land Base

> The amount of cropland that will be paved over, built on, strip-mined, or flooded by a dam by the end of this century is unknown. However, if world population projections materialize, 2.3 billion people will be added between 1975 and the year 2000, a far larger increase than the 1.5 billion added during the preceding 25 years. Given those

> population projections and the projected gains in income, every nonfarm claimant on cropland--urbanization, energy production, transportation--is certain to be greater during the last quarter of this century than during the third.
> -Lester. R. Brown-(2)

To get some idea of the magnitude of the current deterioration of the American farmland base, it is necessary to analyse and combine the major factors causing the land to lose productivity. It is not as simple as measuring the depth of the water in the well to see if it is dropping or holding steady. The farmland resource is a gigantic, complex one, with over 20,000 different kinds of soil used for the growing of crops.(3) Statistical indicators are often lacking, or are difficult to compare with each other, or hard to interpret accurately. But there are enough indicators to provide better insights than ever before, thanks to the accelerated work being done by the Soil Conservation Service in their land inventory and monitoring efforts.

The two main causes of productivity loss are soil depletion and the conversion of farmlands to other uses. Both can be reversed by man, but at such costs that it is prudent to consider both, for practical purposes, permanent.

Preliminary data from the 1977 SCS Erosion and Sediment Survey (4) gives some insights into the erosion loss from the lands currently used as cropland. The survey uses a broad definition of cropland, including row crops, close-grown crops, rotation hay and pasture, occasionally improved hayland, native hay, summer fallow, orchards, vinyards, bush fruit, and "other".

On the 413 million acres included in this "all cropland" category, SCS estimates an average annual sheet and rill erosion loss of some 2 billion tons of soil. Predictably, the rates of erosion are least on the Class I lands (just under 3 tons/acre/year average) and highest on the Class IV and VI lands (averaging from 9 tons/acre/year on all Class IVe cropland to a high of 30 tons/acre/year on Class VIe row-cropped land).

But what does this mean in terms of land loss? How important is a ton of soil, anyway? There are few satisfactory estimates available. So many different

situations exist that it is difficult to generalize. But we can draw some conclusions from this information by converting tons of soil loss into acre-equivalents of productivity loss.

A 4-inch layer of topsoil weighs about 650 tons per acre. Although this will vary for each kind of soil, let us assume that the loss of 4 inches of topsoil will badly compromise the productivity of most cropland, if not make it totally uneconomic to farm. Obviously, there are soils where this will not be the case, but there are many soils in America today that are already badly damaged by past erosion, and another 2-3 inch loss will mean the emergence of rock, clay, hardpan, or other subsurface layers that will limit intensive cultivation.

Thus, it seems reasonable to equate the loss of 650 tons of soil to the loss of one acre-equivalent of cropland productivity. The fact that the soil loss is spread over many acres makes it no less a loss, it only changes the shape of the time-curve on which a specific parcel of land will become totally unproductive.

Table 1. Total annual soil loss to sheet and rill erosion, converted to acre-equivalents of productivity lost from American cropland, by capability class

Capability Class	1977 Cropland acres	Annual Soil Loss tons	Productivity Loss acre-equivalents
I	31,529,000	91,244,000	140,000
II	187,702,000	709,722,000	1,091,900
III	131,710,000	709,388,000	1,091,400
IV-VII	62,226,000	506,603,000	779,300
	413,167,000	2,016,957,000	3,102,600

One fact becomes immediately apparent from Table 1, and that is that two-thirds of the productivity loss being sustained by America's cropland today is coming from the Class II and III lands that make up the bulk of our cropland resource. At the same time, it is clear that the marginal croplands are suffering erosion losses at a far more rapid rate. Class I land, about 9.5 percent of the cropland, only suffers about 4.5 percent of the productivity loss. Equivalent ratios for the other classes of cropland are: Class II--45% of the cropland, 35% of the loss; Class III--32% of the cropland, 35% of the loss; and

Classes IV-VII--15% of the cropland, 25% of the productivity loss. This is not surprising and is, of course, what one would expect to find. Recent trends in farmland use show that farmers have been slowly, but steadily, moving off the marginal (Class IV-VII lands) in favor of the better farmlands. These erosion figures leave little doubt why; the marginal lands are washing out from under the farmers.

When we look at the land lost to urban, built-up, and water storage areas, we get an estimate of acres moved out of the cropland inventory on an immediate and fairly permanent basis. Instead of the insidious, unseen losses from erosion that rob productivity so slowly that few notice, the conversion of a tract of prime farmland from corn to houses is clearly apparent. In the period from 1967 to 1975, it was estimated that about 5 million acres of cropland was lost in this manner, or about 683,000 acres a year.(5) In addition, another 1.6 million acres moved each year from cropland into "other" land, indicating that the magnitude of the impact of land use conversions on agricultural productivity is somewhere in the range of 2-3 times the actual acreage converted at any one time.

Of the land converted to urban and built-up uses between 1967 and 1975, 7 percent was Class I, 30 percent was Class II, 21 percent was Class III, and 42 percent was in Classes IV-VIII. USDA estimated that, during the 1967-75 period, the impact of this conversion affected about 5 million acres each year, with 2 million acres being urbanized, 2 million being isolated, skipped over, or in some other way made unfarmable by the urban growth, and 1 million acres going into water impoundments. (6)

In the 1977 survey, with results to be published soon, Didericksen estimates the average annual acreage of build-up to be about 2.5 million acres. If the trends observed in prior years continue, and one acre is put out of commercial agricultural production for every acre urbanized, we arrive again at the 5 million acre number. If the percentages hold similarly to those seen from the 1975 Potential Cropland Study, Table 2 would indicate the amount of loss likely to be sustained from the different land capability classes.

Table 2. Annual losses of agricultural productivity due to urbanization, water projects, and other building activities in the United States, by capability class, in acre-equivalents.

Capability Class	Percentage of Land Urbanized	Acres Affected	
		Cropland Base	Marginal Land
I	7	350,000	
II	30	1,500,000	
III	21	1,050,000	
IV-VIII	42		2,100,000
Totals	100	2,900,000	2,100,000

Not all of the 5 million acres of urbanizing land comes from cropland, or land that should be considered to have future crop-producing capability. For purposes of this analysis, a conservative estimate of the loss would be to count only those lands in Capability Classes I-III as having future cropland potential. This would meant that the annual losses of agricultural productivity (Table 2) would be somewhere in the 2.9 million acre range. There will be, of course, a small loss of cropland from Classes VI-VIII. This would be minor, however, since those marginal lands account for so little of the future agricultural productive capacity.

Adding the two estimates of the losses to productive capacity from erosion and conversion leads to Table 3.

Table 3. Estimated annual loss of United States agricultural productivity, in acre-equivalents, due to soil erosion and conversion to non-agricultural uses, by capability class.

Capability	Loss to Erosion	Loss to Conversion	Total Loss	(%)
	(Acre-Equivalents)			
I	140,000	350,000	490,000	(8%)
II	1,091,900	1,500,000	2,591,900	(43%)
III	1,091,400	1,050,000	2,141,400	(36%)
IV-VIII	779,300	0	779,300	(13%)
Total	3,102,600	2,900,000	6,002,600	

These figures represent a conservative estimate of the magnitude of the loss ' 'ng sustained from the American farmland base. They are not individual and discrete acres being covered by asphalt or concrete in an absolute and permanent conversion, but they represent the productive capacity being lost each year through the combined forces of soil erosion and land use conversion.

The loss of productive capability that results from the combination of soil erosion and land use conversion is not only large, but it will get larger at an increasing rate. Not only are both processes self-reinforcing; they are also interactive.

Soil depletion not just a steady loss. It accelerates with each increment of topsoil that is washed away, resulting in less absorbtive capacity, organic matter, and plant growth to protect the soil when rain strikes again. Farmland conversion, likewise, feeds on itself. Each plot of farmland lost breeds not only new houses that consume rural resources and services; it also creates another group of farmer-speculators who decide that the time is soon coming when the land will make more money by being sold than by being maintained as a ,.oducing farm.

The interaction between the two processes is more subtle, but no less real. As erosion eats away the productivity of the land--affecting the most marginal lands fastest--it forces more reliance on the prime farmlands of the nation. Yet these are the lands taking the disproportionate share of the urbanization and build-up, so the competition for them is growing from two directions. As good lands become urbanized and unavailable for food production, it forces agriculture onto the more marginal lands, signalling a new round of soil erosion and new pressures on the land and water base.

The losses being taken from the American farmland base are not insignificant. Of the 413 million acres currently in the cropland inventory, they represent some 1.5 percent annually. Of the 135 million acres estimated to remain as potential cropland for future use, they represent over 4 percent annually, meaning that the equivalent of the nation's reserve of cropland could lost in a 25-year period. These are alarming estimates, and lead one to question why there is not more concern. A partial answer may lie in the way in which we place value on the land itself.

The Value of Land

> The real wealth of the planet is its natural resources. Our real wealth is our ability to use these resources without destroying their source. Money has no value unless it represents energy, food, materials, or products. No amount of monetary manipulation can create natural resources.
> -Laurence J. Peter-(7)

What is land's real value to man? Is it a store of basic wealth--a quarry to be mined for the products needed for survival, comfort, or pleasure? Certainly. But it is also more. It is the living, dynamic bridge where crops convert solar energy to human food. It spans the gap between death and life, between what was...and what is to be.

And there is a qualitative dimension to land--as important as any quantitative measure. Not every soil is of equal value to man--or to nature itself. Varying from thin, stony, cold or dry to deep, fertile, and loamy; the patterns of soil that mantle the landscape array themselves in an endless mosaic of value. Additionally affected by climate, slope, vegetation, and the changes wrought by the hand of man, the resulting landscapes can be readily categorized on a qualitative scale.

But what shall be highest on that scale? What kinds of land will people decide are most valuable--most important for human needs? The choice is obvious: farmlands; those lands that produce food. On the qualitative scale, these lands have no peer in terms of their value to people. We treasure mountains... glaciers...deserts...swamps. They are of value in many ways. But is their value so basic as the value of the land that grows food? Hardly.

We treasure scarcity, and the fact that there are certain landscapes that are unique provides a justifiable basis for concern about their preservation. But are not the food-producing lands more essential to man, and therefore of a higher value?

We have, particularly in years of beneficent climate, an abundance or even a surplus of food. Does this mean that the food-producing lands are of less value. Does this mean we can waste farmlands without fear of future reprisal? Does the qualitative value of land rise and fall with annual rainfalls, or new technical

breakthroughs in agricultural technology, or man's tinkering with monetary or conomic systems? Superficially, it can be argued that this is the case.

Measured in economic value, the price of land responds rapidly to economic events. When investors fear the stability of stocks, bonds, or other forms of investment, they turn to land. Their demand drives prices up, making land look all the more lucrative and attracting additional investors. And on and on. But what do the resulting price spirals mean in terms of the land's real value?

When climate has been unfavorable, food stocks drop and prices rise. Land prices skyrocket as investors rush to take advantage of the food price bonanza. They inevitably over-produce when climate returns to a more favorable condition. Stocks rise to glut proportions, and prices plummet. But what of the land? Has it changed value?

We confuse price with value, and money with wealth, and herein lies much of our inability to think straight about the value of farmland.

It is clear that farmland values are not measured simply by price, and that there is a fundamental difference between money and wealth. But economic analysis does not measure--or even recognize--these differences.

The Problem with Economics

> Economics, as currently constituted and practiced, acts as a most effective barrier against the understanding of these (natural resource) problems, owing to its addiction to purely quantitative analysis and its timorous refusal to look into the real nature of things. -E.F. Schumacher-(8)

The economic dimensions of farmland protection are important, and must be carefully and properly addressed, but farmland protection is not an economic issue. It is a conservation issue with an economic dimension. This difference, while at first perhaps appearing to be merely a play on words, is very real, and equally important.

The economic value of land lies in the amount of profit--measured in money--that the land can return to its current tenant. If it is cheaper this year to import food from elsewhere, and more profitable to build condominiums

than plant corn, economic anaylsis tells us to convert or abandon farmland.

One problem with this elementary economic measure is that it treats natural resources in the same fashion as man-made resources. Land becomes an asset to be converted into dollars. The more dollars, the better; the faster, the better. Success--or "good"--comes from profit.

In practical terms, this sort of thinking leads respected American economists to argue that land is best used by being destroyed; that foreclosing the feasible opportunities for future people to harvest food from the land for all time is of no consequence so long as the current owner nets the maximum dollar profit today.

But what are the real values involved? Should we convert prime farmlands to housing tracts on the basis that mediocre lands elsewhere can be exploited for current food needs? Is it rational for people to treat prime farmlands with the same attitude that they would use in trading automobiles? Is $5000 worth of prime farmland, which people did not make and cannot replace once it is lost, to be given the same value as a $5000 car?

The obvious problems with such an approach mean that some force other than simple economics must help guide the use of natural resources, particularly land. There are, after all, higher values than money and better measures of good and evil than costs and profits. But to find such measures, we must look to ethical, not economic, values.

The Ethical Dimension

> An ethic, ecologically, is a limitation on freedom of action in the struggle for existence. An ethic, philosophically, is a differentiation of social from anti-social conduct. -Aldo Leopold-(9)

The search for a land ethic in America is neither new nor novel. It has been the basis for the conservation movement from the beginning. But an ethic is a state of mind. It doesn't occur; it develops. With the doubled pressures of soil erosion and land use conversion threatening the productivity of the land as perhaps never before, it is time for a new public debate to review the prevailing

land ethic. The symptoms of land abuse indicate that our current ethic is in drastic need of improvement.

We do not use a Van Gogh painting for a doormat. Not because doormats have no value--they are very functional, indeed. Not because Van Gogh paintings are so prized for the dollar value of the canvas or the oil. No, we value the Van Gogh as a treasure, a delight to the eyes, succor to the spirit, a reflection of man's highest creativity. We give it a place of honor and protect it for people of all ages to treasure.

We must begin to look on farmlands in the same way. And farmlands, like paintings, have different values. Not all produce alike, given the same level of human management or economic input. Some farmlands are, obviously, of much greater real value than others. And those are the lands, as we have seen from our earlier estimnates, that are being lost at the most rapid rate.

Americans must begin to assess the possibility that anti-social conduct in relation to the land is becoming a very real--and serious--threat to the continued existence of our society. The capability to produce ample supplies of food--far more than enough to feed our own people, has long been assumed by most Americans. But is it only Americans that we must consider?

The loss of 6 million acres of productive capacity a year equates to over 115,000 acres each week; over 16,000 acres every day! That means that our weekly losses in productivity are greater than the annual production capability of many of the world's nations. Those nations, where people starve when the weather turns bad, look to us as a reliable source of food when they need one. That may be, in the near future, an unfounded hope.

But how much suffering around the world and economic stress at home will be needed before we move toward a new ethical basis for treating our land? How long will we, as Bob Cahn has said, "take for granted that the waters, the soils, the trees, and the wildlife can be manipulated at will in the name of progress, even if that progress is short-lived and far outweighed by the loss of the lands long-term ability to benefit mankind?"(10)

What is needed, clearly, is a new land ethic--an ethic forged of our tw' concerns for the land's proper use and its proper care. We must begin to treasure the prime farmlands that have made us the world's richest nation, keep them available for agricultural use, help farmers survive economically and environmentally so that they can profitably produce from them, and insist that they be used in such a manner that soil depletion is minimized. That must be the nature of a new ethic.

But the emergence of a land ethic strong enough to offset our current proclivity to measure in narrow economic terms will not come easily. As Rich Collins has pointed out "An ethic powerful enough to alter patterns of land use must necessarily challenge other accepted habits and vested interests."(11) There are also important values which must be confronted, including individualism, liberty, property, the pursuit of happiness, and the right role of government.

It may be, as Collins proposes, that "The land, because it is so intrinsically important as a source of nuture for life and pastoral values, as well as being the basis for deeply rooted Jeffersonian ideals of individualism and human freedom, is the battleground for the Nation's future."

If land and land use are to be a battleground, then facts, trends, and ideas must be the major weapons. The new land ethic must be a product of education and social evolution. It can't be written, legislated, or imposed on people. It must change first, the way we Americans think about land. Only then will it successfully alter the ways in which we use this vital resource.

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Mr. HANCE. The next witness is Dr. William E. Larson, Research Soil Scientist of USDA–SEA–AR, University of Minnesota.

Please proceed, Dr. Larson.

STATEMENT OF DR. WILLIAM E. LARSON, U.S. DEPARTMENT OF AGRICULTURE, SCIENCE AND EDUCATION ADMINISTRATION, AGRICULTURAL RESEARCH AND PROFESSOR OF SOILS, UNIVERSITY OF MINNESOTA

Dr. LARSON. It is a pleasure to be here.

Over half of the land used for crops in the United States is subject to sheet and rill erosion with a susceptibility ranging from moderate to very severe.

Soil losses on cropland amounted to almost 3 billion tons or an average of about 9 tons per acre in 1975.

Soil loss for most of our productive agricultural soils should not exceed 5 tons per acre per year for sustained crop production.

Currently the estimated soil loss is nearly twice this amount (fig. 1, 11).

Wind erosion, largely in the Great Plains, is also detrimental to sustained crop production.

Of the 29 Major Land Resource Areas (MLRA) in the Great Plains, wind erosion is probably excessive on more than two-thirds of them (10, 11).

Many of the soils in the Great Plains are subject to both wind and water erosion (10, 11).

Most of the projections for needed erosion control practices are based on estimated erosion rates in relation to a soil loss tolerance value (T value).

The T value defines the maximum annual soil loss that can be sustained without adversely affecting the productivity of the land. This value ranges between 2 and 5 tons per acre per year depending upon the properties of the soil.

The T value is arrived at from consideration of (a) the time required for development of soil from geologic materials, (b) downstreams sedimentation, (c) nutrient removal in sediment, and (d) depth of soils.

The soil loss tolerance concept and numerical values have been used for about 30 years with little change.

However, because the T value is partly subjective, discussion continues as to absolute numbers. It would take 33 years to remove 1 inch of soil at the 5-tons-per-acre-per-year rate.

The T value should be considered as the amount that might be removed from a point in the field. It should not be considered as the allowable amount leaving a field or farm. In most cases, the latter should be less than the soil loss tolerance.

Tillage and the proper use of crop residues can be the best means to control wind and water erosion and maintain the quantity and quality of water running off agricultural land (6).

It has been suggested that crop residues (e.g., cornstalks, cereal straws, etc.) represent an immediate source of biomass for energy production (3,8).

Because widespread removal of crop residues might not be in the best interest of agriculture, we recently completed a nationwide study which estimated the amounts of wind and water erosion, and runoff from the MLRA's as influenced by five tillage and residue management alternatives.

The practices were: X_1, conventional tillage (fall moldboard plow, residue removed); X_2, X_3, conservation tillage, such as chisel plow, with 1,500 and 3,500 pounds per acre of corn residue left, respectively; and X_4, X_5, no-till (no tillage except in the seed row) with 1,500 and 3,500 pounds per acre of corn residues left, respectively.

Widespread removal of crop residues would increase wind and water erosion on cultivated land in the United States.

Because erosion on much of the Nation's cultivated area already exceeds tolerance limits, any increase would be particularly serious.

Estimated annual erosion rates in the Corn Belt range from 19.9 tons per acre in MLRA 107 (western Iowa) to 4.3 tons per acre in MLRA 103 (north-central Iowa and south-central Minnesota) for a conventional fall-plow, spring-disc tillage system with all residues removed.

Corn Belt cropland adequately protected against water erosion increased from 36 percent for conventional tillage with all residues removed to 78 percent for no-till with 3,500 pounds of residues per acre on the soil surface.

The remaining 22 percent of the cultivated area in the Corn Belt requires additional conservation treatments to reduce soil loss to acceptable levels.

All water erosion amounts are estimates of soil removal from a land unit in the field, not sediment delivery to a stream.

The crop management (C) factors used in the universal soil loss equation for MLRA 107 in western Iowa with a corn-corn-soybean rotation were 0.49 for conventional tillage (residue removed), 0.42 for conventional tillage (residue left), 0.27 for conservation tillage (residue left), and 0.18 for no-till (residue left).

If all other factors in the equation remain the same, therefore, the erosion reduction compared with conventional tillage (residue removed) is 14 percent for conventional tillage (residue left), 45 percent for conservation tillage, and 63 percent for no-till.

Enough crop residues are produced to protect against wind erosion over about 55 percent of the Great Plains, assuming the soil surface is smooth and residues are left on the surface.

If the soil surface is maintained in a rough condition (K=0.05), there is sufficient residue to protect against erosion over 85 percent of the region (10).

In the Southeast weighted average soil loss with conventional tillage and residues removed exceeded tolerance limits in 13 of 14 MLRA's studied.

Conservation tillage significantly reduced potential soil losses in all MLRA's.

In four of six States 60 percent of the crop residues were needed for water erosion control.

About 90 percent of the residues were needed for water erosion control in Alabama and Mississippi.

In MLRA's B7, B8, and B9 in Northeast Oregon, 1.4 million (M) tons of small grain residue are produced yearly, of which 60 percent could be removed from 88 percent of the harvested 850,000 acres without causing excessive erosion (1).

The increased acreage of land in row crops on many MLRA's has increased erosion on the land.

The percentage of the cultivated acres in corn plus soybeans for MLRA's 103 (MN–IA0, 106 (KS–NE), 108 (IA–IL), and 110 (IL–IN) is 86, 69, 85, and 91, respectively.

Decreasing row crops acreage on the cultivated land in the Corn Belt from 100 to 75 to 50 percent decreases predicted erosion from a relative value of 1 to 0.75 to 0.50 (approximately), respectively.

If the percentage of row crops on slopes over 5 percent could be reduced substantially, it would reduce the need for erosion control practices.

Of the 41 million (M) acres of corn grown in the Corn Belt we estimated that about 20 percent is grown on slopes of 6 percent or greater.

Plant residues, if managed properly, deter runoff.

Up to 1.0 inch of additional water can be stored in the soil to enhance plant growth with plant residues on the surface as compared to residues removed (9).

Onstad and Otterby (9) estimate that the increase in retained water for straight-row corn on hydrologic group B soils (moderate infiltration) would vary from 0.2 inch in the Great Plains to 2 inches in the Southeast.

On hydrologic group D (high runoff potential) soils the increase would vary from 1.0 inch in the Great Plains to 5 inches in the Southeast.

According to these estimates, runoff would be eliminated during most small storms and reduced for all storms.

The resulting increase in soil water storage would be greatest on less permeable soils.

In the western Corn Belt this added water could increase corn yields 10 bushels per acre.

On most soils, management of plant residues on the soil surface would improve surface water quality by decreasing sediment and nutrient concentrations.

Erosion removes large amounts of plant nutrients from the soil.

Eroded sediment contains about twice the amounts of nitrogen, phosphorus, and potassium as the bulk soil from which it was derived.

For calculating nutrients associated with soil loss, we used the value of 0.9 pound phosphorus per tons of soil for all major land resources areas (MLRA's).

For nitrogen the values varied depending on the level of the soil.

Based on these concentrations and the computed soil loss, the average amounts of nitrogen and phosphorus contained in the eroded material for practices X_1, X_2, X_3, for selected MLRA's is given in table 1.

Note that the estimated nitrogen removal in MLRA 108 (central Iowa and central Illinois) varied from 123 to 51 pounds per acre per year depending on management practice.

Much lower amounts of nutrients are contained in the eroded sediments of the Southeast and Northwest because of inherently lower amounts in the soils.

The Soil Conservation Service (11) estimated the changes in management practices required to reduce average annual soil losses from 9 tons per acre per year in 1975 to 4 in 1985 and 3 in 200.

A linear programing model was used in making the projections.

It was assumed that cultivated acres would increase from 335 million in 1975 to 360 million in 200.

The extent and intensity of management measures and land treatment required to move from the 1975 condition to the year 2000 condition are summarized below:

1. Reduced 141 million cropland acres with "no conservation treatment" by 80 percent.

2. Reduce "crop residue use" as a single conservation practice from 109 million acres to 34 million acres, a decrease of about 70 percent.

This conservation practice becomes increasingly beneficial when combined with one or more other conservation practices.

The decline in this practice as a single practice, simply, means that it can be made more effective by using it in combination with other conservation practices.

3. Increase the amount of land with terraces and minimum tillage from slightly less than 1 million acres to 15 million acres.

4. Increase the amount of land with terraces and crop residues left on the surface from 12 million acres to 44 million acres.

5. Increase the amount of land with stripcropping and minimum tillage from about 1 million to 35 million acres.

6. Increase the amount of land with stripcropping and crop residues on the surface from 8 million acres to 18 million acres.

7. Increase the amount of land with contour farming and minimum tillage from about 2 million acres and 42 million acres.

8. Increase the amount of land with contour farming and crop residues on the surface from 8 million acres to 56 million acres.

Adoption of the practices outlined above on the needed acreage would be a tremendous task in technical education and design layout, as well as cost.

For example, increasing the acreage of terraced land from 13 million to 59 million acres would cost nearly $10 billion—at $200 per acre.

Most of the practices outlined are not new but have never received widespread acceptance.

Certainly we don't have the technology to apply all of the needed practices outlined in the most efficient manner.

In short, we do not have all the answers.

A greatly expanded program in research and education is needed so that we can better fit the practices together on each soil mapping unit.

This design information needs development in such a way that scientists and farmers alike have confidence in its applicability.

To get the practices on the land to meet the soil and water needs, environmental protection, and crop production desired is a gigantic task.

We recognize about 10,000 soil series on the 360 million acres of cultivated land.

And these occur in different slopes and under different weather conditions.

But we also need a technology delivery system that can predict with confidence the best management practices on each farm.

This prediction delivery system needs as input soil survey and related soils information, climatic, cropping, and engineering data.

This large data bank and software should be assembled at a central national location.

Access to the central data bank should be readily available to all who wish to use it.

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We have had enough experience with development of prediction models to know that—with proper input—we can develop computer-based technology delivery systems.

Obviously it will also require a large effort, will require bringing together data from many sources, and the development of new information.

It will also require much field testing to give us the needed confirming data.

It is a job upon which we need an expanded effort.

[Table 1 and figure 1 as presented by Dr. Larson follow:]

TABLE 1.—NITROGEN AND PHOSPHORUS IN ERODED SOIL FOR SELECTED MAJOR LAND RESOURCE AREAS OF THE CORN BELT

Major land resource area	Location	Nutrients in eroded sediment tillage and residue practice *		
		X_1	X_2	X_3
	Nitrogen (pounds per acre):			
106	Northeast Kansas, southeast Nebraska	96	77	40
103	North-Central Iowa, south-central Minnesota	54	39	25
108	Central Iowa, central Illinois	123	89	51
111	Central Indiana, central Ohio	48	32	21
	Phosphorus (pounds per acre):			
106	Northeast Kansas, southeast Nebraska	32	26	13
103	North-central Iowa, south-central Minnesota	11	9	5
108	Central Iowa, central Illinois	31	22	13
111	Central Indiana, central Ohio	16	11	7

* X_1=Conventional tillage (fall moldboard plow, residue removed). X_2=Conservation tillage (chisel plow) with 1,500 lb of plant residue on the soil surface. X_3=Conservation tillage (chisel plow) with 3,500 lb of plant residue on the soil surface

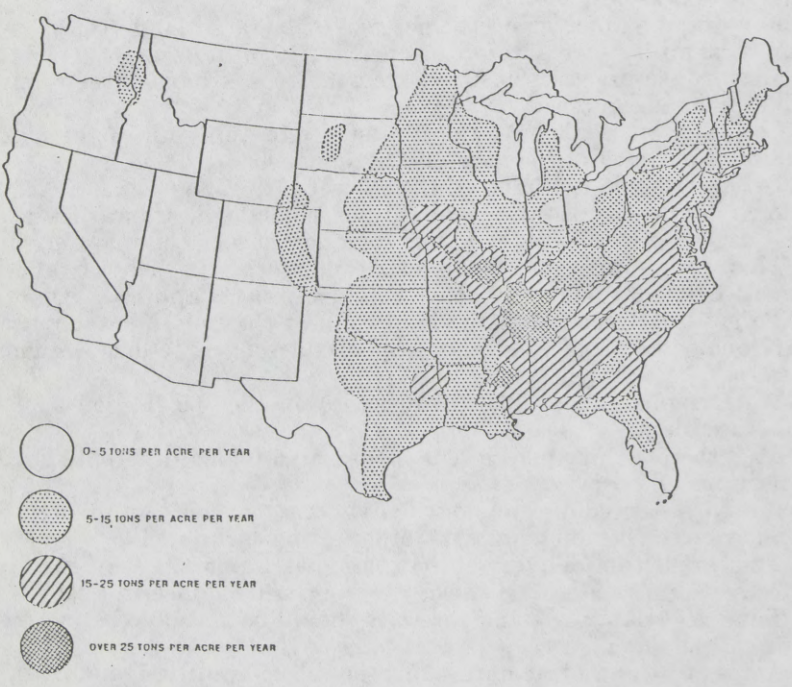

FIGURE 1.—Sheet and rill erosion from water on cropland, 48 States in 1975

Mr. BALDUS [presiding]. Thank you very much, Dr. Larson. I understand you will stay and participate in the panel discussion?

Dr. LARSON. Yes.

Mr. BALDUS. Thank you.

Dr. LARSON. Thank you.

Mr. BALDUS. Our next witness is Mr. Joseph Krivak, Deputy Director, Water Planning Division, EPA.

Mr. Krivak is to speak on nonpoint pollution.

STATEMENT OF JOSEPH KRIVAK, DEPUTY DIRECTOR, WATER PLANNING DIVISION, ENVIRONMENTAL PROTECTION AGENCY

Mr. KRIVAK. As you requested, my remarks will address nonpoint pollution on agriculture and their effects on water quality.

You have raised important and challenging questions and I welcome the opportunity to address them.

On many points there are no absolute certainties or readymade solutions.

However, I believe my testimony will provide a better understanding of the scope of the problem, furnish the committees with information on programs of the Environmental Protection Agency which address nonpoint source activities in agriculture, and provide insight on new initiatives which may be required to meet our Nation's environmental goals.

Last week the Administrator of the Environmental Protection Agency, Doug Costle, in a hearing before the Subcommittee on Oversight and Review, House Committee on Public Works and Transportation, stated that without effective controls, nonpoint pollution would prevent achievement of our 1983 goal of fishable and swimmable waters in parts of river basins in at least 37 States.

There is little doubt that nonpoint sources have a direct, serious impact on the uses Americans make of water.

Nonpoint source pollution has appeared in community after community as a pathway for toxic and hazardous pollutants with direct effects on human health.

We view with increasing concern the frequent findings of heavy metals, pesticides, and herbicides in both rural and urban runoff.

In many rural areas, nonpoint sources have contaminated family wells and livestock water supplies.

Saline pollution, which is also nonpoint in nature, significantly impairs yields of many irrigated crops in Western States.

There are many pollutants from nonpoint sources which can degrade both surface and ground water quality.

Perhaps at this point a brief description of nonpoint source pollution would be helpful.

Storm water runoff brings pollutants from farmland, urban streets, construction sites, and mines into streams and lakes.

Because these pollutants enter our waters in a diffused form, spread out over the entire landscape, we call them nonpoint source pollution.

In contrast, point sources are discharges from industries and municipalities which enter our waters through a conveyance such as a ditch or a pipe.

State and local agencies have been developing water quality management programs under section 208 of the Federal Water Pollution Control Act since 1974.

The initial planning phase is almost completed.

As of July 2, 1979, 107 of the local plans have been certified by the State and 68 have received EPA approval.

Of the statewide plans, 22 have been certified and 7 approved.

The remaining 225 plans will be completed by December 1979.

The information in these plans provides us with much more data on nonpoint source pollution than we have had previously.

I would hasten to add that we will need to know a great deal more before we can be certain of the most effective ways to control all significant sources of nonpoint source pollution.

We need better cause and effect data on the impact of specific sources and on how well specific control measures work.

Agricultural activities are the most widespread cause of nonpoint source problems, affecting over two-thirds of the river basins in the Nation.

Table 1 provides nonpoint source data for all regions in the country.

The regions most affected by agricultural nonpoint source pollution are the North Central, South Central, Southwest, and island regions.

Sediment is the major problem in the North Central region, primarily from spring snowmelt, and in the islands from heavy rains.

Irrigation return flows are the major problem in the Southwest region. This region reports many more problems with dissolved solids (salinity) than the rest of the country.

While every region of the country is affected significantly by some type of nonpoint pollution, the types of problems vary dramatically from region to region, according to the topography, climate, and types of land use which prevail.

One implication of this is that the solution of nonpoint source problems will require a flexible approach which takes these variations into account.

Many specific examples of agricultural nonpoint source problems have been identified in 208 plans and are shown in attachment 1.

These examples show how various aspects of agricultural pollution disrupt recreation, water supplies, and fisheries, with a variety of pollutants ranging from sediment to synthetic organic chemicals.

Let me note just a few:

North Carolina.—Average total nitrogen levels of 7 mg/1 were found in Union County on a creek tributary to Lane Creek where fish kills and 0 mg/1 DO were observed.

Animal operations are believed the cause.

Herbicide related fish kills are found in Richardson Creek and Twelve Mile Creek.

Erosion rates of 20–60 tons/acre/year have been observed in areas of the State.

On the upper Neuse River, DO concentrations fell to about 1 mg/1 during certain storm conditions.

During all storm events measured, high concentrations for suspended solids were observed in both the small streams and larger rivers.

The Chowan River has experienced severe algal blooms which have affected fishery resources in the estuary, ruined recreational beaches, and resulted in objectionable odors and deposits of decaying algae.

About 85 percent of the nitrogen input is from nonpoint sources, with agricultural areas accounting for 50 percent of the total.

Arkansas.—The one basin intensively studied, 2 million tons of sediment are delivered each year; out of 60 streams in this basin, 47 are not suitable for swimming and 37 not suitable for fishing because of agricultural nonpoint sources; streams in eastern Arkansas violate criteria for the pesticide Toxaphene.

Montana.—The Missouri, Yellowstone and the Big Horn Rivers have approximately 4,000 stream miles degraded by nonpoint source pollution—13 percent of State's streams.

Sediment causes 2,500 miles to be degraded and salinity affects 1,400.

Parameters violated are salinity, bacteria, nutrients and suspended solids.

Nonpoint source pollution is a problem not only because of its scope and the large number and amounts of pollutants involved, but also because of the associated economic, social, institutional, and political issues which are difficult to resolve.

Some of the more important issues are the costs of nonpoint source control; the need for regulatory, as opposed to voluntary, control programs; and complexities in water law.

An emerging issue and one possible benefit that could come from increased emphasis on nonpoint source control is energy conservation and production.

1. Cost

Best management practices, although they are generally less expensive than capital intensive facility construction, nevertheless represent a significant demand on manpower and financial resources which must be added to, or diverted from, existing programs.

Best management practices (BMPs) are methods, measures, or practices to prevent or reduce water pollution. They include both structural and nonstructural measures.

Economic, institutional, and technical factors are considered in developing BMPs.

While there is no overall estimate of nonpoint source control costs—partly because we have not identified all the problems—we do have information on the costs of individual activities in specific areas.

BMP implementation costs for agriculture have been estimated as high as $10 billion if all cropland and grazing lands are treated.

However, it may not be necessary to protect the entire land resource to enhance or maintain water quality.

A substantial portion of the more than 400 million acres in crop production may not require BMPs for water quality protection.

The implication is that the ultimate cost of BMPs for water quality should be susbtantially lower than the cost of installing practices on all farm lands.

Consider the following facts:

The USDA National Erosion Inventory (December 1978) indicates that the average annual soil loss is less than 3 tons/acre in 20 States and less than 5 tons/acre in 11 other States.

Thus, 31 States are within the prescribed target of 5 tons/acre, at least on average.

Studies in the Great Lake Basin showed that 60 percent of the sediment load was generated from 30 percent of the agricultural land.

The Black Creek, Ind., study funded by EPA indicated that treating only 80 acres of highly erosive soils out of the watershed's 1,800 total acres could reduce the total sediment load by 40 percent.

2. Regulatory versus voluntary programs

The application of BMP's for nonpoint sources differs from the application of point source controls in that management agencies must work with private citizens—farmers and ranchers—as opposed to local governments or corporations.

In dealing with owners of lands causing nonpoint source problems, the 208 program has used both regulatory approaches and voluntary programs.

Iowa, South Dakota, and Pennsylvania have all adopted regulatory controls for agricultural erosion and sediment problems.

All States are subject to regulatory controls on feedlot discharges through the Clean Water Act.

In the absence of regulatory controls, the voluntary control process appears to be working in the early stages of 208 plan implementation.

The model implementation program (which I will explain later in my testimony), which EPA and USDA initiated in 1978 has brought levels of landowner participation beyond our expectations.

In the first seven prototype project areas, well over half of the farmers contacted agreed to implement the necessary BMP's.

EPA and USDA are seeking a better understanding of the social and economic aspects of voluntary nonpoint source controls.

An attitude survey is underway in Nebraska, and research is beginning to quantify offsite water quality benefits to downstream users.

3. Water law

An issue of increasing importance, especially in the West, is the question of water rights.

While this question has normally involved surface water issues in the past, both the increasing use of ground water and spreading ground water pollution problems make it imperative that we address both surface and ground water rights in the future.

The States' water rights authority is well recognized. There will be no attempt to change water rights authority through section 208.

However, EPA will work closely with the States as they identify problems in this area and address the institutional and constitutional problems regarding water rights.

A number of States have recently made major decisions on water rights which enhance water quality use, including Idaho and Colorado.

4. Energy

The changing energy picture will have a great impact on the development of best management practices.

Research in this area will need to be accelerated.

In some cases, BMP's have a positive effect on energy use.

For example, no-till, a method of planting which is very effective in reducing erosion, is much more energy and labor efficient than conventional tillage and planting methods.

In some situations, it also produces higher yields.

More study will be required to identify which soils are suitable for no-till and to determine whether there are significant adverse effects from the additional pesticides no-till methods require.

The Agency is funding a research project in California to determine whether animal wastes can be used to produce methane gas economically.

Since these wastes have been contributing to water pollution problems in the State, a solution will produce both water quality and energy benefits.

Another area that holds promise for energy savings is irrigated agriculture.

Salinity problems in irrigation return flows may result from too much water being used on crops.

The most efficient BMP may often be to control water application, in some cases reducing it to less than half of the amount formerly used by the farmer.

In those cases where pumping is needed to transport the water, the reduction in water use will save energy and enhance the water quality.

This illustrates only a few of the current BMPs which can have a positive effect on energy costs.

AVAILABILITY OF BEST MANAGEMENT PRACTICES

While we recognize that data gaps exist and that more information is required for the water quality management program to be fully effective, we do have a large body of knowledge on nonpoint controls that is already being successfully applied.

One of the initial steps in 208 planning was to determine the availability of best management practices.

Where it was determined that cost-effective BMP's existed, they were adopted in the plans and approved by EPA.

Generally, they were practices which had previously been used by farmers and ranchers to reduce sediment and water runoff.

This previous experience provides strong assurance that they are the most feasible and cost-effective methods now available to solve some of the more easily identified nonpoint source pollution problems.

Perhaps the most extensive knowledge is available for agricultural BMP's, since many of them have been used as soil and water conservation practices.

A recent Cornell University report provides the most complete information available linking the effectiveness of soil and water conservation practices (SWCP's) to reduction in pollutants.

The Cornell study concluded that:

1. SWCP's significantly reduce edge-of-field pollutant losses in runoff.

Reductions of solid-phase pollutants (sediment, strongly adsorbed pesticides, organic nitrogen, fixed phosphorus) are substantially greater than reductions of dissolved nutrients and pesticides.

The magnitudes of pollutant reductions are site-specific, depending on local weather, soils, and crop management.

2. SWCP's will not reduce total (runoff plus percolation) edge-of-field nitrate losses unless they also reduce fertilizer nitrogen applications.

3. Cropland erosion controls may not efficiently reduce sediment loadings to streams unless they are concentrated on lands with high sediment deliveries.

4. SWCP's often have negative or marginal short-term monetary benefits to the farmer.

In many cases, however, conservation tillage and nontillage can increase farm income.

5. Although SWCP's were not extensively compared with other pollution control measures, it is apparent that efficient management of chemical applications to croplands has significant potential for reducing pesticide and nitrogen losses. Although such management is not always operationally or economically feasible, it does provide a major alternative to the use of SWCP's for pollution control.

A more comprehensive summary of the principal available practices for controlling agricultural nonpoint source pollution, with brief descriptions of their effects, is contained in attachment II.

DATA NEEDS

The approach we should take to reach the goal of fishable and swimmable waters is the one that is most cost effective.

However, we lack information to evaluate the application of a specific BMP in a specific situation and the resultant improvement in downstream ambient water quality for the receiving waters.

For example, agricultural residues of nitrogen and phosphorus may enter surface and ground water from runoff and leaching of animal wastes, fertilizers, and crop residues and from movement of sediments with adsorbed nutrients.

However, the total amount of nitrogen and phosphorus lost to surface or ground water in any specific situation depends on many variables.

For cropland, these variables include application rates, soil properties, terrain, cropping practices, and rainfall amount, intensity, and duration.

Many experiments have determined the amount of nutrients lost in individual agricultural situations, but we cannot predict how effective a particular BMP will be when applied to a particular farming enterprise when we have no previous data on that particular farm for receiving water.

We need to develop a better understanding of these relationships so that we can make accurate predictions without having to collect specific BMP cause-and-effect data for each site.

We also need more work done on NPS pollution occurring from natural sources.

While the state-of-the-art is improving, our techniques are quite general.

EPA has approached the data needs problem in two ways:

1. EPA's Office of Research and Development has initiated studies which will seek answers to these problems both through computer modeling and onsite techniques, and

2. EPA in cooperation with USDA has initiated a series of demonstration projects in agricultural areas where project monitoring is being used to provide insight into these problems.

Let me briefly describe the research activities.

A more complete description is offered in attachment III.

We are concentrating on:

1. Understanding how nonpoint sources affect water quality;
2. Better methods to control nonpoint source pollution; and
3. Effective implementation strategies for nonpoint source control.

CURRENT PROGRESS

Until the 208 program was initiated 5 years ago, little attention had been given to agricultural sources of pollution.

While agricultural activities were generally thought to cause water quality problems in many lakes and streams, there was, and still is, a lack of adequate data on the extent of the problem and the controls required to correct or prevent it.

Many of the answers we need will take both time and money.

However, we have made progress in the agricultural nonpoint source area.

As a result of the initial findings of the 208 program, most States have identified those areas which have the most critical agricultural nonpoint source problems.

EPA is relying on prototype projects to develop cost-effective controls on selected sites for transfer to other sites.

Information transfer is a key aspect of the strategy because of the limited moneys available to monitor and evaluate each project.

EPA recognizes that only a certain level of information is transferable and that it must be tailored to each exact situation.

To enhance the potential of information transfer, EPA has selected prototype projects in a variety of settings with different types of receiving waters, designated uses, possible controls, and involved pollutants.

In addition, on selected projects, EPA is funding detailed monitoring and evaluation of BMPs being implemented.

EPA has placed increased emphasis on these prototype projects to define the extent of the problems, identify cost-effective solutions, and provide a technical base for controls.

The highest national priority for 208 funding is nonpoint source pollution, including urban storm runoff, agricultural pollution, and ground water protection.

To expedite solutions, EPA will continue problem-specific technical assistance contracts with technical experts to assist EPA, the States, and other agencies with their difficult NPS problems.

We have made full use of the expertise and resources of USDA to assist us in implementing agricultural nonpoint source controls.

Their agricultural delivery system is both widespread and effective.

Many farmers and ranchers have applied conservation measures on their lands for years.

Our objective is to accelerate that progress in critical water quality areas and provide more information to land owners regarding more effective BMP's.

Working with the U.S. Department of Agriculture, EPA selected seven critical areas, out of 50 identified by the States, to carry out an accelerated program of water quality management, measure the results, and provide some of the information on nonpoint source pollution that is lacking.

This program, which is named the model implementation program (MIP) has these objectives:

1. To determine how well the agricultural community's delivery system will work in water quality management,

2. To see if farmers will accept a program for establishing best management practices (BMP's), and

3. To monitor the BMP's and water quality to provide information on the best methods for agricultural nonpoint source control and prevention.

The seven projects selected represent various types of farming and are located in New York, South Carolina, Indiana, Oklahoma, Nebraska, South Dakota, and Washington.

Each area has an agricultural nonpoint source pollution problem which adversely affects water quality in downstream lakes and streams.

Program details are found in attachment IV.

The success of the MIP projects encouraged EPA and USDA to expand their cooperative authorities.

In 1979 the Agricultural Stabilization and Conservation Service, USDA, and EPA selected 21 special water quality projects for BMP implementation.

These projects are listed in attachment V.

The benefits to be achieved through a control program on the farms and ranches of the country will be widespread, and may include better crop yields for some areas.

Many benefits will be downstream and not on the farms or ranches where the BMP's are established.

In many cases, the costs of the BMP's for an individual farmer will be greater than the benefits which he receives.

Hence, the need for some financial incentives.

EPA strongly supported the Clean Water Act Amendments of 1977, which recognized the need for assisting farmers in establishing BMP's and authorized a cost-sharing program for that purpose.

The administration requested an appropriation of $75 million to USDA to initiate the program in fiscal year 1980.

Implementing the rural clean water program, as this part of section 208 has been named, will enable EPA and USDA to reduce agricultural NPS pollution in many of the most critical problem agricultural watersheds in the Nation.

In summary, nonpoint source pollution which results from agricultural activities is significant and pervasive.

Every region in the Nation indicates problems in this respect.

The job of controlling nonpoint pollution will not be easy.

The political and economic problems to be solved in applying BMP's are substantial.

In many areas a better technical base on problems and solutions is essential if we are to make effective progress in agricultural nonpoint source control.

If we are serious about meeting our Nations' clean water goals, we must take action to reduce nonpoint source pollution from agricultural activities.

[Attachments to Mr. Krivak's statement follow:]

ATTACHMENT I

Following are specific examples of agricultural nonpoint source problems identified in 208 plans. These examples show how various aspects of agricultural pollution disrupt recreation, water supplies, and fisheries with a variety of pollutants ranging from sediment to synthetic organic chemicals:

Maine: Has identified 9 lakes and portions of 3 rivers (Aroostook, St. Johns, Prestile) as having significant water quality problems (coliform, DO, nutrients, sediment) attributable to agricultural nonpoint sources. Specific water quality standards violations have been documented on some lakes for coliform and DO.

Connecticut: Agricultural erosion statewide was determined to be over 12 tons/acre/year (acceptable value generally 3-5 tons/acre/year). Problems are especially noticeable in Lake Waramug and the Housatonic River. Recreation and water supply uses are being impaired.

Massachusetts: Rural nonpoint source problems (agricultural runoff and erosion, livestock, and rural septic systems) are causing eutrophication problems in several lakes and reservoirs in Berkshire County, which are critical because of water supply and recreation demands of tourist industry. Some 60-90 percent of nutrient loadings to these lakes are from nonpoint sources. Water quality standards violations have been documented for nutrients, coliform, and dissolved oxygen.

Delaware: Rural nonpoint source (agriculture, animal wastes, and rural septic systems) are causing coliform and nitrate problems in ground water drinking supplies in Sussex County. Water quality standards violations have been documented (60-100 mg/l nitrates; standard is 10 mg/l).

Virginia: Agricultural and urban runoff are contributing to eutrophication threatening Occoquan Reservoir (drinking supply for 700,000) and may negate benefits of a very expensive AWT plant.

Maryland: Animal wastes and other agricultural runoff are resulting in coliform water quality standards violations in several rivers (Northeast Maryland, Carrol County, Frederick County, and Howard County) and two reservoirs (Lock Raven and Liberty) which supply drinking water to Baltimore.

North Carolina: Average total nitrogen levels of 7 mg/l were found in Union County on a creek tributary to Lane Creek where fish kills and 0 mg/l DO were observed. Animal operations are believed the cause. Herbicide related fish kills are found in Richardson Creek and Twelve Mile Creek. Erosion rates of 20-60 tons/acre/year have been observed in areas of the State. On the upper Neuse River, DO concentrations fell to about 1 mg/l during certain storm conditions. During all storm events measured, high concentrations for suspended solids were observed in both the small streams and larger rivers. The Chowan River has experienced severe algal blooms which have affected the fishery resources in the estuary, ruined recreation beaches, and resulted in objectionable odors and deposits of decaying algae. About 85 percent of the nitrogen input is from nonpoint sources, with agricultural areas accounting for 50 percent of the total.

Tennessee: High total phosphorus and total nitrogen loadings from agricultural land use have resulted in the Chickamauga and Nicajack Reservoir being classified eutrophic. Algal bloom preclude recreation in certain areas.

Illinois: Eighteen public water supplies in Illinois periodically exceed the nitrate level recommended to prevent methemoglobinemia in infants (similar in effect to the "blue baby" syndrome). A majority of Illinois surface waters violate phosphorous and heavy metal standards at intervals throughout the year.

Arkansas: In one basin intensively studied: 2 million tons of sediment are delivered each year; out of 60 streams in this basin, 47 are not suitable for swimming and 37 not suitable for fishing because of agricultural nonpoint sources; streams in eastern Arkansas violate criteria for pesticide Toxaphene.

Louisiana: Lake Providence (Quanchita Basin) and Round Lake have deteriorated due to high sediment and pesticide residues from agricultural nonpoint sources; private and commercial fishing has been banned by the State in Lake Providence because Toxaphene levels in fish violate standards.

New Mexico: The State projects problems for present and future use of San Juan and Rio Grande Rivers for irrigation due to sediment and salinity.

Oklahoma: Little Washita watershed has a major water quality problem resulting from sediment; 12 other segments (out of 59) have been identified as having major nonpoint source problems.

Texas: 33 out of 297 segments have existing or potential water quality problems related to nonpoint sources.

Missouri: Sediment and agricultural chemicals cause turbidity and pesticide parameters to be violated in the northern 38 percent of the State, in the Salt, Fox, Wyaconda and Upper Middle Fabius River. In the Salt River, 21 percent of basin (363,000 acreas) has erosion of over 30 tons/acre/year.

Nebraska: Eastern and central parts of the state are impacted by sediment, animal wastes, and agricultural chemicals, causing violation of standards for nitrates, turbidity, fecal coliform and TDS. Over 1.5 million acres have been identified as sources.

Kansas: Six areas have nutrient and salt problems from agricultural chemicals and irrigation return flows (Stranger Creek, Upper Nemaba, Upper Wakarusa, Wolf River, Washington State Lake, and Soldier Creek). These cover a total of 627,000 acres.

North Dakota: In the Souris River agricultural activities have resulted in nutrient, TDS and suspended solids violations. These parameters are violated 80 percent of the time and nonpoint sources account for 90 percent of the load. The area recently experienced a major duck kill. The State has identified 10,000 acres as a high priority for treatment.

South Dakota: The James River is impacted by agriculture activities that affect fishery and drinking waters. Parameters violated are suspended solids, TDS and nutrients. The State has identified 17,000 acres needing treatment. Lake Herman suffers from sedimentation and nutrients. Parameters are violated 100 percent of the time with 90 percent of load coming from nonpoint sources.

Wyoming: The Green River is impacted by irrigation returns, overgrazing and septic tanks, which threaten agriculture, recreation and drinking water uses. Public lands contribute 8.9 million tons/year of sediment and 145,000 tons/year of salt. About 78 percent of the phosphorus loadings are contributed from nonpoint sources and they are causing eutrophication in the Flaming Gorge Reservoir. The Wind/Big Horn River is similarly impacted. Nonpoint sources contribute 99 percent of the total phosphorus load to Yellowtail Reservoir. Sources of phosphorus are agricultural fertilizer, septic tanks, feedlots and erosion. Eleven of the 20 problem stream segments will fail to meet water quality standards in 1983 due to nonpoint sources.

Colorado and Utah: The Colorado River is impacted by agriculture and hydrologic modification, causing salinity parameters to be violated. About 42 percent of the salinity in the upper basin is caused by irrigation.

Montana: The Missouri, Yellowstone and the Big Horn Rivers have approximately 4000 stream miles degraded by nonpoint source pollution (13 percent of State's streams). Sediment causes 2500 miles to be degraded and salinity affects 1400 miles. Parameters violated are salinity, bacteria, nutrients and suspended solids.

Idaho: Severe water quality problems have been identified in 5 stream reaches in irrigated areas involving 350,000 acres, and 18 reaches in nonirrigated areas involving 1,300,000 acres. In these cases, fisheries and recreation uses are impacted because of turbidity, sediment, algae, reduced oxygen, bacteria, salinity, temperature, and reduced flows.

Washington: Priority water quality problems have been identified in 27 stream segments involving 1700 dairies, 1,000,000 irrigated acres, and 5,200,000 nonirrigated acres. Fisheries and recreation uses are impacted because of turbidity, sediment, algae, reduced oxygen, temperature, bacteria, salinity, and reduced flows.

ATTACHMENT II

PRINCIPAL PRACTICES FOR CONTROL OF AGRICULTURAL POLLUTION [1/]

Table __. Principal types of cropland erosion control practices and their highlights

Erosion Control Practice	Practice Highlights
No-till plant in prior-crop residues	Most effective in dormant grass or small grain; highly effective in crop residues; minimizes spring sediment surges and provides year-round control; reduces man. machine and fuel requirements; delays soil warming and drying; requires more pesticides and nitrogen; limits fertilizer and pesticide placement options; some climatic and soil restrictions.
Conservation tillage	Includes a variety of no-plow systems that retain some of the residues on the surface; more widely adaptable but somewhat less effective than E1; advantages and disadvantages generally same as E1 but to lesser degree.
Sod-based rotations	Good meadows lose virtually no soil and reduce erosion from succeeding crops; total soil loss greatly reduced by losses unequally distributed over rotation cycle; aid in control of some diseases and pests; more fertilizer-placement options; less realized income from hay years; greater potential transport of water soluble P; some climatic restrictions.
Winter cover crops	reduce winter erosion where corn stover has been removed and after low-residue crops; provide good base for slot-planting next crop; usually no advantage over heavy cover of chopped stalks or straw; may reduce leaching of nitrate; water use by winter cover may reduce yield of cash crop.
Timing of field operations	Fall plowing facilites more timely planting in wet springs, but it greatly increases winter and early spring erosion hazards; optimum timing of spring operations can reduce erosion and increase yields.
Plow-plant systems	Rough, cloddy surface increases infiltration and reduces erosion; much less effective than E1 and E2 when long rain periods occur; seeding stands may be poor when moisture conditions are less than optimum. Mulch effect is lost by plowing.
Contouring	Can reduce average soil loss by 50% on moderate slopes, but less on steep slopes; loses effectiveness if rows break over; must be supported by terraces of long slopes, soil, climatic and topographic limitations; not compatible with use of large farming equipment on many topographies. Does not affect fertilizer and pesticide rates.

[1/] Control of water pollution from cropland - USDA - HRs # H-5-1.

Contour strip cropping	Rowcrop and hay in alternate 50- to 100-foot strips reduce soil loss to about 50% of that with the same rowtation contoured only; fall seeded grain in lieu of meadow about half as effective; alternating corn and spring grain not effective; area must be suitable for across-slope farming and establishment of rotation meadows; favorable and unfavorable features similar to E3 and E9.
Terraces	Support contouring and agronomic practices by reducing effective slope length and runoff concentration; reduce erosion and conserve soil moisture; facilitate more intensive cropping; conventional _____ terraces often incompatible with use of large equipments, but new designs have alleviated this problem; substantial initial cost and some maintenance costs.
Grassed outlets	Facilitate drainage of graded rows and terrace channels with minimal erosion; involve establishment and maintenance costs and may interfere with use of large implements
Change in land use	Sometimes the only solution. Well managed permanent grass or woodland effective where other control practices are inadequate; lost acreage can be compensated for by more intensive use of less erodible land.

Practices for Controlling Direct Runoff and Their Highlights.

Runoff Control Practice	Practice Highlights
No-till plant in prior crop	Variable effect on direct runoff from substantial reduction increases on soils subject to compaction.
Conservation tillage	Slight to substantial runoff reduction.
Sod-based rotations	Substantial runoff reduction and sod year; slight to moderate reduction in rowcrop year.
Winter cover crop	Slight runoff increase in moderate reduction.
Timing of field operations	Slight runoff reduction.
Plow plant systems	Moderate runoff reduction.
Contouring	Slight to moderate runoff reduction.
Contour strip cropping	Moderate to substantial runoff reduction.
Terraces	Slight increase to substantial runoff reduction.
Grassed outlets	Slight runoff reduction.
Contour listing	Moderate to substantial runoff reduction.
Change in land use	Moderate to substantial runoff reduction.
Construction of ponds	None to substantial runoff reduction. Relatively expensive. Good pond sites must be available. May be considered as a treatment device.

Practices for the Control of Nutrient Loss From Agricultural Applications and Their Highlights

Nutrient Control Practice	Practice Highlights
Eliminating excessive fertilization	May cut nitrate leaching appreciably; reduces fertilizer costs; has no effect on yield.
Leaching Control	
Timing nitrogen application	Reduces nitrate leaching; increases nitrogen use efficiency; ideal timing may be less convenient.
Using crop rotations	Substantially reduces nutrient inputs; not compatible with many farm enterprises; reduces erosion and pesticide use.
Using animal wastes for fertilizer	Economic gain for some farm enterprises; slow release of nutrients; spreading problems.
Plowing-under green legume crops	Reduces use of nitogen fertilizer; not always feasible.
Using winter cover crops	Uses nitrate and reduces percolation; not applicable in some regions; reduces winter erosion.
Controlling fertilizer release or transformation	May decrease nitrate leaching; usually not economically feasible; needs additional research and development.
Control of Nutrients in Runoff	
Incorporating surface applications	Decreases nutrients in runoff; no yield effects; not always possible; adds costs in some cases.
Controlling surface applications	Useful when incorporation is not feasible.
Using legumes in haylands and pastures	Replaces nitrogen fertilizer; limited applicability; difficult to manage.
Control of Nutrient Loss by Erosion	
Timing fertilizer plow-down	Reduces erosion and nutrient loss may be less convenient.

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Practices for the Control of Pesticide Loss from Agricultural Applications and Their Highlights

Pesticide Control Practice	Practice Highlights
Broadly Applicable Practices	
Using Alternative pesticides	Applicable to all field crops; can lower aquatic residue levels; can hinder development of target species resistance.
Optimizing pesticide placement with respect to loss	Applicable where effectiveness is maintained; may involve moderate costs.
Using crop rotation	Universally applicable; can reduce pesticide loss significantly some indirect cost if less profitable crop is planted.
Using resistant crop varieties	Applicable to a number of crops; can sometimes eliminate for insecticide and fungicide use; only slight usefulness for weed control.
Optimizing crop planting time	Applicable to many crops; can reduce need for pesticides; moderate cost possibly involved.
Optimizing pesticide formulation	Some commercially available alternatives; can reduce necessary rates of pesticide application.
Using mechanical control methods	Applicable to weed control; will reduce need for chemicals substantially; not economically favorable.
Reducing excessive treatment	Applicable to insect control; refined previctive techniques required.
Optimizing time of day for pesticide application	Universally applicable; can reduce necessary rates of pesticide application.
Practices Having Limited Applicability	
Optimizing date of pesticide application	Applicable only when pest control is not adversely affected; little or no cost involved.
Using integrated control programs	Effective pest control with reduction in amount of pesticide used; program development difficult.
Using biological control methods	Very successful in a few cases; can reduce insecticide and herbicide use appreciably.
Using lower pesticide application rates	Can be used only where authorized; some monetary savings.
Managing serial applications	Can reduce contamination of non-target areas.
Planting between rows in minimum tillage	Applicable only to row crops in non-plow based tillage; may reduce amounts of pesticides necessary.

ATTACHMENT III

NONPOINT SOURCE RESEARCH

EPA's goals for nonpoint source research encompass most of the research needs identified above. Our first goal will be to understand further the complex relationship between nonpoint source pollutant discharges and the quality of the affected waterways. Here, particular emphasis will be placed on the effects of toxic pollutants. Our second goal will involve the development and evaluation of cost-effective management methods to limit pollution from nonpoint sources. This goal will address structural as well as nonstructural approaches to the control of these pollution sources. Finally, our third goal for research will focus on the development and demonstration of effective implementation strategies for nonpoint source control methods. This research goal is needed for the development of improved voluntary acceptance approaches to the use of control methods for nonpoint sources.

A. Understanding How Nonpoint Sources Impact Water Quality

Our first task will be the development of methods to evaluate the physical, chemical, and biological water quality impacts from the discharge of nonpoint source pollutants from urban runoff and agricultural production. Here techniques will be developed which relate climate conditions and urban and rural land use activities to enable the prediction of the total amount of pollutants discharged to a receiving stream. (Other nonpoint sources such as forestry activities will receive attention in the future.) This information will then be used to obtain criteria for the level of nonpoint pollutant discharges allowable for specified water uses.

In addition, monitoring techniques will be developed to measure the amount of nonpoint source pollutant discharges.

B. Research Will Aid in Determining the Most Cost-effective Method of Meeting Established Water Quality Standards

Some of this research will improve our capability to monitor and predict both the quantity and quality of precipitation and should therefore assist in the evaluation of watershed impacts caused by acid rain. Here, we plan to focus on impacts in the following general areas: aquatic environments, soils, agriculture, forestry, natural ecosystems, and long term trends.

Finally, we will address the relationships between point and nonpoint source pollutants on an individual watershed basis. This research will aid in determining the most cost-effective method of meeting established water quality standards. As part of this work, methodologies will be developed for determining allowable discharges for both conventional pollutants (such as organic matter, suspended solids, and fecal coliform) and toxic materials based on land use, climate, soil types, and pollutants for an entire watershed.

C. Methods for Controlling Nonpoint Source Pollution

The first step here will be to evaluate the effectiveness of existing methods to control conventional as well as toxic nonpoint source pollutant discharges in a

watershed. Since local conditions may be such that more than one nonpoint source control method is required, various combinations of methods will be evaluated Methodologies will be developed to match the most appropriate control method combination of methods to a given set of local problems. In line with this approach, we will publish guidelines for planning. conducting, and evaluating field demonstrations of nonpoint source control methods to assist State and local water quality management agencies in developing effective nonpoint source control programs.

Because nonpoint source control for agriculture and silviculture is a voluntary program, it will be crucial that users in the field be aware of the latest developments. To this end, we will evaluate information transfer mechanisms currently available for nonpoint sources to determine their effectiveness in reaching the user community. In the years ahead, these mechanisms will play a major role in the transfer of nonpoint source assessment and prediction capabilities, results from demonstration studies, and improved or new management concepts to the field.

As a final task, we will demonstrate and evaluate new or improved control methods which have been developed by other Federal and State agencies. Particular emphasis will be placed on those methods which are appropriate for multiple uses. Since accurate and timely information will be needed by State and local management agencies during the implementation phase of nonpoint source control programs, we will also develop an information system to retrieve water quality monitoring data on the effectiveness of nonpoint source controls.

D. Implementing Nonpoint Source Controls

In order to improve our capability to implement nonpoint source control programs, EPA's research will focus on the development of relevant economic impact data, the analysis of existing institutional mechanisms, and opportunities to integrate nonpoint source control programs with other pollution control programs. Special attention will be paid to economic impacts at the local, regional, and national levels for agricultural and silviculture nonpoint source control methods. Here, various incentives also will be investigated to determine those that are the most feasible and appropriate for local problems and conditions.

Second, we will evaluate the effectiveness of existing institutional mechanisms in encouraging the use of nonpoint source control methods. Current laws and regulations will be reviewed to identify impediments to effective nonpoint source control. Educational programs will be assessed and successful examples of voluntary implementation of nonpoint source controls will be evaluated and documented.

Finally, we will investigate opportunities to integrate nonpoint source control efforts with other pollution control efforts.

ATTACHMENT IV

MODEL IMPLEMENTATION PROGRAM

Indiana: The project is located in the Indiana Heartland Region, which includes the Eagle Creek and Stotts Creek watersheds. About 80 percent of the area is cropland. The project involves land treatment to protect a 1,400 acre reservoir within the Nation's largest city park. The 146,000 acre area covers part of six counties. Measures used include: establishing vegetative cover, cover crops, terraces, critical area seeding, ponds, sediment and chemical retention, sod waterways, diversions, and windbreak restoration.

Nebraska: In the Maple Creek Watershed in northeast Nebraska, an area with about 230 miles of streams, farmers crop intensively on uplands sloping loose soils. High intensity, short duration storms wash soil from this cropland, producing water quality problems downstream. The watershed has 33,000 acres in three counties. Measures used include: terraces, diversions, conservation tillage ponds, sod waterways, windbreaks, erosion control structures, animal waste control, and seedings.

Oklahoma: Sediment is the problem for this MIP area in the Little Washita Watershed. This is an experimental watershed of USDA's Science and Education Administration (SEA), which monitors water quality. Measures used: seedings, terrace, diversions, grazing land protection, windbreak restoration, sediment retention, erosion, sod waterways, and ponds.

South Carolina: Anderson County's Broadway Lake, located in a 24,196 acre MIP area, is plagued by erosion, sedimentation, agricultural chemicals, and animal wastes. All 302 acres of lake show sediment damage. Local groups strongly support the project aims of improving the lake for fishing, swimming and boating. Measures used: seedings, terraces, diversions, conservation tillage, critical area seeding, ponds, erosion control structures, and sod waterways.

South Dakota: Water quality problems in this MIP area are from feedlot runoff and sediment from cropland. The project provides land treatment in the 45,000 acre watershed draining into Lake Herman in Lake County. The Lake Preservation Committee of South Dakota ranks Lake Herman among the 40 most in need of treatment. Measures used: seedings, terraces, grazing land protection, windbreak restoration, conservation tillage, permanent wildlife habitat, seedings, and crop rotations.

Washington: Farmers in the Sulphur Creek Watershed in Yakima County, this 63,835 acre MIP area, use irrigation in growing a variety of fruit, vineyard, vegetable, and grain products. This farming technique creates erosion problems on the sandy loam soils and rolling terrain. Measures used: irrigation water conservation, erosion control structures, sod waterways, seedings, and water management systems.

New York: In the West Branch of the Delaware River, this MIP area is marked by a concentration of dairy farms and large acreages of sloping cropland and forest land with erosion problems, causing water quality difficulties in a municipal reservoir--a condition the project hopes to correct by applying animal waste management and erosion control practices such as seedings, stripcropping, diversions, erosion control structures, timber stand improvement, tree planting, and cover crops. The area covers 287,000 acres in Delaware County.

The New York project is located immediately above the Cannonsville Reservoir one of the major dams supplying water to New York City. The Cannonsville Reservoir contains 98 billion gallons of water and is the third largest reservoir in the City system. The 4800 acre lake has a safe yield of 310 million gallons daily (MGD) of which 200 MGD is used on an average day, 15 percent of the City's needs. Although the reservoir has been in use only since 1964 its water quality is deteriorating. As a result the City does not use all of the water it could from Cannonsville with only 8 percent of the water released from the dam going to the City with the remainder used to maintain flows in the Delaware River.

The water supply has taste and odor problems caused by severe algale blooms in the summer and early fall. The algale blooms result from the high level of nutrients entering the stream with phosphorus presumed to be the major cause. Since the City will require additional water in the near future and Long Island may tie into the City supply, cleaning up the water would result in significant savings from not having to build additional storage.

The 450 square mile watershed is predominantly dairy farms, with about 25 percent in cropland and pasture and 70 percent in woodland. BMP installation started in the spring of 1978. It is progressing very well. One of the objectives of the program was to determine how well farmers would cooperate. Participation has been excellent with most of those contacted to date agreeing to cooperate. The work is being concentrated on certain critical watershed areas. In the first area 37 of the 43 farmers in the watershed indicated willingness to cooperate. Of those 37, three had no problems and the remaining 34 are installing the needed BMPs. The people working at the local level believe this level of cooperation can be attained throughout the entire county if they had the resources to work with all of the farmers.

Most of the BMPs required are animal waste facilities such as barnyard controls, manure storage and better feedlot operations. The average per farm cost of the facilities has been $3,500. While not excessively high, it can be seen that capital investment requirements are significant.

Since this watershed is typical of much of the northeastern dairy country, EPA will monitor and evaluate the BMPs being installed and determine their effects on water quality. This work will be done in conjunction with New York State and Cornell University. New York City has a number of monitoring stations in the watershed and our work will tie into the monitoring being done by the City. One of the reasons more data does not exist for identifying the causes of agricultural nonpoint source pollution is because intensive monitoring of this type is expensive. We may spend about one million dollars on the New York project in the next 3 to 5 years for data collection and analysis. In addition, USDA will spend a similar amount of funds to provide both technical and financial assistance to the farmers in establishing BMPs.

A major feature of the MIP projects is the use of presently available resources to implement the program. In the New York project both USDA (through the Agricultural Stabilization and Conservation Service and Soil Conservation Service) and EPA are providing substantial support. This activity can be carried out in only a few projects. Additional technical and financial assistance will be required if significant progress is to be made.

Another MIP is the Broadway Lake project located near Anderson, South Carolina. It provides an example of the typical water quality problems which are associated with farming in the Piedmont area of the southeastern United States. This 25,200 acre area has 6,500 acres in cropland, 8,200 in hay and pasture, 7,000 acres in woodland and the remaining 3,500 acres in residential and recreational uses.

The one crop pattern of farming, continuous soybeans, results in large amounts of erosion and sediment. Although many of the slopes are only 3 to 4 percent, the fields wash badly with erosion rates of 10 or more tons per acre common. The sediment is very evident on the roads, in ditches and streams, and in Lake Broadway.

Lake Broadway is a 300 acre lake formed by a 40-year-old dam. The Lake provides extensive recreational opportunities such as fishing, swimming and boating for the people in the area. It is owned by Anderson County, which maintains recreation facilities at a number of locations around the Lake. The area surrounding the Lake has been developed with more than 500 homes. Deteriorating water quality is affecting the use of the Lake by the general public and surrounding homeowners.

There are about 400 farmers in the watershed, many of them part-time, working relatively small farms with a single cash crop soybeans. This is a typical situation in many areas of the southeast. The average yield of 25 bushels of soybeans per acre at the present price of $8.00 per bushel brings a gross return of about $200/acre to the farmer. Farm income is not very high.

The project, initiated in 1978, has made a lot of progress in 2 years. Of the 400 farmers in the watershed 85 had been cooperating with their local Conservation District when the project started. Within one year more than 90 additional farmers have begun to install BMPs.

The local people working on the project have indicated they believe 80 to 90 percent of the farmers will cooperate in establishing required BMPs, but it will take about six years to get all of the work done.

The BMPs being used are terraces, grass waterways and sediment dams on the cropland and seeding and renovation of the hay and pasture areas. In 1978, 7.5 miles of terraces were established while 15.5 miles were constructed in the spring of 1979 with more scheduled this fall. BMPs are being established in the watershed at a rate of three times that being done in the remainder of Anderson County. People working on the project indicated the program could be duplicated in surrounding areas if additional technical and financial resources were made available.

This project, along with all of the MIPs, has had good cooperation among local, State and Federal agencies. Not only did the environmental and agricultural agencies work together, but others such as highway and forestry agencies have assisted in establishing BMPs. An estimated 2-3 years of volunteer assistance is being provided by the local people in managing the project.

The USDA has provided technical assistance through the Soil Conservation Service and Forest Service and cost sharing of BMPs by the Agricultural Stabilization and Conservation Service. EPA funds are being used to help construct sediment basins on critical watersheds and for monitoring and evaluation of the stream quality to determine the effectiveness of BMPs. EPA has combined three programs--section 208 water quality management, Clean Lakes, and research--to assist this project.

As with the other NIP projects, one of the primary objectives is to obtain more information on nonpoint source problems and the effectiveness of BMPs. EPA has provided $190,000 to Clemson University to conduct a water quality monitoring program in the watershed. The monitoring program was set up in 1978 and extensive sampling has already been completed. The sampling program is concentrating on storm events since this is when runoff occurs and most of the sediments and nutrients enter the streams and Lake. The Clemson group is working on six small drainage basins within the watershed. It is measuring physical, chemical, and biological parameters on areas where BMPs are being established on three similar watersheds where no work will be done during the project in order to compare the water quality results. The information gained from this project will be used to determine BMP effectiveness and water quality benefits in similar southeastern farming areas.

ATTACHMENT V

AGRICULTUPAL CONSERVATION PROGRAM (ACP) PROJECT SUMMARY

STATE	LOCATION	NO. FARMS	TOTAL COSTS		1979 FUNDS		LENGTH OF PERIOD
			COST	COST-SHARES	COST	COST-SHARE	
Illinois	Pike County Blue Creek	59	$1,400,000	$400,000	$470,000	$200,000	3 years
Tennessee	Gibson-County North Fork Forked Deer River	570	3,425,000	2,740,000	500,000	400,000	3 years
Nebraska	Hall County Buffalo Bottom	325	979,000	780,497	325,000	250,000	3 years
Alabama	Limestone County Swan Creek	675	1,313,335	738,750	325,000	250,000	3 years
Kansas	Jackson-Nemaha Counties Soldier Creek	410	1,801,952	1,621,758	325,000	250,000	5 years
Connecticut	Windham County	35	274,000	201,685	87,500	70,000	3 years
Oregon	Wasco County Center Ridge	21	500,000	375,000	166,500	125,000	3 - 5 years
Arkansas	Searcy County Chief Wiley's Area	150	775,000	620,000	162,500	130,000	3 years
Puerto Rico	Caguas District Gurabo and Valenciana River Basins	998	720,000	575,000	87,500	70,000	3 years
Kentucky	Fulton County Mud, Rush and Little Bayou de Chien	250	2,500,000	2,022,425	440,000	350,000	3 - 5 years

STATE	LOCATION	NO. FARMS	TOTAL COSTS COST	TOTAL COSTS COST-SHARES	1979 FUNDS COST	1979 FUNDS COST-SHARE	LENGTH OF PERIOD
Michigan	Huron and Tuscala Counties Southeast Saginaw Bay	1851	$5,519,645	$4,729,502	$500,000	$400,000	3 years
Ohio	Seneca, Crawford, Huron Honey Creek	710	349,705	192,214	115,000	65,000	3 years
Mississippi	Marshall and Benton Eroding Wolf	229	1.193,060	1,073,754	375,000	300,000	3 years
New Hampshire	Cheshire County Great Haughton Brook	10	80,000	64,000	31,250	25,000	3 years
Missouri	Monroe County Middle Fork of Salt River	185	1,878,750	1,503,000	440,000	350,000	3 years
Indiana	Allen County Dirty Bakers Dozen	200	616,000	462,000	100,000	75,000	3 - 5 years
Maine	Aroostock County	630	5,000,000	4,000,000	500,000	300,000	10 years
South Carolina	Greenville-Spartanburg Tyger Rivers	1100	800,000	582,000	250,000	200,000	3 years
Texas	Hopkins, Wood, Hunt, Rain Lake Fork Creek	193	660,000	525,000	190,000	150,000	3 years
Maryland	Cecil County Northeast	60	200,000	150,000	125,000	100,000	3 years
New Mexico	Lincoln-Otero Counties	140	1,210,000	968,000	345,000	275,000	3 - 5 years
	TOTAL	8801	$31,195,447	$24,334,585	$5,860,250	$4,335,000	

TABLE I

NONPOINT SOURCES OF POLLUTION[1]

Region (Number of Basins)	Percentage of Basins Affected* by Type of Nonpoint Source							
	Urban Runoff	Construction	Hydrologic Modification	Silviculture	Mining	Agriculture	Solid Waste disposal	Individual disposal
Northeast (40)	70	15	20	10	20	55	35	63
Southeast (47)	57	2	21	30	15	62	9	40
Great Lakes (41)	54	7	2	15	41	59	15	39
North Central (35)	54	6	3	6	40	89	9	29
South Central (30)	50	0	23	13	53	87	13	40
Southwest (22)	23	0	18	5	36	73	0	35
Northwest (22)	23	23	23	27	23	55	9	32
Islands (9)	67	67	22	0	0	78	22	89
Total (246)	52	9	15	15	30	68	14	43

*In whole or part.

[1]EPA's "National Water Quality Inventory -- 1977 Report to Congress" (October 1978)

Mr. BALDUS. I thank you for your testimony, and I hope you will stay for the panel.

Mr. KRIVAK. Yes, Mr. Chairman.

Thank you.

Mr. BALDUS. Our next witness is Dr. Richard L. Barrows, Department of Agricultural Economics, University of Wisconsin.

I notice your testimony is rather short.

STATEMENT OF DR. RICHARD L. BARROWS, DEPARTMENT OF AGRICULTURAL ECONOMICS, UNIVERSITY OF WISCONSIN

Dr. BARROWS. I will try to keep it very brief.

My work at the University of Wisconsin and the State Agricultural Department is in the area of natural resources and land use policy, and I have worked with the State Legislature, and I would like to talk very briefly about farmland retention policy in Wisconsin.

I think it is one of the areas in which furthering the goal of increasing agricultural production, can also further the goal of better environmental quality so, this is one of the areas in which these two goals are compatible. I would like to talk about that with respect to the Wisconsin program.

Briefly, the Wisconsin experience can be the basis for a possible Federal policy. I will follow along through the outline very quickly. Starting on page 2, the Wisconsin farmland preservation law was designed to attain objectives of both environmental and agricultural interest groups in the State.

The purpose of the new law is to help local governments that want to preserve farmland through local planning and zoning, and to provide tax relief to farmers who participate in local programs.

For the first 5 years, any farmer in the State can qualify for tax credits by voluntarily signing a contract. The farmer agrees not to develop his land and in exchange is eligible for State income tax credits.

The farm has to have a conservation plan or the farmer cannot qualify for the tax credits if the land is not sound for agricultural use by the farmer.

Now, after 1982, any farmer in the State can qualify for tax credits, but counties must first take some action.

In urban counties, to maintain eligibility for the tax credit, the land has to be under a State-certified exclusive agricultural zoning ordinance to be eligible for credits.

If it is in a rural county, they have the option of doing the zoning, or doing an optional plan.

The program really is a local program. The success and failure depends on what local governments do.

It is not a State mandate. Instead, decisions must be made by local citizens.

There were two basic groups that supported enactment of the law—the environmental groups and the agricultural groups.

The environmental groups were interested in maintaining open space and scenery; and people in urban areas care greatly about the visual quality of the environment.

The second reason is to control urban sprawl. The third reason is some people want to control urban growth, to minimize water pollu-

tion from malfunctioning on-site household waste disposal systems. The fourth reason was to protect the best agricultural land, so we did not have to bring in marginal land, with all of the associated conservation problems and additional fertilizer that might be necessary.

The agricultural interests, No. 1, wanted to protect farm operations. People are saying we have got a good operation going, we want to protect it, and also we want to protect our rural lifestyle at the same time.

The second objective of the agricultural people was to stabilize farm income. A third objective was to protect the agricultural land base for future expansion of their own farm, or their neighbor's farm.

There was not so much concern about feeding the world, but there was more concern about maintaining their own operation for the future. Finally, No. 4, at the bottom of page 3, agricultural groups were interested in protecting the good farmland by encouraging better conservation practices.

So the support from the law came from these two groups.

Over on page 4, what happened?

Well, the program is only a year and a half old. It is hard to tell what the final result will be, but it looks very good so far. Over 2 million acres are protected in less than 18 months.

Now, a very modest State grant program of about $400,000 a year has been very instrumental in stimulating local government planning and zoning, and over two-thirds of the agricultural counties in the State are engaged in some kind of agricultural zoning and planning activity.

Now, several generalizations about what I think that means for possible Federal policy.

No. 1, of course, if there is some overlap here between the environmental quality goal and agricultural production goal, that should be examined carefully.

No. 2, the environmental interests must be recognized, the agricultural interests must be given some recognition, and farmland preservation has to be made a local program. It can be stimulated by some Federal incentives in the form of grants to local governments to help them out and possible tax incentives.

I think I will end with that, and we can come back later for questions.

Mr. BALDUS. Thank you very much, doctor, and I am sure you will stay for the panel discussion.

I think it is best the committee recess for a few minutes. We have a vote on the floor. We may run into two votes rather than one.

Mr. JEFFORDS. If it does run into two votes, I have testimony I have to give in another committee, so I want to apologize, it is not lack of interest, because I am deeply interested in this subject, and I hope I will be back.

Mr. BALDUS. That is one of the hazards of our occupation.

But we do thank you, Dr. Barrows.

Dr. BARROWS. Thank you.

[The prepared statement of Dr. Barrows follows:]

TESTIMONY BY RICHARD L. BARROWS, DEPARTMENT OF AGRICULTURAL ECONOMICS, UNIVERSITY OF WISCONSIN-MADISON

The conflict between the goals of agricultural production and environmental quality is widely recognized in both academic journals and the popular press.

For example, restrictions on the use of various agricultural chemicals result in reduced agricultural production, or at least higher costs for maintaining previous production levels. Or, the environmental costs of concentrated animal feedlots or fencerow-to-fencerow cultivation have been given widespread attention.

However, it is not always the case that agricultural production and environmental quality conflict. In particular, farmland preservation policies may result in both increased agricultural production (or potential) and a higher level of environmental quality. The potential farmland preservation policies for advancing both agricultural production and environmental quality will be briefly summarized, with special reference to the Wisconsin Farmland Preservation Program. The applicability of the Wisconsin program to other areas will be discussed, and some policy recommendations will be advanced.

I. Advancing Environmental Quality and Agricultural Production Through Farmland Preservation: The Wisconsin Program

The Wisconsin Farmland Preservation Law was designed to attain objectives of both environmental and agricultural interest groups in the State. The purpose of the new law is to help local governments that want to preserve farmland through local planning and zoning, and to provide tax relief to farmers who participate in local programs.

In the first five years, 1977–1982, any farmer in the state can qualify for tax credits by voluntarily signing a contract: the farmer agrees not to develop his land and in exchange is eligible for State income tax credits. Also, to qualify to sign a contract, the farmer must either have an SCS farm conservation plan or request that a plan be prepared by the local soil and water conservation district and SCS. Or, a farmer can qualify for tax credits if his land is zoned for exclusively agricultural use by his local governments.

In order for farmers to remain eligible for tax credits after 1982, counties must take some action. Counties could act earlier if they wish, but by October, 1982:

1. Urban counties—in counties over 75,000 population or adjacent to counties with over 400,000 population, the land must be under a state-certified exclusive agricultural zoning ordinance to be eligible for credits.
2. Rural counties—in counties with 75,000 population or less, the land must be under either a State-certified farmland preservation plan or an exclusive agricultural zoning ordinance to be eligible for credits.

The Farmland Preservation Act was passed to assist local people who want to preserve farmland, and to provide tax relief to farmers who participate in the local programs. The success or failure of the program rests in the hands of farmers, local citizens, and local elected officials. There are many options for local government under the law, and the State will not dictate local planning and zoning policies—those policy choices are the proper business of local citizens and local government. The Farmland Preservation Act will assist local governments in what they decide to do, but the decisions must be made by local citizens.

In supporting passage of the law, the major objectives of environmental groups were:

1. Maintain open space near expanding urban areas, in order to retain the scenic values of agricultural land use.
2. Encourage counties to adopt planning and zoning programs to preserve farmland and control urban sprawl.
3. Control urban growth to reduce the reliance on septic tanks in order to minimize water pollution from malfunctioning onsite household waste disposal systems.
4. Protect the best agricultural land (much of which is near cities in Wisconsin) in order to avoid the necessity of bringing into production more marginal land which would require larger inputs of fertilizers, pesticides and herbicides, and which might result in increased soil erosion.

The major objectives of agricultural groups were:

1. Protect farm operations and the local farm economy from disruption by scattered urban or dispersed rural development.
2. Help insure stability in farm income by minimizing property tax increases due to urban sprawl and by providing State income tax credits if property taxes imposed too great a burden on farm income.
3. Protect the agricultural land base for future expansion of existing farm operations.
4. Protect the most productive farmland by requiring good soil conservation practices as a condition for participation in the program.

It is important to note that agricultural and environmental objectives are compatible in this program. In fact, the legislative support for the law came from a coalition of rural-agricultural and urban-environmental groups. To date after only 18 months of operation, the program has been extremely successful in stimulating local planning and zoning to preserve farmland. About two-thirds of the counties are engaged in preparing preservation plans, and one-tenth of the counties have already adopted agricultural preservation zoning. A modest State grant program ($400,000 per year) has been instrumental in stimulating local government action.

II. Policy Recommendations

There are several generalizations which can be made, based on the Wisconsin experience:

1. Environmental quality and agricultural production goals are not necessarily in conflict. Farmland preservation policies are one means of advancing both goals simultaneously.

2. The environmental interest in farmland preservation must be recognized: the desire to protect scenic open space, control sprawl, minimize soil erosion, and preserve the best agricultural land to prevent the environmental damage from production on marginal land.

3. The agricultural interest in farmland preservation must be recognized: the desire to maintain the local farm economy, provide land for future expansion, and conserve soil resources.

4. Farmland preservation policies are best implemented at the local level. Both the environmental and agricultural objectives are most accurately defined and advanced locally.

5. The role of State and Federal Government is to provide incentives and technical assistance grants to local governments which wish to develop plans and ordinances. Tax incentives can be provided to individuals, and planning and zoning grants to governments. The incentives should be tied to strong local preservation zoning, and to soil conservation.

Mr. BALDUS. The committees stand adjourned.

AFTER RECESS

Mr. BALDUS. The committees will please come to order.

It is my understanding that Dr. Richard Sparks is not here, so we do have his prepared testimony, and without objection it will be made a part of the record.

Hearing none, so ordered.

[The prepared statement of Dr. Richard Sparks follows:]

TESTIMONY BY RICHARD E. SPARKS, PH. D., ILLINOIS NATURAL HISTORY SURVEY, RIVER RESEARCH LABORATORY, HAVANA, ILL.

My name is Richard E. Sparks. I am an Associate Aquatic Biologist employed by the Illinois State Natural History Survey. Together with other biologists, I have been engaged in research on the biology of the Illinois and Mississippi Rivers and their bottomland lakes for the past 7 years.

My own research experience is largely confined to the state of Illinois and to the Illinois River. However, this area is an excellent example of how farming has degraded wetland resources and water quality. Illinois is one of the Nation's most important farm States, leading all others in production of corn and soybeans during 1977. Furthermore, 70 years ago the Illinois River was among our Nation's foremost fisheries and duck hunting grounds. In 1908 the Illinois River produced more commercial fish than any other river in the United States with the exception of the salmon-producing rivers of the Northwest. The Illinois has been described as the world's most-studied river: systematic records dating back to 1894 enable us to document the effects of pollution and land use as we can for few other rivers in the world.

The Illinois and Mississippi Rivers are not just drainage channels for the surrounding land. Both rivers are lined for miles with extensive bottomland lakes, overflow ponds, side channels, marshes, and sloughs. Where these have not been leveed and drained for farming or filled with dredge spoil, the river as a

whole looks more like a tangled skein of land and water than a simple, straight channel. These backwaters provide most of the food and shelter for fish and wildlife associated with the rivers. Without the backwaters, the rivers themselves would be nothing.

Let me add that as a biologist I speak primarily of the environmental gains and losses. But backwater marshes and swamps have considerable economic value as well. William J. Mitsch of the Illinois Institute of Technology has recently calculated the economic value of a 74-acre swamp along the Cache River in southern Illinois. He found that it holds back floodwaters and takes up excess nutrients that would otherwise pollute the river—services that would cost more than $18,000 a year if we had to pay for them. According to the Second National Water Assessment of the U.S. Water Resources Council, we have been losing 318,000 acres of wetland to draining, dredging, and filling every year since 1956. If you add to that the acreage lost to siltation, we may be suffering real economic damage as well as deterioration of environmental quality.

As a result of our research into declines in fish and wildlife of the Illinois River, we have become convinced that the single most important factor now affecting the river is sediment eroded from farmland. In the Illinois River valley alone, cities, towns, and sanitary districts have already spent over four billion dollars to clean up their effluents. Even when they have completed the job, and comply with the state and federal waste treatment requirements, we do not see much prospect for improvement in the fisheries, wildlife, recreation, or aesthetic appeal of the river until soil erosion is reduced. Sediment in water is a general problem in the Midwest. We think that other rivers, such as the upper Mississippi River—which still have viable fisheries and receive much recreational use—will decline in the near future unless sediment input is reduced.

So far from being reduced, sediment input to streams now appears to be increasing, largely because of several popular farming practices:

(1) Fall plowing, which leaves the ground bare during snow melt and spring rains;

(2) Increased planting of row crops at the expense of hay and small grains (since 1940, Illinois farmers have increased corn acreage and more than doubled the acreage planted to soybeans, while cutting down on wheat, oats, and hay);

(3) Replacement of crop rotation with continuous corn;

(4) Use of bigger machinery and tractors which are difficult to maneuver around grass waterways, contours, and irregular stream channels;

(5) Removal of hedgerows, grass waterways, and green belts between fields and next to streams, to provide more tillable acreage;

(6) Draining of wetlands to provide more tillable acreage; and

(7) Channelization of streams to speed runoff in the spring, so farmers can plant earlier.

All of the above changes in agriculture contribute to soil erosion and sediment transport to mainstem rivers. Illinois' Agriculture Task Force, an advisory group to the state Environmental Protection Agency composed mainly of agriculturists, found that 86 percent of Illinois soil erosion comes from farmland, exclusive of gully and streambank erosion.

Not all of the 157 million tons of sediment per year washed from Illinois farmland reaches a body of water. But enough does to transform the character of the state's rivers and lakes. Sediment is Illinois' largest water pollutant by volume; and as it happens, the most troublesome kinds of sediment are the most likely to get into the water.

Since the smaller soil particles are generally most easily dislodged by rain, and carried farthest by water, they end up in the quiescent backwaters of the slow-moving rivers. A pound of these fine sediment particles has a much greater surface area for absorption of pesticides and fertilizers than a pound of coarse particles. Fine particles are likely to be clays and organic matter, which have a high binding capacity. Hence the fine particles may start their journey to the river already loaded with fertilizers and pesticides. On the way, they may pick up more nutrients and toxic substances from industrial and municipal effluents.

Since most of our large rivers serve as navigable waterways, the sediment in the main channel and along the banks is continually stirred up—"resuspended"—by wave wash and the propeller thrust of commercial and recreational boats. In the backwaters, winds generate waves which continually resuspend the sediment on the bottom. As a result the Illinois River and its backwaters are turbid most of the time.

Even when the sediment settles out, the materials absorbed on the particles cause problems. Clay particles which contain the common fertilizer element potassium swell and do not easily settle out. As a result, the sediments in the Illinois River are extremely hazardous; they are both too thin to walk on, and too thick to push a boat or run an outboard through. At various times in the past few years, several recreational boaters who were not familiar with the river have driven their boats into what appeared to be extensive backwaters, only to stop when their motors became clogged with sediment. Some then tried to walk or swim from their boats to shore, and died in the process.

Sediment in water usually does not kill fish and wildlife—or people—directly. Instead it works insidiously, sometimes interacting with toxic substances and nutrients, to change once-productive bottomland lakes into shallow, muddy pools barely capable of supporting even the most insensitive organisms.

Aquatic plants, which form the base of the food chain, need sunlight to grow and are soon eliminated when sediment clouds the water. They died out of Illinois River backwaters about 20 years ago. Waterfowl feed directly on many species of rooted aquatic plants. Some fish feed on the microscopic animals that live on the plants; many gamefish consume these microscopic animals when small, then graduate to insects and forage fish as they grow. As long ago as 1955 it was known that when ponds exceed 25 Jackson Turbidimeter Units (a measure of muddiness), they lose 80 percent of their microscopic animals. Average turbidities in much of Illinois' surface waters now exceed 50 JTU.

Organic matter associated with sediment depletes oxygen in the overlying water as it decays, thereby affecting both fish and the organisms on which they feed. Bottom-dwelling organisms, such as worms, insects, clams, and snails, may find the sediment too watery to move upon or too watery for the construction of burrows. Toxic materials may also be associated with sediment. The insecticide dieldrin, for instance, still accumulates in snails that graze on the bottom, even though dieldrin has not been used on farms for several years. The sediments contain a legacy of toxic materials which may affect the organisms which ingest the sediments or the fish and ducks which in turn consume the bottom-dwellers.

Even if the creatures fishes eat could survive muddy waters, the desirable game fish wouldn't be able to find them. Game fish depend largely on sight to find their food. When suspended sediment muddies the water, they have difficulty finding food or artificial lures. In 1940, at Fork Lake in Macon County, Illinois, Natural History Survey researchers found that fishermen caught more than twice as many fish per man-hour in clear water as they did in relatively muddy water.

Even if the desirable fish could somehow feed in the muddy waters, they wouldn't be able to perpetuate their kind. For example, male sunfishes build nests at the beginning of the breeding season. But if they cannot see well, they will be unable to distinguish between a rival male and a ready female at spawning time. If they do succeed in spawning, the eggs may be smothered by sediment.

Some adult organisms can withstand enormous amounts of sediment in water for days or weeks. But eventually, the population is likely to be decimated by starvation, failure or reproduction, or cumulative stress (such as from abrasion and clogging of gills).

Nevertheless, the bottomland lakes of the Illinois River are not yet devoid of fish. Instead of game fish feeding by sight on insects and breeding among aquatic plants in clear water, we have forage fish such as carp and gizzard shad feeding by smell on bottom debris in muddy water where no plants and few snails grow. Sediment does not just pollute the river. It changes the entire habitat, favoring some species over others, and causing the ecosystem to shift from generally desirable to less desirable conditions.

Nor is it a simple matter to switch back to the old, less-polluted days: once aquatic plants have died out due to muddy water, for example, any small breeze can generate waves which stir up the loose sediment on the lake bottom. The water stays muddier longer than it did when aquatic plants grow and held the bottom in place. This muddiness in turn makes it virtually impossible for these plants to get a roothold and recolonize the area. Nowhere is it more true that an ounce of prevention is worth a pound of cure.

But this is not the end of the story. Sediment is an inexorable pollutant. As long as it keeps pouring off the land, it keeps piling up in the river. The deepest spots fill fastest, so that a bottomland lake loses its "holes"—usually the best spots for fish—first. The shallow, platter-shaped lakes become hot and short of oxygen during the summer; they either freeze solid or become short of oxygen during the winter. As a result, in most of the lakes along the Illinois River,

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we have both summer kill and winterkill of the fish populations. These lakes, by the way, now average only two feet deep.

Finally, some time after they have lost their biological value, these lakes will cease to exist altogether as the sediment raises the lake bottoms above low water levels. Lake De Pue, a 500-acre bottomland lake along the Illinois River in Bureau County, used to be eighteen feet deep, and hosted annual speedboat races and regattas. The last such race was held in 1963. The 1974 race, and all since, were cancelled because the water had become too shallow. The Illinois State Water Survey reports that at present rates of fill the lake will become dry land thirty years from now.

My colleagues at the River Research Laboratory have found evidence that siltation, like soil erosion, is increasing. Six typical bottomland lakes in the Illinois River are filling faster now than they did in the past. At a depth of five feet, for instance, the bottom of Lake Chautauqua rose .04 inches per year from 1926 to 1950, but .06 inches per year from 1950 to 1976—a 50 percent increase. The Illinois State Water Survey has given this lake a remaining lifetime of less than ninety years. Natural, "geologic" rates of erosion would have taken thousands of years to fill in the Illinois River's bottomland lake. Man-made erosion will do the job in less than two hundred years.

The same silting-in process is occurring in bottomland lakes of the Mississippi River, which forms Illinois' western border. But it seems to be taking longer there, perhaps because the Mississippi is a much larger river. Once the Illinois and Mississippi backwater lakes are gone, Illinois' only remaining natural lakes will be in the extreme northeastern portion of the State.

In short, even if there were enough fish food in the muddy waters, even if they could easily breathe and reproduce under these conditions, they would still be done for. The lakes themselves—the key to the fish and wildlife productivity of the Illinois and Mississippi Rivers—are disappearing.

You may well ask at this point how we can pin all this on the farmer. Don't highway building, home construction, and urban runoff send silt into the rivers, too? This question is pertinent to the Illinois River, since its upper reaches drain the entire Chicago metropolitan area. But as a matter of fact, the upper Illinois River is considerably less muddy than the lower river. Beds of sago pondweed (an aquatic plant) grow in the Des Moines River below the entrance of the Chicago Sanitary and Ship Canal. (The Des Plaines joins with the Kankakee to form the Illinois River shortly downstream). Only in the lower Illinois River, where tributaries draining extensive prime farmland flow in to the main stem, does the turbidity rise and the aquatic plants disappear.

The Illinois River and its backwaters today stand as a horrible example of how we have squandered an economic and environmental resource of immense value. The river has been and still is beset with other environmental problems. But siltation from farmland is now the principal threat to its survival as anything more than a glorified drainage ditch. Indeed, it may be too late to restore the Illinois to full productivity. But for the upper Mississippi River and for other American rivers there is still time, if we heed the warning.

Mr. BALDUS. At this juncture then, if the witnesses who have testified will come forward to the witness table, if there are questions, again the committee must apologize for the situation.

Chairman Jones is here now, but he has not been able to be here during most of the testimony.

I know he has for the last several days heard a great deal of testimony.

So our questions may not be as much on point, that is on point of your testimony, as you would like; however, we know that you are knowledgeable in a number of fields, and your interactions with each other are great, that your interest in these other subjects are very, very important to us, and I think that is testimony to the fact that this is a joint hearing of the Agricultural Committee and the Committee on Science and Technology.

Mr. Krivak, I have one question that relates to testimony on page 5 and No. 3, you touched on it a little bit about water rights.

I have been concerned, and you very correctly said that the water rights are State policy and very jealously guarded; I do not think anybody wants to dispute that.

On the other side of that, the aquifers, the underground rivers, they do not seem to have any respect at all for State lines and still I am concerned with what occurs in one place may have an effect on some other place, and we do not know where or how in this other place.

Mr. KRIVAK. We do not know that, and EPA certainly does not, and I doubt that any water expert in the field of ground water would indicate that we have sufficient information to predict with accuracy both the water quantity and water quality problems that issue from overdraft use of water or pollution of ground water.

It is an area that we need a lot of research in, and before we even consider legislative or administrative actions regarding ground water use——

Mr. BALDUS. If I may interrupt, in an agricultural appropriations bill and in soil conservation, we discussed this, and we added authority for study of these kinds of aquifers.

How about the Department of Interior, from your knowledge, do you have any studies that have been done, and I will address this question to everyone at the table. We had a map that showed us where underground water aquifers were, but it seemed to me that beyond that, that there was not an awful lot of knowledge, or at least it was not brought forward to our committee at that time.

Mr. KRIVAK. I would say quickly that USGS and the Department of Interior by far have the most knowledge related to this scale.

I would estimate that there were literally hundreds of ground water studies underway in the country right now.

In fact, EPA through its research program is involved in a number of them, most of them in the populated East, Long Island, they are reporting and putting a lot of our resources into studying ground water now, but I am not an expert in that particular field, I do know that USGS has literally hundreds of those studies going on in most part of the country at this time.

Mr. BALDUS. Any others at the table have knowledge, or can be helpful in this way?

Mr. SAMPSON. The Water Resources Council has been doing work in this, and I cannot quote from memory what they have discovered, but I suspect that if there is any information in captivity right now that leads us to a better understanding, they have tried to get their hands on it, and that is the best source I have.

Mr. BALDUS. We assume they share information from one agency to another and from one scientist to another.

It would be a safe assumption they do that, but I am not sure it is so.

Dr. Barrows, you spoke about the Farmland Preservation Act in Wisconsin, and I was in the Wisconsin Legislature at the time we were contemplating that.

I think I told you that at the time I was in the legislature 5 years ago, I regarded it as kind of hopeless, and then an interesting thing happened, two ladies got elected from rural areas, and it is my understanding they helped put it together to make it law.

There has also been some criticism, what is your analysis of the staying ability in Wisconsin, there has been some criticism here, and

some amendments offered, but I think none of those were passed in this session of this Legislature; is that correct?

Dr. BARROWS. That is correct. There were a series of technical amendments that were made to the law, in September of 1977. There was another series again, largely technical amendments in March of 1978. We have been working to modify it as we put it on the ground. We can see all sorts of things that need to be changed, and that is happening.

Now, I should add that there has been no change in the basic concepts or the basic requirements, from the beginning.

That stayed very constant. Now, the question about the staying power of the law. I think that is an excellent question, and it is precisely the uncertainty at this point. The program is only a year and a half old, but all of the available evidence that we have so far says that it has been extremely effective. I do not see anything coming that would turn that around or change that, so I say it looks good now.

I think the prospects for the future look good, but I think we have to watch it fairly carefully.

It may not work as well in some areas as in others, and we may need to do something further in some particular areas of the State in the future. In general, I think this is the attitude in Wisconsin, certainly among most legislators, as well as agency people. We should watch this program very carefully and see what happens.

Mr. BALDUS. A key ingredient to that is that the agricultural land that is taxed as agricultural land versus the highest use, and that differential of taxation that would otherwise be achieved by the local unit of government is paid by the State, and I say that correctly, that is that the State pays into the local treasury the amount that would have been paid by the farmer if he had paid the highest use, a record is kept of that, and if the farmer breaks his contract, then he would have to pay the State what he would have paid if he had maintained the contract?

Dr. BARROWS. That is correct.

The conclusions are correct, and there are a couple of points in the middle that we need to define further.

It is correct, No. 1, that the local unit of government does not lose revenue because of the program It is correct, No 2, that the landowner would have to pay back part or all of the tax credit if he breaks the contract or develops the property some time in the future.

Now, the mechanism that actually gets the tax relief to the farmer is not the property tax mechanism, but is the State income tax.

Mr. BALDUS. It is the income tax?

Dr. BARROWS. Right, and the tax payment to the State. The farmer sees a tax credit against his income tax, based on a comparison of how high his property tax is compared to his family income. So as property taxes go up, compared to income, the family gets more tax relief from the program.

This system is unique in the United States, with the exception of Michigan.

Michigan has a very similar kind of farmland tax relief program.

Most other States have a system that is based entirely on property tax.

Mr. BALDUS. Since we are on that point, do you have current information as to what the cost in Wisconsin is of subsidizing that program?

Dr. BARROWS. The estimates of costs in the first years were fairly low, based on the assumption that participation was expected to be fairly low in the beginning.

They expected about $900,000 of tax relief in the first year. In fact, because the participation is higher than expected, I think the final bill will come in at about $2 million in tax relief for the first year, and it should be higher than that in the future.

I think in the budget bill just passed, that is in process right now, the figures are $3 million and $5 million per year for the 2 years in the budget.

Mr. BALDUS. And that could conceivably grow based on present land values, to how much, if you had higher participation?

Dr. BARROWS. At full participation, the estimate of the total cost is around $24 million.

Mr. BALDUS. Mr. Jones?

Mr. JONES. Thank you, Mr. Baldus.

Gentlemen, let me say I am sorry I was not here for your testimony, but we had a conference going on for food stamps, and some of us had to be over there for that, but I do appreciate Mr. Baldus and others hearing your testimony.

I have had a chance to skim through the testimony that you gentlemen have given, and I have a question I would like to ask Mr. Neil Sampson, and it is along this line, Neil, I have not been able to find the figure in your testimony, but I know about what you would say in this regard, as the law is concerned, but yesterday we had Mr. Koelzer here from Fort Collins, Colo., he is a civil engineer, and he told us, I questioned him on this, that we had no reason to worry about the loss of cropland in this country, and I asked him to explain what he was talking about, and he simply said in the irrigated sections of Fort Collins, Colo., if cropland had to be abandoned, for building purposes, that you just moved on down, and move somewhere else and irrigate another piece of soil.

Well, where I come from, that is not the way you do it, and from where a lot of the rest of us come from, you could not do it.

Now, you said in your testimony that the loss of prime agricultural land, especially in the West, is great, and I am aware of the fact that we are losing prime agricultural land in a very big way, but because we can simply shift irrigation to unused land and replace it, that would work in some specific areas of the country, so what else do we do?

What I am saying is, what are we going to do about the conservation of our prime cropland that we have in this country, when we are losing it at a fairly rapid rate. If the statistics I read are correct, and I believe they are, I am not even sure of that. I sort of feel we may be losing more crop soil than we sometimes are told that we are. From what I see, and from the shift we made in this country from livestock to row crops, what I am asking you and any other member of the panel, what do we really do about this rate of natural loss of the soil we have?

We have been talking about the conservation of soils all of my life, and a lot of other people's lives, too, but we are still losing it at a very rapid rate.

Dr. TIMMONS. If I had been on the panel when that statement was made, I would think we would have had a lively thing going.

I am a native Iowan, and the Federal Government owns about two-thirds of the State, and we cultivate one-third. I think that is a make-work argument. It is a simple argument. There is always somebody ready to say something like that, but the fact is that the irrigating of lands of the West, that started out with organic percentages, are down about one-half of 1 percent, and that took two generations of hard work by the farmers of the West to build irrigation systems and to get those soils to the point where they irrigate well and yield right, and to suggest we simply put concrete on that investment of lifetimes, and move right onto that old desert and start over again with an entire new construction project, is an excellent justification for construction projects, but it is very damaging, in my opinion, for agriculture.

In those irrigated situations, we have that terribly intensive agricultural development of paved road every mile virtually throughout the country, a powerline and a phone line on virtually every mile, on virtually every small farm.

You have the primary ingredient for this buckshot urbanization to take place, and it is not uncommon any more in the West for a person to have enough 1-acre lot owners along the highway, that it begins to affect the availability of irrigation water supply through the irrigation ditch system and the water right systems. We find some terribly frustrated farmers, who still have the acreage to farm, but who are terribly frustrated because, instead of working with 3 other farmer neighbors to trade water on a lateral system, they have 3 other farm neighbors and 47 urbanites to trade with, and so we have got a tremendous problem in those areas, and I quite frankly think the numbers we have got here, between what Mr. Berg's agency has done, and what I have looked at, simply indicates that rate of loss is too high, that the rate of replacement of acres is diminishing, and is lower than we thought, seriously lower than we thought 10 years ago, and simply cannot afford that kind of logic as policy any longer, I guess would be the best way to put it.

Mr. JONES. Does Mr. Berg or any other member of the panel have anything to add to that?

Mr. BERG. Mr. Jones, this topic has reached the point, as you know both in the Congress, and in the executive branch of Government, where it has received a lot of attention. Very recently, our Secretary of Agriculture, and the Chairman of the Council on Environmental Quality, joined to cosponsor a study over the next 18 months of agricultural land availability for the future, and what is happening in terms of the allocation of these lands along with the competing demands. Even though we are not predetermining the outcome of that study, it is certainly evident that this is a problem, and we believe that this study will show for the first time in a clear way, how much of this land is being lost, and what the consequences are of having less productive land resulting in more energy use and possibly less yield per acre. We will look at some of the experiences such as Dr. Barrows points out are being tried around the country, to determine what can work.

Friday we reviewed the study plan of this group which was only formed about a month ago, and it is a good plan, it needs support, and I think we will find eight or ten of the major departments helping by joining the study, in terms of both personnel and funding.

One of the things we need very soon is some sort of reference guide or document that would help State and local governments, in terms of what kind of experiences are underway now. The advantages and disadvantages of the various systems need to be assessed. This is certainly just an interim step because during the time of the study I believe we will see that 2½–3 million acres of our best farmland will be converted to a nonagricultural purpose that is primarily irretrievable. Therefore, I think the urgency of this is here now, it is very late in this decade, and it is finally getting the attention it needs.

Mr. JONES. I am glad to hear the study is already underway.

Dr. TIMMONS. I was going to add that in the study we recently made which was published in the Journal of Soil and Water Conservation last October, we showed in this study that if we would increase to 1985 the crop acres in the agricultural plant we would increase the planted crops by 17 percent, which would give an estimated increased erosion loss of 39 percent in the Corn Belt States.

Now, if we are going to try to use the agricultural plant to bail us out of our balance-of-payments problem even more than we have now, and would step that up to a 29-percent increase in cropland, this would bring an estimated increase in erosion of 72 percent.

Now, I think the essence of this kind of a study is that if we are going to use agricultural resources to correct the deficiencies in our balance of payments, we are going to have to take a look at what that does to our soil resources, or otherwise, we will be treating them just like the OPEC countries are treating their oil.

Mr. JONES. I think what you are saying is that we are not really balancing our payments as I think we are.

We are just moving them from one place to another.

Dr. TIMMONS. It is a little bit like the old concept of gross national product, which does not give a net national product in terms of what is happening to disinvestment in natural resources and environmental quality.

Mr. BALDUS. We have some awfully good examples of that in Wisconsin where we have some hills, but we also have some good conservation projects, and you go on to Iowa, up there you tear out those strips and plow up and down the hill, and it just drives us up a wall.

Dr. TIMMONS. Of course, you can find a few of those strips in Wisconsin, too.

Mr. BALDUS. It was the Iowa people who did it in Wisconsin.

Mr. HARKIN. If the gentleman will yield on that point, they were just trying to get the rocks out of the soil to make the soil better [Laughter.]

Mr. JONES. Professor Timmons, what you are saying is something I have been believing for a good, long while, we have some problems that you and I and many of the landowners of this country do not have a lot of control over, because so much of this land today is absentee farms, and the people who rent farmland, farmer or not, and I classify him as a farmer if he has a tractor and a combine, and a few things like that to work with, but it seems to me if we want to control soil erosion, we will have to get some new innovations, and some new talent to the people who will be farming that land, plus the people who own the land that live off of the land, long-term lessees, and, Neil, you know I have been advocating this for a bit, we are going to have to

put some challenges out there to the people who do the job in the way of built-in incentives.

Now, what they need to be I am not sure I know, I am not sure that anybody can come up with that, but we are going to spend money for farm programs, somehow or other, we will have to come around to the realization that in order to be a participant, something in regard to saving the soil needs to be inclusive, if you receive some compensation from the Federal Government for help.

Mr. SAMPSON. Could make one other point, I had it in my testimony, I did not take time to take a look at it, and that is the interaction between the agricultural land conversion problem, and the soil erosion problem, both of those problems are not only serious, but they are self-accelerating, and not only do they accelerate, but they interact.

The way it really basically works is this, the soil erosion problem is as we would expect, far worse on the more marginal land, the steeper the land gets, the worse the problem.

The fifteen percent of the land which is marginal or unsuited, is providing 25 percent of the soil erosion according to the 1977 survey, so consequently the production loss is by far the worse on those marginal soils.

The effect of that is obviously to move production reliance to the better soils, and as we see historically that has happened.

On the other hand, the agricultural land conversion process takes a disproportionately high percentage of those flat soils like the gentleman from Colorado was referring to.

Out of about 25 percent of our non-Federal lands, we will find about 40 percent of our urbanization taking place on those best prime lands.

Now, the flat lands are the most intensively farmed, it is the easiest also to build on, and that building has the effect of forcing production back toward the marginal lands, and you have a pair of interacting processes, and the most damaging thing of that agricultural land conversion is not the acre it takes, but the quality of the acre it takes, and the effect that that has to push back toward the marginal land, and as Dr. Timmons says, if you depend on agricultural production to bail us out, then we are letting domestically those kinds of trends push us toward the marginal lands.

We will be talking about a bushel of soil for a barrel of oil is what we will be talking about.

Mr. JONES. Mr. Chairman, I will yield back my time so somebody else can be heard.

Mr. BALDUS. Mr. Walker, the ranking minority member of the Natural Resources and Environment Subcommittee, welcome.

Mr. WALKER. Thank you.

Thank you, Mr. Chairman. I wanted to pursue a little bit the farmland preservation area, and I am sorry I was not here to hear the testimony on it, and I am hopeful what I go over was not something you previously covered in your testimony, but this is an area that is of real concern to me, because I ran recently in the Lancaster County area in Pennsylvania, where we have some of the better farmland going, but we really have seen the encroachment of urbanization on that land, and, of course, we have a large Amish population, and we are concerned about preserving the farmland, and we find they have to bid against developers coming into the area, and we have been looking

at some kind of alternatives that will allow individual decisionmaking in the area of farmland preservation, and I would like to throw out a couple of concepts we have been talking about, and basically get your reaction to it.

We have been trying to individualize and localize it, and there has to be some local government involvement, but for one thing, we talked rather extensively about, this is indeed restrictions, actually putting into the deed itself a restriction that says the land is available for farm use only, and that each individual would have the determination to sell, whenever it would be sold, it would be sold with the restriction in the deed, that anybody buying it, it is sold with the purpose of farming only.

I am wondering if any of you have had experience with that kind of concept, and what the value of it is, or what some of the problems of that kind of thing is.

Dr. TIMMONS. There is a study going on now under the auspices of the American Land Forum to look at the options, and that is one of them.

The best patterns is found in West Europe, I think France has probably the best example.

They have set up a public body at the local level, which basically has the ability as the buyer of first opportunity, and they only act in the case of a piece of property being put up for sale, and in that event, then they have the right of first refusal.

If they see that as an agricultural property of significance to the continued agricultural critical mass in the area, they can be the purchaser at an arm's-length price from the person willing to sell.

They then retire the deed restrictions, and put it on the private market and sell it back to again an arms length transaction to whoever wants to pick it up privately, but with the deed restriction in there that you mentioned, and obviously, the value changed between when it was purchased originally, and when it sold back with the deed restriction, becomes the public cost of assuring that deed restriction has been put in and retired.

That is one of the examples.

Mr. WALKER. I would like to get some other comments, under what we called, this is an option there in Pennsylvania, where the State comes in to buy the land under the same sort of provision, there has been some fear expressed within the agricultural community of getting the State in the position of being the purchaser, you know, the State power over property concept becomes the question, and what we had hoped was maybe there were options available for the individual to make the determination, exclusively on their own, for perhaps some tax incentives down the line, legislation either introduced here would give tax incentives to somebody who makes that kind of a determination, nevertheless, the individual would have the opportunity to make it without the State interfering, but I appreciate your comments.

Mr. BERG. Mr. Congressman, the study I mentioned goes into just exactly what is being talked about here.

The most expensive type of deed restriction is the one being tested in several States with limited money, and in Suffolk County, N.Y., where they are putting in considerable money to long-term purchase of development rights on that particular acre, or on that particular farm.

What they are doing is restricting development by buying the development rights which will keep it in farmland from there on out, under a very restrictive deed.

Mr. WALKER. If I could follow, does it appear from the studies being done, that somehow you will have to purchase those development rights, is that an absolute essential?

Our feeling from the local people is that that may not be an absolute.

Mr. BERG. We agree; this would be very expensive.

However, this test is in very densely populated areas, where they feel they may have reached that point. These options have been explored in Massachusetts, Connecticut, Suffolk County, N.Y., and New Jersey. In Maryland, we are trying this with limited money, but it is a good law.

Now, what are the other opportunities? We understand there are some efforts being made to have land zoning for long-term agricultural purposes that in turn is recognized, and the owner receives a tax benefit, and that becomes a restriction.

Now, we understand there is some of that underway in Wisconsin, Michigan, and Virginia.

Mr. SAMPSON. Virginia is doing this, and they have about 10,000 acres which somebody donated.

Somebody has to receive them and hold the rights. Second, it would help if there were some tax credits, and one of the problems in the Virginia area, if we go up to New York, and they talk about purchase of development rights, they talk about many thousands of acres as a value. If you give them to the State, the IRS gives you credit for about $200 an acre. Obviously, that needs to be addressed a little more equitably, to really elicit private donation.

Mr. WALKER. Dr. Barrows?

Dr. BARROWS. I think your ideas are reasonable, and I think there are some places in the country, where this has been done with the tax incentives attached.

California has a system whereby individuals voluntarily can sign contracts, similar to Wisconsin, and the contract is actually a covenant that runs with the property, not to develop for a set period of time, in exchange for a tax incentive. Generally, it is a property tax relief incentive that comes along with the contract.

Now, the experience with that has been that in a rural area, where there is not too much development pressure, it will work pretty well.

Many people will have that long-term interest in agricultural, you will get lots of people signing up, you will get large blocks of land, and it will protect agriculture, and it works pretty well.

However, it does not work very well when you have much development pressure, the problem being that not everyone will want to enter into a contract, or into the deed restriction, in the California areas specifically.

So in those cases, the result is one piece of land that is under a contract, and right next door somebody puts in a subdivision, and maybe he wants to run the sewerlines over the farmland, and you get some real complications.

Mr. WALKER. That is one reason we felt, probably you have to basically agree to agricultural zones in which the deed restrictions would be applicable to get around that.

That I realize.

The other thing I would like to pursue just for a moment, when we talk about tax incentives, one thing that has occurred in our discussion, is the tax incentives might in fact be counterproductive in the sense that that then makes the property more attractive for investment, and thereby encourages absentee landlords, rather than operator owners on the farms, and I wonder if maybe you would comment on that aspect too, which has been a fear of going too heavily toward the tax credit route in the whole process.

Dr. BARROWS. I think that fear is very well founded.

There is evidence in New Jersey, from Maryland, from other States that use the tax incentive, that precisely what you fear has occurred. It does make agricultural land more attractive for the speculator, for the investor, and in Wisconsin, that is one of the things we have tried to avoid.

The way we tried to avoid it is by, number one, zoning; number two, requiring a contract for the tax credits. We reasoned that anybody really speculating on that land development value will not be very happy about having his land zoned agricultural by a group of farmers or will certainly not sign a 10- or 20-year contract to maintain the land in agricultural use.

Number two, we try to get around it in Wisconsin, by tieing the tax credit to the family income of the owner.

This is not a perfect guarantee by any means, but if an individual has a large off-farm income from some other activity that they are engaged in, then their income may be too high to get much tax credit out of the program, so you do not really have any tax incentive.

Mr. WALKER. Thank you very much.

Mr. BALDUS. On that point, would you agree that the restrictive covenants in the deed would cut back the amount of participation very severely?

Dr. BARROWS. I think that is correct. In fact, I think it will cut back the participation in that program in precisely the areas where you need it the most, where there would be some amount of development pressure. Again the California experience is fairly instructive in that sense. Again, from California, as the result of the USDA study, one of the variations of the program seemed to work: combining this kind of a contract (and there it was a 10-year deed restriction) with a tax incentive, and combined both with local zoning. So, if your land was zoned for agriculture, you could sign a contract, and receive tax relief. That seemed to have some good results, and we tried to build on some of it in Wisconsin.

Mr. BALDUS. Mr. Berg, on pages 13 and 14 of your testimony, you listed criteria against which any new soil conservation strategy should be tested, and among those is the avoidance of internal USDA duplication.

As I mentioned before, when we were talking about aquifers, was the question of the EPA doing it, the question of Interior doing it, or Agriculture doing it, do you also check around with other agencies as to conflicts that may occur?

Mr. BERG. Yes, we had purposely constructed our study teams to involve several major departments.

We have asked the U.S. Department of Interior to help, especially in the water resources area, and in the fish and wildlife habitat area.

We have worked very closely with EPA in terms of their concerns about water quality and air quality, as USDA is impacted either because of air quality impacts on agriculture, or on agricultural impacts on air quality, so we have established in the beginning of this process some of the communication network that we need.

Now, the RCA gives our Secretary the leadership to take an indepth look at the 30-plus soil conservation programs in the Department of Agriculture that I mentioned, but it is obvious from the wording of the law and it is our intention that we work in harmony with all levels of government and the private sector in this effort. The National Soil and Water Resource Conservation program is to be presented to the Congress for their consideration, because it will have to be looked at in context of all of the needs of the country.

I am suggesting that we have just about got our hands full to deliver in the early part of the new year what is required, but this act runs, as the Resources Planning Act of the Forest Service runs, for as much time as we need, and we will be working towards a much more comprehensive overview between now and 1985.

Mr. BALDUS. I have one more question, but it might be lengthy.

Anybody have any plane problems?

All right.

Dr. Timmons, I will direct this to you, and I also apologize for picking on Iowans, I can do that because my family migrated from Iowa, but they did not tear up any of the land.

In your testimony you went over very well the problems, and I think all of you recognize the problems of soil conservation, the necessity for conservation.

Let me word it this way, you know also that the amount of money that we have available for soil conservation programs has gone down, has diminished in terms of real dollars, actual dollars even from the 30's and 40's, and I am afraid that will have a serious effect.

What we are trying to do of course is come up with a more comprehensive program.

If you could describe at this stage what you would envision as an ideal program for let us say the Midwest, Iowa, the Corn Belt area, would you care to embark upon that kind of response?

Dr. TIMMONS. If I could do that, I would probably be in Congress, but I would speculate a little bit on that.

The market system as it exists in this country, I do not think it will bring us conservation, or I do not think it will keep prime agricultural land in the agricultural arena.

Mr. BALDUS. We will have to use the carrot and the stick?

Dr. TIMMONS. I think we will have to use disincentives, or combine disincentives and incentives.

Last year I was asked to review the resolutions of a large national organization. At about resolution two, they stated keep all of the prime agricultural land in the agricultural plant, do not let it get out, a very strong statement.

Three resolutions later they stated the private rights of the individual should never be interfered with.

Now, you see, this really is the problem, and I think this is probably the problem of the bills introduced here. So it seems to me that what we are going to have to do, a lot of things. Some things can we accomplish with education, but there is a limit to education.

You cannot educate people to go bankrupt, if they know what they are doing.

In other words, it is hard to educate people to overcome their inclination to maximize their value product from their labor, capital and land. But there are other problems such as, rental arrangements, size of farms, and debt problems that have been with us since the 1930's. A lot of progress has been made by Soil Conservation Service, the Extension Service, and by other agencies. So I think it will have to be a combination of incentives and disincentives, and I think we will get into that when we start using our agricultural plant more and more to help pay for our foreign imports, and oil is one of them.

However, there are other imports coming along that will be as serious or more serious than oil, that are held by three or four countries, and it will be easy for them to create a government cartel.

Mr. BALDUS. Including governmental involvement in those problems.

Dr. TIMMONS. It will be hard to avoid that. But we must also consider the cost. We must also realize that soil erosion and its control are inherently involved with the broader issues of land use planning. Prime agricultural land by urban developments pushing into rural areas, that is not unrelated to soil erosion problems. In using up the better agricultural land for development, which means you have to bring in more acres to replace acres that went out of cropland and the areas you are bring in are more fragile lands, they are more subject to erosion, or they would have already been in use. They are also less productive, which means you have to bring in more, and that is what we are getting into.

The study we made recently in Iowa—I did not go into this in my statement, you cannot cover everything—is that the incorporated urban areas in Iowa are stockpiling land. What we call the absorption coefficient—acres of land per person has been going up—and some of the areas in Iowa have enough land within the metropolitan boundaries to satisfy their projected growth through the year 2020. They are still stockpiling it. As to why they are doing that, it is a difficult question, but I am convinced this is what is happening.

I think one reason they are doing it is they are protecting their expansion paths for growth. They think they may grow out this way, and they incorporate a lot of the land into the metropolitan area so they can control it through zoning, since county zoning laws and most rural States are not very effective.

Another thing is that cities are kind of ambitious, they think they are going to grow more than they are sometimes, particularly in some of the rural areas and this is what is happening.

Mr. SAMPSON. The cheapest lot of any lot that can be touched is right at the end. It is about a quarter of a mile off the end of the sewer line, therefore you hopscotch a whole bunch of farmland, and you get out to the end.

Dr. TIMMONS. Not only that, but I think government investment through grants and loans is probably one of the worse violators of orderly land use and development.

The funds you appropriate for agencies, some of those public loans and grants are going for public investments that determine the way the land use will go.

If you can control transportation, sewage, water supplies, education, recreation, housing, all of these things with public funds, then this is the way developments will go.

If you spearhead thousands out into the agricultural areas, that is where your development will be going.

Dr. BARROWS. Let me state, it seems one of the things the Congress could do would be have some substantial benefit would be No. 1, to say the policies of some of those Federal agencies, with respect to sewer, water and transportation should be consistent with the actions of a local government that wants to do something about protecting good farmland in that local area, as Lancaster County, Pa., or whether it is a county in Wisconsin or Iowa. At a minimum, the Federal Government should not get in the way of what the local people want to do.

No. 2, I think the Federal Government could help the local people with what they want to do.

In Wisconsin, we took $400,000, and we got 43 counties doing agricultural preservation work.

That was not because of any great ideas at the State level, that was because local people, all over the State wanted to do something, and had wanted to do something for a long time, and all of a sudden, they had some resources to do it with. So, you could provide the Lancaster County, Pa., area with a little bit of start-up funds, a little bit of help, some technical assistance from the Soil Conservation Service, and help them get going with something they want to do.

That will not solve all of the problems, but it will give us a couple of steps in the right direction, and it is something that could be done immediately.

Mr. SAMPSON. I would like to come back to a bill, it is in your Agricultural Committee that would in fact set a Federal policy that would begin to get agencies outside of the Department of Agriculture and EPA, which now have internal policies, they do not really effectively get at anyone else, that bill would essentially establish national policy that would as a first cut attempt to reduce the amount of this conversion that is being fueled by the Federal investment.

When we asked our districts around the country whether they had an agricultural land conversion problem, and then asked them where Federal actions were a significant part of it, of those that said they had a problem, well over half said the Federal Government was either a major cause, or a significant cause of that problem, again from the investment point of view, so the policy statement, I think it is title I of the bill the Agricultural Committee is considering, is a statement that should move forward.

We are going to have studies, and there will be other things that come later, when we talk about specific solutions, but to stop being part of the problem is a fairly easy first step on this route, and I really believe that is an opportunity the Congress ought to seriously consider.

Mr. BERG. Mr. Chairman, let me make it a part of the record here, I want to get into the details, as a part of our RCA process, we have joined with the ESC as the economic group in our Department on a major cooperative effort over this past year to determine the effect of erosion on future productivity.

We have taken county-wide data from 1,100 of our offices and in a very detailed look at those 1,100 counties, using the data on erosion rates from the inventory we talked about today, projected those

recent erosion rates to the year 2030 to estimate the impact over a 50-year period. We selected two of these areas for the record here. These are based on the water resources aggregated subareas of the country. We took area 703, which is a soybean area in the Midwest, and 705, which is a corn area. What we find is that based on the present losses of around 15 tons per acre per year, and that is not undue loss, we are going to have reduced potential yields of at least 15 percent in that 50-year period.

Now, when you couple that with your question, we are going to have to face, as Professor Timmons pointed out that the landowner, land user, and the present operators of the land do not have that kind of planning horizon; nowhere near it. Yet the results of many of the things they are doing today will impact on the future. The parallel terracing in Iowa is a very expensive operation, and we have to face up to the fact that the public benefit is long range. So how are we going to balance the demands of the marketplace, the need for information, the technical assistance needs, and the research capability that we have with the fact that people are not looking at that sort of time horizon. They are not looking at it in terms of our prime agricultural land, and they are not looking at it in terms of the destruction of the resource base. We are now getting the benefits of work that we did in the thirties and forties, and the fifties, and that is what we are going to have to realize as we look down the road. The strategy we are looking at is not easy to explain and there is a complete interrelationship of many things we have been doing, plus some things that have to be done differently than we have ever done in the past. We are suggesting that if you want to devise a strategy for Iowa or any specific locality, it will have to be on the basis that we join hands, Federal, State and local, and determine where are the resources that can best concentrate on what the people want to do in that particular area. We must recognize that the private sector will have to have, as you mentioned, both incentive and disincentives to do some of the things that are presently under study.

Dr. TIMMONS. There is another point if I could add it that we have been emphasizing, the matter of increased demand in terms of exports.

We should also try to keep a caution in back of our minds, that these demands for agricultural products, particularly overseas demands, are very vulnerable. They are based on such things as a frost in Russia, a political change in China, or the ancloirta catch in Peru, and we have to remember that there is also a possibility we could backslide and end up with some surpluses again.

We do not want to forget that. It is hard to think about that when you have ample markets. We ought to keep that in mind, and some kind of assurance has to be made to underwrite the capacity of agriculture to meet our demands, if they are periodic demands.

Demands may well vary up and down to a degree at least in some of the crops, because, you see, if our agriculture goes into a tailspin, with $2,000 or $3,000 an acre cropland and commitment we are now getting throughout the Midwest, and the tax structure and land debts become geared to that, the pressure of debt might force farmers to plow up fragile lands and to put them back to corn. So there is something here that we do not want to forget.

Mr. BALDUS. We saw examples of that in 1973.

Mr. SAMPSON. The study done on that very point took the historical corn yields, and we did the best we could with the most eminent scientists to weed out all of the other changes and discover what yield fluctuations could be said to be related strictly to climatic patterns alone.

The results of that study, I am working from memory, but it seems to me the long-term standard deviation is plus or minus 13 percent on the basis of climate, of weather change alone.

If I remember, wheat was down about 12, sorghum was in around that same range, but what that points out, I think we are getting more and more vulnerable to that, that our agricultural plant gets more and more intensively used, and we put in as much or all of the technological input that we can, we become more vulnerable to the varying amount of natural input, in other words, again, energy, frost, the whole thing that comes from weather, so we are more and more vulnerable, and I will stick my neck out scientifically and say the agricultural plant being used intensively today is more vulnerable to change from climatic variation than before, and I think we have to realize that today we do not know within 25 percent what next year's crop will be, unless we believe in Ouija boards, the statistics will not hold us up.

Mr. BALDUS. You can add to that the worldwide demand which may influence the way people react will be more volatile as the Third World nations gain in average annual income, and as they gain in becoming accustomed to having a full diet, because it will be that much more difficult for them to be without, so I think, it seems to me, the demand will be a great deal more volatile.

I want to thank you very much for being here, and it certainly has been a learning experience for members of the committee.

I hope it has been useful to you, and in your professional ability, and to share with us and with each other your discipline.

Thank you very much.

The committees stand adjourned.

(Whereupon, the committees were adjourned at 4:45 p.m.)

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APPENDIX I

AGRICULTURAL PRODUCTION

AND

ENVIRONMENTAL QUALITY

A SERIES OF ISSUE PAPERS PREPARED FOR:

SUBCOMMITTEE ON CONSERVATION AND CREDIT
AGRICULTURE COMMITTEE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
SCIENCE AND TECHNOLOGY COMMITTEE

AND

SUBCOMMITTEE ON NATURAL RESOURCES AND THE ENVIRONMENT
SCIENCE AND TECHNOLOGY COMMITTEE

U. S. HOUSE OF REPRESENTATIVES

BY SCIENTISTS FROM:

TEXAS A & M UNIVERSITY
CORNELL UNIVERSITY
UNIVERSITY OF FLORIDA
THE PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY OF CALIFORNIA
UNIVERSITY OF ILLINOIS



National Association of State Universities
and
Land-Grant Colleges

July 25, 1979

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National Association
of State Universities
and Land-Grant Colleges

Robert L. Clodius, President

July 18, 1979

The Honorable Ed Jones, Chairman
Subcommittee on Conservation and
Credit
Agriculture Committee
U. S. House of Representatives
Washington, D. C. 20515

The Honorable George E. Brown, Jr.
Chairman, Subcommittee on Science,
Research and Technology
Science and Technology Committee
U. S. House of Represenatives
Washington, D. C. 20515

The Honorable Jerome A. Ambro
Chairman, Subcommittee on Natural
Resources and the Environment
Science and Technology Committee
U. S. House of Represenatives
Washington, D. C. 20515

Dear Chairmen Jones, Brown, and Ambro:

We appreciate the opportunity to present written testimony for the jointly sponsored Congressional hearings on the interactions between agricultural production and environmental quality to take place on July 25 and 26, 1979.

We are submitting for the record seven issue papers bound as one presentation from the Association on five specific topics of interest to your investigation that we have discussed with Dr. Chris Bernabo of Representative Brown's staff.

We are delighted to be of assistance to the Committees and look forward to the presentation of our scientists' papers by Dr. Sam Aldrich in connection with his testimony.

Enclosed please find the requested sixty bound copies of our statement. Thank you again for this opportunity to be of service.

Sincerely,

Robert L. Clodius

Robert L. Clodius
President

Enclosures

One Dupont Circle, N.W. Washington, D.C. 20036 202 / 293-7120

NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES

STATEMENT

BEFORE

THE JOINT HEARINGS

OF

U.S. HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON CONSERVATION AND CREDIT, AGRICULTURE COMMITTEE
CHAIRED BY THE HONORABLE ED JONES

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
SCIENCE AND TECHNOLOGY COMMITTEE
CHAIRED BY THE HONORABLE GEORGE E. BROWN, JR.

AND

SUBCOMMITTEE ON NATURAL RESOURCES AND THE ENVIRONMENT
SCIENCE AND TECHNOLOGY COMMITTEE
CHAIRED BY THE HONORABLE JEROME A. AMBRO

ON

THE INTERACTIONS BETWEEN AGRICULTURAL PRODUCTION AND ENVIRONMENTAL QUALITY

ON

JULY 25 and 26, 1979

PAPERS BY

DR. EDWARD A. HILER, TEXAS A & M UNIVERSITY
DR. HOWARD E. CONKLIN, CORNELL UNIVERSITY
DR. J. M. DAVIDSON, AND DR. G. T. EDDS, UNIVERSITY OF FLORIDA
DR. DONALD J. EPP, THE PENNSYLVANIA STATE UNIVERSITY
DR. ANDREW CHANG, DR. ALBERT PAGE, DR. WALTER FARMER,
DR. PARKER PRATT AND DR. HENRY VAUX, UNIVERSITY OF CALIFORNIA
DR. SAM R. ALDRICH, UNIVERSITY OF ILLINOIS

RELATIONSHIPS BETWEEN THE ENVIRONMENT AND AGRICULTURE: SOURCES AND IMPACTS OF AIR AND WATER POLLUTION

Executive Summary

Perhaps the greatest challenge facing society in the remainder of this century is that of providing ample high-quality food supplies for our increasing population with dwindling energy, water, and land resources while maintaining and hopefully improving the quality of our environment. This testimony deals with sources and impacts of air and water pollution as they relate to agriculture and the environment.

Three major sources of water pollution are:

(1) water erosion and sedimentation of soils,

(2) leaching of fertilizers and salts to pollute groundwaters and in some cases surface waters,

(3) direct runoff from confined animal feeding operations reaching streams.

Major sources of air pollution are:

(1) wind erosion and sedimentation of soils,

(2) dust at grain elevators resulting in grain dust explosions,

(3) dust at cotton gins and cottonseed oil mills which may be a causal factor of the respiratory disease called byssinosis.

The testimony reported herein highlights two of these; namely, water erosion and sedimination of soils and dust at grain elevators resulting in grain dust explosions. These sources of air and water pollution were chosen for special emphasis because of their high level of impact on both agriculture and the environment.

Author: Dr. Edward A. Hiler, Professor and Head of the Department of Agricultural Engineering, Texas A & M University

RELATIONSHIPS BETWEEN THE ENVIRONMENT
AND AGRICULTURE: SOURCES AND IMPACTS OF AIR AND WATER POLLUTION

Prior to the 1950s, agriculture flourished with minimal concern among the populace related to degradation of the environment in which we lived. With the publication in the early 1950s of Rachel Carson's Silent Spring, the public was brought to a new awareness of environmental impacts and their potential long-term effects. Air and water pollution caused by big industry was most visible and hence related environmental controls were enacted in these areas first. Soil erosion by wind and water had been recognized for centuries as undesirable because of the depletion of the soil productivity. With the advent of increased environmental concerns in the 1950s, soil erosion by wind and water was quickly recognized as a major source of air and water pollution. This recognition culminated in the passing of Public Law 92-500, the 1972 Federal Water Pollution Control Amendments which mandated the analyses of agricultural non-point source pollution controls.

Following the environmental concerns of the 1950s and 1960s, the early 1970s brought the recognition of an energy crisis. Little has been done throughout the 1970s to bring any long-term solutions to our energy problems and they are today at a higher level than at any time previously.

The period of 1950 through the 1970s has also been one of phenomenal population expansion both in the United States and the world. With this increased population, society is today faced with the tremendous challenge of providing ample high-quality food supplies with ever-dwindling energy, water and land resources while maintaining and hopefully improving the quality of our environment. I hope that these hearings will contribute to meeting this challenge--the enormous challenge of making wise decisions at the critical interfaces between food, resources, energy and environment.

There are many sources of air and water pollution related to agriculture. Three sources of water pollution having major impacts on both agriculture and the environment include:

(1) water erosion and sedimentation of soils,

(2) leaching of fertilizers and salts to pollute groundwaters and in some cases surface waters,

(3) direct runoff from confined animal feeding operations reaching streams.

Major sources of air pollution impacting agriculture and the environment are:

(1) wind erosion and sedimentation of soils,

(2) dust at grain elevators resulting in grain dust explosions,

(3) dust at cotton gins and cottonseed oil mills which may be a causal factor of the respiratory disease called byssinosis,

(4) air pollution from chemicals and engine exhausts near urban areas resulting in reduction in plant growth and development,

(5) odors in the vicinity of large confined animal feeding operations.

This testimony will deal with a specific analysis of two of these pollution sources; namely,

(1) water erosion and sedimentation of soils,

(2) dust at grain elevators resulting in grain dust explosions.

The other topics are treated in companion testimony.

WATER EROSION AND SEDIMENTATION OF SOILS

Erosion by water is the dominant conservation problem on 179 million acres of cropland and about 32 million acres of non-Federal pasture and rangeland on the U.S. mainland. Erosion on construction sites and related developments in urban areas, and areas in transition from rural to urban industrial uses, is a problem of growing national concern. Erosion control on Federal and State highway systems and on railroad and utility rights-of-way require the expenditure of large sums of money. Erosion along country and private roads is frequently a major and unresolved problem.

Erosion results in drastic losses to a precious natural resource--the land. It results in reduced efficiency of farm operations and reduced crop yields. It results in tremendous losses of plant nutrients, and hence soil fertility. The efficiency of water utilization is reduced and in some cases, as illustrated by the once highly productive Brown loam soils of Mississippi, the use of the land for agricultural purposes is seriously limited.

Erosion is the source of sediment which impairs the quality of the water resources in which it is entrained and frequently degrades the location where it is deposited.

Sediment, a product of erosion, becomes a pollutant when it occupies water storage reservoirs, fills in lakes and ponds, clogs stream channels, settles on productive lands, and interferes with their use, destroys aquatic habitat, creates turbidity that detracts from recreational use of water, as well as when it degrades water for consumptive or other use, increases water treatment costs, or damages water distribution systems. In addition, sediment is a carrier of other pollutants, such as phosphates and some pesticides.

Separation from their sources of the varied eroding materials that become sediments may be accomplished by gravity, frost-heaving, temperature expansions and contractions, raindrop splash, scouring wind and running water. Activity of these natural agents is increased by the numerous activities of man that remove the protective cover and disturb the soil, or change the dynamic equilibrium of a river. Transport of the separated particles may be by wind, water, or gravity.

Sediment derived from land erosion constitutes by far the greatest mass of all the waste materials resulting from agricultural and forestry operations. Committee Print No. 9 of the Senate Select Committee on National Water Resources states:

> "Rough estimates of the suspended solids loadings reaching the Nation's streams from surface runoff show these to be at least 700 times the loadings caused by sewage discharge."

In an average year, approximately 450 million cubic years of material are dredged from U.S. rivers and harbors in order to maintain the navigation channel. Much of the material removed is sediment.

Erosion by surface runoff produces some 4 billion tons of sediment each year, and of this total, one-fourth is transported to the sea. About three-quarters of the sediment comes from agricultural lands.

Sediment may come from forested lands that have been devastated by fire, construction of forest roads and other forest improvement, certain logging practices, over-grazing and trailing of animals on rangelands, cultivated lands that are improperly treated or inadequately protected, industrial construction sites, highway construction, unprotected roadside cuts, suburban development projects, spoil banks from strip mining and other mining activities, unstabilized streambanks, and natural erosion of such areas as the Badlands of South Dakota. The land is robbed, and the water despoiled.

Erosion from cropland is the most significant single source of sediment and constitutes the greatest single cause of loss. Sediment production from a construction site may be spectacular and of extreme local importance, but such incidents make up a small percentage of the total sediment burden of our rivers. Of the 17 million tons of nutrients flowing down the Mississippi annually, a large share originates on agricultural land.

Methods of preventing erosion and sedimentation are known and are being applied to some degree to most source areas and causes; however, there remains much to be done to control erosion on crop and rangeland and on unreclaimed mined lands. Although some protective measures are being applied for protection of denuded sediment producing areas in suburban development and in road and highway construction, the rate of expansion of the highway network and of growth of towns and cities is such that we are barely keeping even with the increase in the problem. We are a long way from attaining the reductions in erosion and sediment movement that could be made with present knowledge; even at best we could not expect to stop all of it. We will always have some sediment to contend with; for a long time yet, it will remain a major problem.

In some cases, the limited application of erosion control practices is due to lack of realization of the consequent damages or unfamiliarity with the available techniques. More often, the cause is associated with the costs of control, or the apparent disparity between the beneficiary of and the investor in control measures.

Technology is currently available to permit reduction in the movement of sediment. However, even with the application of current and prospective technology for erosion and sediment control, some sediment will continue to be carried in moving water and will carry with it various available pollutants. It is the fine particles that are the principal carriers, the most active chemically, and transported farthest before deposition. We do not yet have adequate controls for the clay and colloidal sediment fractions, both at source and in final deposition.

Control of erosion at the source is the most direct, and usually the most satisfactory, approach in dealing with most sediment problems. Such erosion control practices are multibeneficial by preserving land and vegetation resources and at the same time reducing sediment yield.

For instance, where the sediment is derived from sheet and rill erosion on agricultural, forest, or rangelands, certain agronomic and forest and range management practices, as well as mechanical and structural measures, effectively reduce sediment yields. Changing cultivated fields from row crops to small grain may reduce soil loss due to sheet erosion by from 60 to 90 percent, depending on cover conditions, soils, and seasonal distribution of rainfall. Rotation of crops to include meadow in the cropping sequence may reduce average soil loss from fields by 75 percent. Such practices as mulching, strip cropping, and contour cultivation have been shown to be highly effective in reducing soil erosion on farmlands. Graded cropland terraces may reduce erosion on fields by 75 percent and in combination with crop rotations, mulching, minimum tillage, etc., can reduce to practically nothing soil loss from cultivated cropland fields. Converting cropland to good grassland, pasture, or woodland can reduce soil erosion by 90 percent or more.

The conversion of cropland to grassland may result in a reduction in income to the farm operator. Some types of terraces may greatly increase the cost of farming. These examples illustrate the need for development and evaluation of practices that integrate control of erosion with a viable farm production system--conserving the resource, providing reasonable farm income, and reducing damage from sediments.

Another area of concern is the role of sediment in transporting pesticides and other chemicals. Increased interest in managing the quality of the environment has focused attention at the lack of data in this area.

Particular attention should be given to the integration of the use of mulches, vegetative cover, and structures to obtain the most feasible, most acceptable, most effective system of erosion control.

> For example, waste fibers from logging operations or from agricultural processing plants might be economically converted into cover materials for treating disturbed areas. Also, special techniques and treatments are needed for arid and semiarid areas.
>
> Prevention of all soil erosion is highly unlikely and possibly not even desirable. Since some sediment production will continue, methods must be devised for handling it. Is it better to provide sediment trapping basins on major streams or should sediment be permitted to flow to the ocean? Can sediment be made useful for developing new lands or for improving present unproductive lands?[1]

In order to provide more specific information and to explore the area of policy options related to water erosion and sedimentation of soils, I am including an executive summary of a report indicating economic analyses of erosion and sedimentation in five diverse agricultural watersheds in Texas (see Figure 1).

> Economic analyses of the study areas considered both the on-farm economics of soil conservation and the economic consequences of various sedimentation control options. These topics were joined in the studies because they deal with different facets of the same problem. Unlike some potential pollutants, soil particles transported from a farmer's field that may become a problem downstream are a valuable resource, not a waste product. Because soil is valuable in itself, some level of soil conservation is going to be economically desirable even if downstream damages are not present or are not considered by the farmer. Results of the studies show that soil conservation does indeed pay in many situations and that its value is greater the longer the planning horizon of a farmer. This suggests that an educational program in this regard may reduce sediment damage while increasing farm income at the same time.
>
> Sediment can cause environmental damage (off-site costs) both directly and indirectly. Directly, the soil particles can cause environmental damage by filling up reservoirs and flood control structures and by deposition in other places. Indirectly, sediment can cause environmental costs by carrying plant nutrients that are potential pollutants. For the study watersheds, no evidence was found that the concentration of plant nutrients in the water posed health hazards to livestock or humans, nor caused undue eutrophication in the watersheds. Consequently, the study focused on off-site sediment damages resulting from shortened economic lives of reservoir and flood control structures and from sediment deposition in the watershed.

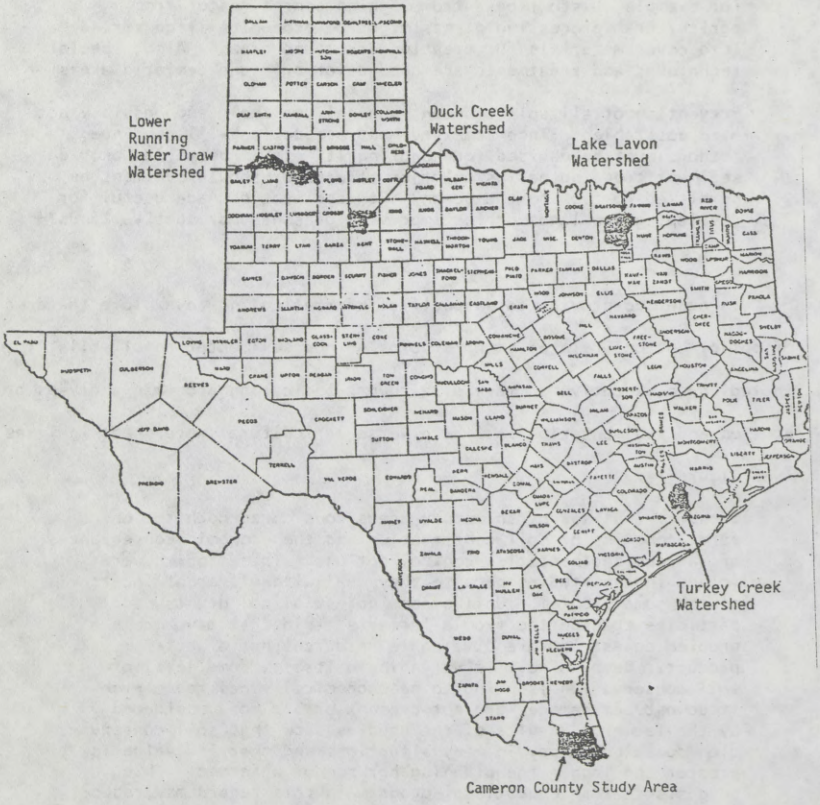

Figure 1. Location of the Study Area.

Annualized off-site sediment damages ranges from a high of 26 cents per ton of gross erosion in Lake Lavon watershed to 14 cents per ton of gross erosion in Duck Creek, to 13.5 cents per ton of gross erosion in Lower Running Water Draw, to a negligible amount in Turkey Creek and Cameron County. These estimates are considerably lower than off-site sediment damages in corn belt watersheds.

Public policies that can be implemented to abate off-site sediment damages include direct regulation, provision of economic incentives, education, and public investment. For point sources of pollutants, regulations are typically directed toward the pollutant at or near the point of emission into waterways. However, this is infeasible with non-point sources such as sediment because they enter waterways at an infinite number of points. Hence, regulations must be directed toward the practices that cause erosion and thus sedimentation.

The economic incentive option includes alternatives such as Federal or State cost-sharing for adoption of conservation practices, and disincentives such as taxes or penalties on erosion. Education is a viable policy option in situations where producers are not adopting soil conservation practices that would be profitable. In these situations a successful education program would increase producer's income as well as reducing off-site sediment damages. Public investment could be used to pay for dredging sediment from reservoirs and flood control structures to prevent loss of flood control, water supply and recreational benefits.

Social benefits and costs of various policy options based on direct regulation, taxation, and provision of economic incentives were estimated for three watersheds: Lake Lavon, Duck Creek, and Lower Running Water Draw. Items considered in the benefit-cost analysis were: (a) farm income consequences; (b) off-site sediment damages abated; (c) governmental cost or revenue; and (d) administration and enforcement costs associated with each policy. The major conclusion of this social benefit and cost analysis is that off-site damages are not large enough to warrant controls on agricultural activities in any of the watersheds; that is, the costs to society of controls exceed the total benefits to society for all of the policy options considered. Another conclusion is that an education program that emphasizes the on-farm profitability of conservation practices may reduce sediment damages while simultaneously increasing farm income.[2]

DUST AT GRAIN ELEVATORS RESULTING IN GRAIN DUST EXPLOSIONS

The remainder of this testimony is devoted to the problem of grain dust explosions at small elevators as well as large export terminals. Several major explosions at large export terminals occurred during the last week of December 1977. The explosions greatly highlighted the problem and there was a flurry of interest in new research and educational programs to identify solutions to this major air pollution problem which has resulted in not only tremendous property losses but also loss of many lives. Currently, this interest has waned and there are still no major research efforts oriented toward providing viable economic solution to the grain dust explosion problem. The following material defining the grain dust explosion problem is presented in the hope that the seriousness of this problem will be recognized again and funds will be provided for solving it.

> One of the first explosions recorded in which dust was recognized as a contributing factor occurred at a flour mill in Turin, Italy, in 1785. The deflagration was thought, at that time, to have resulted from the ignition of flammable gas evolved by the disturbed flour dust. It was not recognized until over one hundred years later that ignition of the dust alone could initiate and propagate an explosion.
>
> The first type of dust explosions to be investigated extensively were coal dust explosions, precipitated by the many coal mining tragedies in the late 1800s in Europe. In 1907, 1148 miners were killed in the United States which provoked the establishment of the U.S. Bureau of Mines in 1908.
>
> Due to the use of non-enclosed machinery and weak construction of buildings, which did not allow for the buildup of explosive pressure, early dust explosions other than coal were characterized only by rapid flame propagation and resulting fires.
>
> The earliest reported agricultural dust explosion in the United States was in 1846. From 1846 to 1878, ten explosions were recorded, nine of which occurred in flour mills and one in a candy factory due to starch. A total of fourteen injuries were

attributed to the first nine of these explosions but in Minneapolis, Minnesota, in 1978, the tenth explosion was the first in the United States to record loss of life when eighteen persons were killed.

Handlers of agricultural dusts other than flour were also alerted to the dangers of dust explosions when a total of 72 dust explosions and 60 deaths occurred in U.S. agricultural industries between 1878 and 1913. The last of this series of explosions involved a loss of 33 lives and 80 injuries in a feed mill explosion in Buffalo, New York. The exact cause of the Buffalo explosion was never determined, but it appeared to have originated in the feed grinding process and probably involved ignition of oat-hull dust. Although the subsequent record of feed and cereal mills did not improve as favorably as flour mills, the 1913 disaster marked a peak in feed and cereal mill fatalities.

The most catastrophic agricultural dust explosion ever recorded in the U.S. in terms of lives lost, occurred in a Cedar Rapids, Iowa, starch factory when 43 people were killed and 30 injured. Only one-half hour earlier, the full workforce of approximately 600 people had left for the day. Five years later, another starch factory explosion in Pekin, Illinois, killed 42 and injured 22.

Dust explosions have also occurred in a number of other industries processing agricultural products including coffee, spices, cotton, malt, powdered milk, tobacco, nuts, cocoa, and sugar. However, in all of the recorded history of agricultural dust explosions, grain elevators rank first in the number of explosions, people killed, and amount of property damage.

From 1846 to 1956, almost twice as many dust explosions occurred in grain elevators than in flour mills, nearly four times as many as in starch processing and utilization, and over one and one-half times as many as in feed and cereal mills. Since 1925, grain elevators also assume the number one position in terms of persons killed in dust explosions, although until recently, the most lives lost in any one grain elevator explosion occurred in 1908 when seventeen persons died in Richmond, Vermont.

Thus far we have discussed only dust explosions. Historically, dust fires have far outnumbered dust explosions. Over 29,000 grain elevator fires occurred in the U.S. from 1964 to 1973, an average of more than 2900 per year with an average annual loss of over $33,000,000. A significant decrease in the number of annual grain elevator fires has occurred since 1969 possibly due to the increased use of fire protection equipment including the use of automatic detection, alarm, and sprinkler systems.

The first concrete elevator was built in Chicago in 1905 and considered to be "fireproof." However, it became apparent that fireproof structures and explosion proof structures were not equivalent when a series of concrete elevator explosions culminated in 1921 in Chicago

when the largest concrete elevator in the world at that time exploded killing six, injuring four, and resulting in $4,000,000 damage. The force is said to have lifted loaded concrete bins from their foundations, each about 300,000 tons, shifting 40 of them six inches.

Table 1 indicates the total number of agricultural explosions, persons killed and injured and estimated damage accrued in the U.S. for the years 1900 to 1957. Table 1 also illustrates the percent of agricultural explosions for 1900 to 1957 related to grain handling and storage.[3]

TABLE 1

AGRICULTURAL DUST EXPLOSIONS

1900 to 1957

	Total	Grain Only	Percent Grain
Number of Explosions	1,085	490	45%
Persons Killed	640	381	60%
Persons Injured	1,712	991	58%
Damage in Million $	100	70	70%

Table 2 lists data related to grain dust explosions in the U.S. through 1978. Table 3 lists the same data in terms of yearly averages. It is seen that the number of explosions, persons killed and injured, and the amount of property damage and production loss has risen significantly in recent years. Table 4 illustrates how suddenly large losses can occur when during a one-week period in 1977, four explosions claimed 10% of the theretofore recorded deaths and nearly approached the total property damage and production loss of all previous explosions.

TABLE 2

DUST EXPLOSIONS - GRAIN

Year(s)	Number	Killed	Injured	Damage ($ Millions)
1900-1957	490	381	991	70
1958-1975	220	148	499	148
1976	16	19	82	50
1977	12	61	71	100s (est.)*

*Many lawsuits are still pending.

TABLE 3

DUST EXPLOSIONS-GRAIN

Year(s)	Average Number Per Year	Average Killed Per Year	Average Injured Per Year	Average Million $ Loss Per Year
1900-1957	8.4	6.5	17.1	1.2
1958-1975	12.2	8.2	24.9	8.2
1976	16.0	19.0	82.0	50.0
1977	12.0	61.0	71.0	100s (est.)*

*Many lawsuits are still pending.

TABLE 4

DUST EXPLOSIONS-GRAIN

TIME PERIOD	NUMBER	KILLED	DAMAGE ($ MILLION)	PRODUCTION LOSSES ($ MILLION)
1900-1976 (4,004 weeks)	726	548	265 (est.)	100s
Dec. 22-27, 1977 (1 week)	4	53	100 (est.) (10% Gulf Coast Export Capacity)	100s

Research to date has identified many of the causal factors in grain dust explosions and these are being communicated to the public through our Extension program of the Land Grant System. An example is a series of workshops for grain elevator operators and insurance specialists held in Texas during 1978 under the auspices of the Texas Agricultural Extension Service. There is, however, a tremendous need for research to identify and develop economically viable early warning and control systems for the prevention of grain dust explosions.

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Urban/Agricultural Interface and Farm Land Preservation

Executive Summary

1. Urban growth is cutting agricultural production two ways: by moving onto farm land and by discouraging farmers from updating real estate improvements in areas of urban scatteration.

2. The urban/agricultural interface no longer is a sharp line. Urban influences have penetrated deeply into most farm areas over large parts of the nation. Farmers often are outnumbered by nonfarm neighbors. Nonfarm rural people are growing in numbers faster than other components of our population.

3. The debilitation of agriculture caused by the scattering of nonfarm people into rural areas is cutting production more than the physical transfer of land to subdivisions, shopping centers, and the like, though both are important.

4. There are two ways to reduce urban impacts on agriculture:
   a) Keep the nonfarmers out of farm areas.
   b) Facilitate the peaceable and productive coexistence of farm and nonfarm people.

5. Keeping nonfarmers out is favored by professional planners but is difficult and expensive. Some methods will work in selected circumstances, especially close-by locations. Special forms of zoning and government purchase of development rights are most promising.

6. Facilitating coexistence is more common at present. Farm-value assessments were an early start. Agricultural districts are more sophisticated. Methods can be further improved.

7. There already is intermingled diversity in the rural areas of much of the nation. This cannot be rolled back. Special emphasis on new methods for facilitating coexistence seem justified.

The Urban/Agriculture Interface and Farm Land Preservation

Howard E. Conklin

Cities no longer are points of concentrated populations. Suburbanization, sprawl and scatteration have made cities into much larger areas and have fuzzed their edges so it is hard to tell where the city ends and the country begins.

Cities no longer have a single government. What is usually referred to as city government now only controls the "inner" city. A meriad of small government units encircle nearly every city and often control more area in total than city government. A large scattering of urban people usually extends even beyond the peripheral villages and small cities to areas in which traditional town and county governments provide what local services there are.

In much of eastern United States, from Maine to Louisiana, urban scatteration extends to all but the most remote corners of the rural countryside. Farmers have held out against scatteration in most of the more prosperous parts of the Corn Belt and nonfarm employment opportunities are too small to support a large nonagricultural population over most of the Great Plains. Rural populations are increasing sharply, however, in Arkansas, northern Wisconsin, Minnesota and Michigan, with the increases fueled in part by a quest of retirees for comfortable and interesting surroundings in which they can afford to live. The mountainous parts of the Pacific states and scattered spots from Tuscon and Santa Fe to the Flathead Lake area of Montana are experiencing nonfarm rural population

growth, partly from retirees but also partly from urban workers.

The Northeast often has experienced new trends (both good and bad) ahead of other parts of the country. The rural population of New York, for example, has been increasing for over 40 years, and still is increasing, even though the metropolitan population of this state has been dropping for the past few years. Many of the new rural residents of New York are the children of rural residents but some here too are retirees, and a few are younger escapees from conditions they consider intolerable in the inner-city. Most have medium incomes but a few are near the poverty line.

Connecticut and parts of New Jersey have experienced an influx of upper middle income professionals and executives who are essentially suburbanites but have moved out far enough to be called rural. Maine, New Hampshire, and Vermont have been favored more by what might be called suburbanite drop-outs -- people who are well educated and capable but prefer a rural lifestyle.

Maryland and the Philadelphia area of Pennsylvania still are experiencing massive suburban growth of the commuting kind once common through the Northeast. It is sparked by continued increases in highly paid urban jobs (many in government) and by the growth of newly suburbanized industries.

Many of the Midwestern states appear to be following the overall patterns of the Northeast -- slow total growth resulting from a balancing of urban decline against rural increase, with spots of special activity here and there. The South shows unusual strength in both urban and rural sectors and the West is mixed but generally very strong.

Farmers once lived in cities and villages and commuted to their farms in rural areas. They still do in some parts of the world, but in the United States most of them always have lived on their farms. Throughout most of our history, farmers and people who worked in related occupations dominated rural America. This now is changing rapidly.

New York still ranks ahead of half the states of the country in the value of its farm production but we have reached the point where every full-time farm family is outnumbered by nonfarm people in their home community. Farmers, by their numbers, can no longer control their schools, roads, police protection, fire protection, or taxes. They share the countryside with hikers, snowmobilers, horseback riders, and, unhappily, vandals. They are powerless to prevent ordinances that restrict their activities and the chemicals they use. The old-timers say it is like farming in Grand Central Station, and the newcomers speak of being squeezed between the vagaries of the export market and the fads of the local "ecofreaks".

Two Ways to Address the Problem

There appear basically to be two ways to address the urban/agricultural conflict that has arisen in recent decades: keep the nonfarm people out of the farming areas, or develop new kinds of institutional arrangements that will permit farmers and nonfarmers to live peaceably and productively together in rural areas. Fortunately these two approaches are not mutually exclusive.

Professional planners and many agricultural economists have focused especially on means to keep nonfarm people out of farming areas. The most common legislative actions, however, have tended to promote farm and nonfarm coexistence.

Keeping Nonfarmers Out

Zoning. Conflicts among land uses in cities traditionally have been dealt with through zoning. Zoning is an exercise of the police power in which specific areas are set aside for given kinds of use: residential, commercial, and industrial, and many subclasses of these. Those who advocate using this method for rural areas would add an agricultural class. Some rural areas have zoning ordinances now, and most have an agricultural zone, but in almost no instance is it a zone exclusively for agriculture. Nearly always it really is what was left over after the other zones were established, and is a general use zone. Those who advocate zoning to preserve farming want to see zones established in which no other use is permitted. Zoning to preserve farming has both legal and political difficulties. To be supported by the courts, a zoning ordinance must be reasonable. If a farmer is prohibited from selling his farm to a nonfarmer even though the latter offers a very high price, the courts are likely to conclude that an unconstitutional taking of property from the farmer has occurred.

Farmers, especially those being offered high prices for their farms by nonfarmers, are far too few in number in most states to affect the political acceptability of exclusive agricultural zoning very much. Yet exclusive agricultural zoning has not been enacted. The New York case is illustrative. Senate Bill 9028 of 1970 was designed so it would have, among other things, brought effective agricultural zoning to that state. Farmers opposed S-9028 but their opposition nowhere near accounted for the overwhelming defeat of this bill.

Nonfarmers do not want to be fenced out of rural areas and those now in rural areas do not want to be considered nonconforming land users. There are large numbers of nonfarm people already, in rural areas and more are dreaming about a home in the country.

TDR. Efforts have been made to modify zoning to meet court objections. A device known as "transfer of development rights" is the most widely publicized. It is complicated and so far has proven successful in only a few localized areas, even though it has been tried in both New York and Pennsylvania. A New Jersey study is pessimistic about its possibilities there.

Wisconsin's Program. Wisconsin is undertaking a program of providing special tax incentives for the adoption of exclusive agricultural zones. Wisconsin used rural zoning to keep people from trying to live and farm on submarginal land in the 1930's. This earlier favorable experience with zoning may encourage the acceptance of zoning in its present new form. The program is too new to be sure, however.

Government Purchase. Governments at various levels could buy fee or lesser rights in the open market and thus gain control of farm land for the purpose of keeping it in farming. It has been suggested that governments could reap large capital gains through purchase of fee simple title to lands that eventually will become urbanized, and in the meantime they could hold them in farming. There are two problems: most governments make very poor landlords for farm land, and government employees have not proven to be any better as speculators than private persons who specialize in that activity.

The purchase of development rights (PDR) to farm land, however, has

been much more generally accepted. So far the Suffolk County, New York, program is the largest -- $21 million. Massachusetts, Connecticut, and Maryland also have programs in motion though much smaller. So far all purchases are made without exercise of eminent domain, and are based on expert appraisals by consulting firms and subsequent bargaining. Farmers so far are very happy with PDR.

But PDR costs a lot of money. Each farmer is free to believe that his land would sell to a nonfarm user at the top dollar if he did not sell his development rights separately, so asking prices are likely to be especially high. Still, the more affluent semi-suburban communities may be convinced that they should save a few pastoral scenes especially if, as in Suffolk County, it requires more than a hundred miles of city driving to reach pastoral scenes elsewhere. It has been suggested that the power of eminent domain be used in the acquisition of development rights. In general, however, this power is limited by constitutions and courts to rather specific purposes. Constitutional amendments might be made, however, to permit its exercise for preserving farming.

A special variant of PDR is being tried in the affluent semi-suburban town of Perinton near Rochester, New York. Farmers, including some of the semi-suburban part-time farmers, are being offered flat percentage reductions in their assessments in return for a temporary transfer of development rights to the town; the percentages being higher for longer periods of transfer. Participation in the program has increased rapidly. The schedule of assessment reductions is high enough and the periods of sign up extend to time intervals long enough to give farmers a sense of security even for such

major investments as new barns and tile drainage. The Town of Southhold on the outer part of Long Island has undertaken a similar experimental project with some apparent success. Average nonfarmer incomes in that town, too, are quite high.

Facilitating Peaceable and Productive Coexistence

Nature of the Problem. Over large regions of the country nonfarmers already outnumber farmers in farming areas and cannot be chased out. In those areas, at least, there is need for a concern with arrangements to facilitate the peaceable and productive coexistence of farmers and nonfarmers.

The impact of urban pressure on agriculture is most spectacular when it physically displaces farming. When an area that once was a farm suddenly becomes a subdivision, a shopping center, or an industrial plant, people take notice. But the physical displacement of farming is limited to a very small part of the total area impacted by urban pressure.

In the rest of the impacted area it is only here and there that a lot sells for a new residence or a small commercial or industrial building. But in time these sales add up to a lot of new faces and new activities that affect farmers. Farmers in most areas are aware that not all land in their community ever can become wall-to-wall city. Even in a highly urbanized state like New York, less than 10 per cent of the land has become truly urban in more than 300 years. Most farmers watch the local land market close enough to know that only a small acreage moves into house lots and other high priced uses each year in most rural communities.

But farmers in most parts of the country know too that some land is being sold each year for urban uses in their communities. They know too

that a few parcels are going for part-time and hobby farms and for just plain speculation. They are worried when they hear about proposals for market value assessments, and in states where real estate taxes are high, they wonder about their survival when assessors start using nonfarm sale prices as indicative of the value of farm land.

Farmers are worried, too, of course, when their nonfarm neighbors ask for increasingly expensive public services. Money for these services often comes out of property taxes and a farmer's exposure to this tax usually is high compared to his nonfarm neighbor's.

On the other hand, farmers seldom take kindly to the idea of excluding nonfarm people from their communities. They are not accustomed to the idea of "separating green people from purple people" as is so often done in cities and they are afraid a movement in that direction could easily spread to controls on their own activities.

But farmers are still very much concerned about the things that are happening as a consequence of the steady and substantial growth in the numbers of their nonfarm neighbors. Not only are their taxes increasing, but a variety of other troublesome things are happening. Nonfarmers sometimes have taken control of local government and passed regulations that hamper farmers. More commonly it is only verbal complaints and threatened actions that require more costly practices and tax their patience: objections to spreading manure, to use of fertilizers and pesticides, to noises and to unsightly appearances. It may be dogs that chase the farmer's animals, off-road motorcyclists who cut his fences, or vandals who damage his equipment.

The point at which a farmer's concerns about these things becomes critical is when he needs major farm improvements -- a new barn, an orchard replanted, or new tile drains. If nonfarm pressure is high enough he may decide to bet on a nonfarm sale even though it is a gamble. In that case he makes no further new investments. Agriculture in this manner can become seriously debilitated long before the land is needed for city uses. Poorly improved farms often pass to speculators when the farmers retire. Speculators almost never improve them for farming. They often rent to farmers at low rental rates but not on terms that encourage intensive farming. In such areas, farm machinery dealers often convert to garden equipment, feed stores cater increasingly to the horse trade, and veterinarians substitute cats and dogs for farm animals. Agriculture may lose its services to a point where capable farmers no longer find it attractive to stay. There are areas in the eastern United States where good land can be rented at no cost but there are no takers.

Farm Value Assessments. Legislative efforts to preserve farming in most states has taken the form of granting farmers a farm value level of assessment on their farms. These laws have taken many forms but the intent in all cases is to prevent farmers from being driven out of business or allowing their farms to deteriorate or their farm improvements to become obsolete due to tax assessments based on speculative values and the prices of nonfarm properties.

Professional planners and many economists have severely criticized the farm-value assessment laws as being unable to keep nonfarmers out of

farm areas. These critics fail to recognize the legitimacy or significance of actions to facilitate the peaceable and productive coexistence of farmers and nonfarmers over the large areas of the country into which nonfarmers have scattered with no promise of bringing wall-to-wall city at any time in the indefinite future. These critics have failed to recognize, too, some of the problems of fencing nonfarm people out of rural areas that were discussed earlier in this paper.

Tax Exemptions for New Farm Improvements. New York in 1968 undertook to provide a measure of tax relief for farmers that was sharply focused on encouraging them to keep their improvements up to date. It provided for a 5-year exemption on all new farm buildings. The 5-year period was extended to 10 years in 1978. New building exemptions have the advantage of providing no "free rides" to speculators.

New York's Agricultural Districts. New York in 1971 passed a law that was intended to keep good farm land in aggressive farming until a clear urban demand developed for it. Part of this law, like those in other states, provides for farm value assessments. Other parts provide special features.

The farm-value assessment part of the agricultural district law requires the annual production for sale of $10,000 of farm products. This limits participation by speculators. The special features of the law provide farmers freedom from new tax levies for sewer and water systems, discourage government financing of nonfarm public services in farm areas, and contain some limitations on the exercise of eminent

domain. One feature instructs administrative agencies to interpret all laws in ways that encourage farming within the districts to the full extent compatible with health and safety.

No comprehensive study of the effectiveness of New York's agricultural district law has been undertaken. Many individual instances of effectiveness have been recorded, however, and farmer participation is high. The formation of a district is a costly and time consuming process yet over 5 million acres have been put in districts in the state.

This agricultural district program is an experiment. Nothing like it had been tried before. It seems to be helping, but it certainly has not solved all problems. Some features of the law have not been used as yet and some problems have arisen in the administration of other features. New features surely need to be added.

The philosophy of the agricultural district law contrasts so sharply with the traditional urban planning model that many professional planners see no value in it. The idea of forcibly separating uses (classes of people, really) has become so dominant, particularly in suburban thinking, that action to encourage a use (farming) without exercise of coercive power is dismissed as an interim measure at best. And there undoubtedly are instances in which the coercive force of the police power will be acceptable and useful, as is suggested by the new Wisconsin program.

Summary

The urban/agricultural interface is very fuzzy over large areas of the nation. The rural nonfarm population is increasing rapidly. Already over much of the eastern one-third of the nation farmers are outnumbered by nonfarmers in their home communities. Urban influences are pervasive in a

large part of rural America, and these influences inhibit efficient farming.

There are instances in which it may be possible and worthwhile to fence nonfarm people out of farm areas through zoning or some variant of it. In most instances, however, effective zoning will not be politically acceptable to either farmers or nonfarmers.

The purchase of development rights to farm land already has proven effective in keeping nonfarm people off from farm land in a few instances. This method for preserving farming, however, is very expensive where it now is being used.

The most popular current method for holding farm land in farming is the provision of farm-value assessments. These only help give farmers the option of remaining in farming. They cannot preclude a nonfarm sale. The New York agricultural district program includes several additional features designed to facilitate the continuance of intensive farming and discourage nonfarm encroachment.

Farm-value assessments and related features facilitate the pleasant and productive coexistence of farm and nonfarm activities. Since the area into which nonfarmers have scattered very greatly exceeds the area that will be converted to wall-to-wall city in the foreseeable future, since this scattering tends to debilitate farming by discouraging new investments in farm improvements, and since it is very difficult to fence nonfarm people out of farm areas, it is important that attention be focused on means for facilitating coexistence.

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APPLYING URBAN WASTE TO AGRICULTURAL LANDS

SUMMARY

Application of municipal sludges or effluents to agricultural land is generally of value because these materials act as soil conditioners and/or sources of essential plant nutrients. However, certain health risks are associated with these practices because of the presence of toxic metals in sludges and pathogens in sludges and effluents. These subtances may contaminate edible crops to such an extent that they have a deleterious effects on animals and humans. Studies to evaluate benefits and health risks associated with the application of urban wastes to agricultural land have been underway for a number of years in many Agricultural Experiment Stations throughout the United States, including the Institute of Food and Agricultural Sciences (IFAS), University of Florida, Gainesville.

The health risk associated with toxic chemicals in sludges applied to agricultural land can be reduced considerably by proper selection of the crop to be grown. The benefits of growing nonedible (fiber, trees, etc.) or processed crops such as sugar beets and sugar cane are obvious. However, considerable flexibility is available through the proper selection of edible. crops. For example, the entry of toxic metals (e.g., cadmium, lead, mercury, nickel) into seeds of some crops is limited and the potential health hazard can be reduced by harvesting only grain for human and animal consumption. In general, leafy vegetable tissues accumulate higher levels of toxic metals than do grain crops.

Incorporation of municipal sludge or grain and forage grown on sludge amended land into animal and poultry rations has been studied in IFAS for the past four years. Results from these studies indicate that no hazardous levels of bacteria, viruses, parasites, mycotoxins, drugs, or pesticides were detected in steers, swine or poultry feed rations containing 10 to 20% sludge. These studies also illustrated that grain and forage grown on sludge and effluent amended soils were not hazardous to animal health.

APPLYING URBAN WASTE TO AGRICULTURAL LANDS

This paper, "Applying Urban Waste to Agricultural Land", was prepared by Dr. J.M. Davidson, Professor of Soil Science and Dr. G.T. Edds, Professor of Toxicology of the Institute of Food and Agricultural Sciences (IFAS), University of Florida, Gainesville. The paper contains information regarding the application of urban waste to agricultural land in Florida and at other sites within the Agricultural Experiment Station network. Research presently underway in IFAS on applying urban waste to agricultural land is of particular importance in that the results obtained from these studies will be used by the Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) to assess health risks associated with the practice.

The soil has long been recognized as an active biological media capable of recycling and reclaiming waste materials in an efficient manner with minimum contamination of the environment. Because of this, the United States Environmental Protection Agency has committed itself to "press vigorously for public-owned treatment works to utilize land treatment processes to reclaim and recycle municipal wastewater." Also, on November 9, 1977, EPA issued a technical bulletin entitled "Municipal Sludge Management" encouraging land application of municipal sludge whenever it was environmentally acceptable. However, a number of health questions still remain regarding the application of municipal wastewater

and sludge to agricultural land on which crops are grown for human or animal consumption. These questions include the fate and effects of pathogens (viruses, bacteria, or parasites), fate and effects of trace organics, and uptake and accumulation of toxic metals in food (plant and animals) grown on land receiving municipal wastewater and sludge.

Several beneficial effects generally result from the application of municipal waste to land. For example, sewage sludge contains a significant quantity of organic matter which acts as a soil conditioner when used in revegetation and reclamation of land which has been disturbed by urban development, coal and gravel surface mining, or road construction. Also, even though the plant nutrient concentration of municipal wastewater and sludges is generally low, they can be applied to the soil in quantities sufficient to meet the nitrogen and phosphorus requirements of crops.

If all the sludge produced in the United States were applied to agricultural land at a rate sufficient to meet crop nitrogen requirements, less than 2% of the cropland would be required (based on projected 1985 sludge production) to recycle the sludge. Thus, the total land requirement for landspreading municipal sludges is small. However, where the population is concentrated (e.g., the Northeast), the ratio of sludge produced to available agricultural land exceeds the national average. For example, about 55% of the cropland in New Jersey would be needed in 1985 to landspread the sludge generated by that state. This example points out the problem facing some localized areas where available agricultural land for sludge application may be a limiting factor On the other hand, vast acreages of forested land exist in the Northeast and these areas may prove to be effective sites for urban waste disposal according to a study by Pennsylvania State University.

Because of potential benefits associated with municipal waste applications to agricultural land and the health risks associated with these applications, numerous Agricultural Experiment Stations in the United States have taken an active role in assessing the potential benefits and risks. The Institute of Food and Agricultural Sciences (Florida Agricultural Experiment Station) at the University of Florida began studies involving municipal wastewater and sludge application to agricultural soils several years ago. Recently these studies were expanded to include animal feeding trials to assess health risks associated with raising animals on pasture and grain grown on municipal sludge amended land. This research work has been supported by the U.S. Environmental Protection Agency, Cincinnati, Florida Agricultural Experiment Station, State of Florida, and various Municipalities in the state.

The willingness of Agricultural Experiment Stations in the United States to cooperate in solving a common problem is illustrated by the Regional Project (W-124) developed to determine the influence of sludge type, sludge chemical composition, soil characteristics, and climate on the fate of sewage sludge constituents in soils, drainage waters, and plants. The project was initiated to assist in establishing guidelines for the optimum utilization of sewage sludge on agricultural land. Over 15 Agricultural Experiment Stations and two federal agencies are involved in the cooperative study. All regions of the United States are represented including Hawaii. The Florida Agricultural Experiment Station (IFAS) is participating because it represents an extreme because many of the soils in Florida are sandy and naturally low in plant nutrients. Also, Florida's climate is warm and humid and provides a maximum oppor-

tunity for recycling large quantities of sludge per year if managed properly.

SOIL AND CROP RESPONSE TO MUNICIPAL WASTES:

Field experiments involving the application of anaerobically digested sludge (3% solids) from the City of Pensacola, Florida have been underway since 1974 at the Agricultural Research Center, Jay, Florida. This study was initiated to determine soil and crop responses, nutrient and toxic metal uptake by plants and the fate and movement of virus particles on land treated with municipal sewage sludge. In addition, two methods of applying Pensacola liquid digested sludge (LDS) to winter annual pasture were evaluated for plant and animal performance and possible toxic metal (cadmium, mercury, nickel, lead, etc.) accumulation in beef animals. The soils on which the study was conducted are sandy and respond well to commercial fertilizer applications.

Results from the third year of the study at Jay, Florida indicated that corn, sorghum and soybean yields were suppressed where greater than 53,500 pounds of LDS was applied per acre per year. The soil pH in these treatments had been lowered by mineralization and nitrification of nitrogen compounds in the sludge and because of the poor buffering capacity of the soils. By adding dolomitic lime to these treatments and potassium (municipal sludges are generally very low in potassium), the soils were restored to their original production level. Toxic metal (Cd, Hg, Ni and Pb) uptake by the plants was greater when the soil pH was low and decreased as the soil pH was raised to 6.5. The concentration of toxic metals (Cd, Hg, Ni, and Pb) in the plant portions marketed for food or animal feed presented no major health risk when the soil pH was 6.5 or higher or the LDS applications were 20,500 pounds per acre

per year or lower. These results are not dissimilar to those obtained by other Agricultural Experiment Stations in the United States (California, Colorado, Georgia, Indiana, Illinois, Kansas, Michigan, North Carolina, Pennsylvania, and Wisconsin) and point out the need for proper management by individuals trained in agriculture rather than "disposal".

Initial results from long term studies conducted by several other Agricultural Experiment Stations in the United States indicate that applications of all available sludge to cropland would not increase appreciably the total amount of toxic metals in agricultural crops. Toxic metals of most concern at this time are cadmium and lead. However, significant quantities of some metals may enter the food chain over a period of several decades. In general, the increase in toxic metal content of plants is greater for the initial sludge application than it is for subsequent applications of equal size. The long-term impact of applications of sludge on toxic metals in the food supply can be reduced substantially by growing corn and other selected crops harvested for their edible seeds or fruits rather than forages or leafy vegetables. Industrial pretreatment of wastewater from industrialized areas could decrease substantially (e.g. Chicago area) the toxic-metal content of many municipal sludges, and this in turn would reduce the possible health hazards associated with using these sludges on agricultural land. These steps have already been taken by some major industrial cities, and significiant reductions in toxic metal concentrations in the sludges have occurred.

The results from the pasture studies at Jay, Florida indicated that incorporating the LDS into the soil prior to planting increased forage

growth, but top dressing the LDS on the soil and forage was detrimental to forage production. Top dressing resulted in a loss of nearly all the crimson clover seedlings. The gain in animal weight per acre was highest for steers on pasture in which 20,500 pounds of LDS were incorporated into the soil and lowest where the LDS was applied directly to forage foliage. Top-dressing with LDS during the grazing period appeared to be detrimental to the forage owing to a coating of the leaf surface. Also, the forage coated with the LDS appeared to be less palatable to the animals in that selective grazing by the steers was observed.

Irrigation of crops with municipal wastewater or effluent has been studied extensively since some of the original work conducted by the Pennsylvania Agricultural Experiment Station. Field experiments have been underway at Tallahassee, Florida since 1966 to evaluate the growth characteristics of several forage crops irrigated with municipal effluent or wastewater. Both rye and ryegrass responded well to frequent (1, 2, 3, and 4 inches of wastewater/week) applications of secondary municipal effluent (6.8 lb of nitrogen per acre inch of effluent). Dry matter yields showed a positive response to increased irrigation applications which was in agreement with commercial fertilizer studies on this soil. Nutrient uptake by the forage generally increased with application rate, while recovery efficiency declined for all elements measured. Irrigations of one to two inches/week appear to be reasonable for well-drained sandy soils in Florida. Applications of these rates may be acceptable in other regions of the United States, but the total quantity applied per year would not be as great since the growing season in Florida is generally longer. Other crops studied in Florida include sorghum, corn and coastal bermuda grass. These crops responded to irrigations with

particles could be recovered from soil 7 to 11 days after irrigation with a municipal sludge inoculated with a poliovirus. During cooler periods of the year, poliovirus particles were shown to survive in soils for at least 96 days after the final sludge irrigation application. In addition, two research groups and possibly a third have shown that virus uptake through the plant root system is possible, indicating that both the internal and external portion of the plant may contain virus particles.

A number of factors such as solar radiation, temperature, humidity, soil-water content, and rainfall affect virus persistence on plant vegetation and in soils. Studies by various Agricultural Experiment Stations have illustrated through experimentation that virus particles may pass through the soil surface of some sandy soils and thus are protected from solar radiation and high soil surface temperatures.

Virus survival and transport to the groundwater was studied by the research group in the Florida Agricultural Experiment Station using the Jay, Florida site receiving Pensacola, Florida liquid digested sludge (LDS). The soil surface at this site was shown to retain in excess of 99% of poliovirus type 1. Furthermore, it was found that the poliovirus in the sludge was not detectable in the soil after 3 days of drying under summer field conditions. No virus particules were found in groundwater samples taken under these field plots (30 to 50 feet below Jay, Florida site receiving Pensacola, Florida liquid digested sludge (LDS). The soil surface at this site was shown to retained in excess of 99% of the poliovirus type 1 applied to the soil. Furthermore, it was found that the poliovirus in the sludge was not detectable in the soil after 3 days of drying under summer field conditions. No virus particles were found in groundwater samples taken under these field plots (30 to

municipal effluent in a similar manner to the rye and ryegrass experiments described above.

Much of the southeast region of the United States contains large acreages of forested land. The soils in these forested areas are generally low in plant nutrients and are ideal environments for recycling municipal wastes which contain essential plant nutrients and/or substances that should not be allowed to enter the human food chain. Recent studies by the Florida Agricultural Experiment Station (IFAS) have shown that when waste treatment materials and forest species are properly selected and managed, both nutrient renovation and increased biomass production are possible. Biomass production by slash pine with municipal solid waste (garbage) compost material was nearly three times the biomass from untreated areas. Biomass production was also markedly enhanced by applying secondary treated wastewater to tree species favoring wet, nutrient-rich regimes (generally hardwood species). The results from these studies point out the importance of carefully selecting the proper tree species if the natural environment of the forest is to be changed significantly by the municipal waste material.

Numerous pathogens (virus, bacteria, and parasites) have been shown to be associated with municipal wastewater and sludges applied to land. Because of this, concern has been expressed regarding their potential for contaminating surface and groundwater supplies as well as plant vegetation. Poliovirus 1 has been shown to persist for 36 days on lettuce and radish crops spray irrigated with inoculated sewage sludge and wastewater. It has also been shown that crops grown on soil previously irrigated with wastewater inoculated with poliovirus were contaminated for at least 13 days after application. During warm periods poliovirus

50 feet below ground surface) after five years of annual applications of Pensacola, Florida LDS. Because very little was known about the movement of sludge-associated viruses through Florida soils, the information gained from this study was of value in the assessment of the potential health risks associated with sludge applications to Florida's sandy soils.

HEALTH RISK ASSESSMENT USING ANIMALS:

Digested municipal sludge has been used to irrigate various crops at Rickmansworth, England (about 20 miles north of London) since 1952. The soils are gravelly, fairly firm and well drained. There have not been any accumulations of toxic elements, associated cattle diseases, objectionable odors, fly problems, or community objections to date. Livestock were not allowed to graze fields receiving recent applications of digested sludge unless rain had washed the plants reducing the potential hazard of sludge ingestion.

The Illinois Agricultural Experiment Station has conducted a study to determine the fate of a known swine enterovirus which had undergone anaerobic digestion. The virus could not be detected or demonstrated by infection of germ-free piglets after the fourth day of anaerobic digestion.

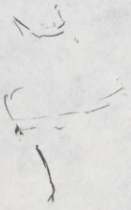
A review of the literature on sewage effluent and sludge applications to soils for many situations in the world has reported no instances where livestock suffered adverse conditions from being fed crops grown with the application of either sewage effluent or sludge. In many instances, raw sewage was used until the advent of sewage treatment systems in the 1920's and 1930's or until the growth of cities expanded beyond the ability of small land areas to assimilate the undigested or

untreated wastes. Livestock are currently produced using crops grown with sewage effluent from the Melbourne, Australia treatment plants and various treatment plants in the United Kingdom.

The Metropolitan Sanitary District of Greater Chicago is presently recycling digested sludge on its farm in Fulton County, Illinois. Cattle are grazed on Sudax grass irrigated with liquid digested sludge as well as fed crops grown from land treated with digested sludge.

Based on reports by Hanson the protozoan (coccidian) and nematode parasites in a control and monitored herd grazing on pastures were not different; and they were not able to detect any parasites in the monitored herd which could have come through the sewage treatment plant from abattoirs, kennels, or human dwellings in Chicago. Sludge produced earlier from the Metropolitan Sanitary District of Greater Chicago contained significant quantities of potentially toxic elements, principally cadmium, lead, nickel and chromium.

Municipal sewage effluents and sludges may contain toxic elements, industrial chemicals, and pathogens that pose a health risk to animals and humans. All or part of these constituents may enter the human food chain or water supply. It has been inferred by some that the application of these municipal wastes to soil-plant systems render them innocuous. Because of this, the Florida Agricultural Experiment Station (IFAS) initiated a study to trace the fate and pathway of deleterious materials through the food chain using animals to evaluate health risks. These studies were performed to establish if prolonged exposure or ingestion of municipal sludges or forages or grains grown on sludge amended land would produce genetic, reproductive, or pathological problems or result in deposition of deleterious materials in cattle, swine or



poultry tissues. The animals and poultry were monitored biochemically, physiologically, and toxicologically during the trials, and total pathology, chemical, and biochemical analyses were performed at the termination of the trials. Some animals, swine and mice were carried through several generations for possible cumulative effects.

Sludge treated animal rations as well as feeds containing forage or grain from soils pretreated with Pensacola liquid digested sludge were fed to steers, bred gilts or sows and young weaned pigs as well as poultry broilers and hens. The animals were examined for growth, reproductive performance, feed efficiency, hematological or clinical chemistry changes which would indicate cumulative toxicities.

Swine trials suggested that inclusion of either 10 or 20% dried sludge from the University of Florida sewage treatment facilities in the rations of sows resulted in an increase in the number of pigs farrowed per litter. However, the pigs from such sows had a lower rate of gain. Offsprings of both first and second litters fed growing and finishing rations containing sludge from weaning to market weight had decreased daily weight gains and feed efficiency.

Later trials involving swine receiving rations containing 10 or 20% dried sludge from the University of Florida showed no significant differences in farrowing rates. Again, there was decreased rate of growth and feed efficiency. This may have been due to a decreased level of total digestible nutrients (TDN). In addition, blood and tissue chemistry suggested that accumulation of cadmium and lead in liver and kidney tissues may predispose tissue to cell damage and lower the animal's resistance to diseases.

Liver and kidney tissues from steers receiving 500 grams of liquid digested Pensacola sludge per day for 150-180 days and swine receiving rations containing 10 to 20% dried University of Florida sludge were assayed for metals and the liver and kidney from these animals used in the rations of three generations of mice. The tissue from the steers contained higher levels than normal of cadmium, lead, nickel and chromium. Cadmium and lead are known to cause liver and kidney damage and may be involved in carcinogenesis. Liver damage may also predispose animals to hemorrhagic diseases as well as cause increased susceptibility to bacterial, viral and protozoan diseases. This area of the research is incomplete at the present time.

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Issues Relating to the Control of Agricultural and Urban Influences on Surface Water Quality

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The quality of surface waters in the United States has become a major environmental issue. In response to public insistence, governments at all levels have established goals for achieving clean water, have passed regulations limiting the amounts of pollutants that may be discharged and are in the process of spending billions of dollars to improve the quality of water permitted to enter our lakes, streams and oceans. While much of the regulatory action and spending to date has focused on urban and industrial sources of pollution, agriculture is a major contributor of pollutants, too, and is increasingly coming under the scrutiny of agencies charged with managing water quality. As the efforts to restore the purity of our water continue, we face increased risk that the expensive programs designed to improve water quality may seriously interfere with our ability to provide food and fiber and governmental services at a price affordable by nearly everyone. Since many of the pollutants are discharged from both urban and agricultural sources, we can expect increasing pressure to shift the burden of abatement to one side or the other. This paper addresses several aspects of the problem of trade-offs between urban and agricultural interests and indicates areas where improved knowledge will be needed to make good decisions and where different governmental programs and policies may be needed to facilitate equity between various groups as well as making the best use of our resources.

I. What's A Clean Stream Worth?

One of the major impediments to achieving agreement on the level of pollution abatement for particular lakes or streams is the great difficulty in comparing the costs of abatement with the benefits of abatement. While there may be uncertainty in some cases as to the nature of the benefits and costs, one more frequently finds that benefits and costs are known, but measured in different units. Most of the costs of reducing pollution levels can be stated in dollars. In most cases the benefits are expressed in terms of physical and chemical properties of the water (e.g., pH, BOD) or the diversity of biological activity (e.g., trout fishery). Only in occasional studies of specific sites have attempts been made to impute a dollar value to the benefits of water pollution abatement. Attempts to extrapolate from these few studies to national estimates of recreational and aesthetic benefits of water pollution abatement have been criticized as suspect (Stevens, 1978).

Further efforts are needed to refine the techniques available for determining dollar values of the major benefits of water quality improvement. The U.S. Environmental Protection Agency has funded a study which is designed to develop and improve the technique of measuring these values and apply them to a number of sites throughout the United States in such a way that they may be extrapolated to national values. This effort should improve the reliability of analyses that are used to determine water quality levels in surface waters.

Additional efforts will be needed to refine the techniques to provide estimates of abatement values for specific components of water quality as well as for water quality in general. In some cases, the economic research

must await results of biological research in order to have estimates of the biological relationships between levels of a specific pollutant, such as phosphate, and the levels of biological activity of interest, such as sport fish populations. While the general relationships are usually understood, the precise relationship is frequently unknown. In order to make reliable evaluations of the benefits of incremental reductions in the levels of a pollutant, greater precision is needed in the statement of the biological relationships. In other cases, the biological and physical relationships are well established and economic studies must be repeated in enough different settings to adequately estimate the value of incremental changes in water quality for a particular stream, lake or river basin. Then it will be possible to give an answer to the question, what is a clean stream worth?

II. Sharing the Costs of Pollution Abatement: Agriculture vs. Nonagriculture

While the research is still to be completed to determine the value of a cleaner stream or lake, enough evidence is at hand to know that society will benefit from at least somewhat reduced levels of pollution. It may not yet be possible to say exactly how much pollution levels should be reduced, but we know we want less, and in some areas, a lot less pollution. As we come to recognize that not all pollution will be eliminated, the problem arises, who will be permitted to continue polluting while others must reduce their pollution? Will farmers be permitted to have higher levels of runoff from fields and livestock holding areas so as to keep down the costs of producing food? Then municipal sewage treatment plants may have to achieve higher levels of phosphorus and nitrogen removal using expensive advanced

wastewater treatment systems. In order to determine the appropriate trade-off between agricultural and nonagricultural pollution abatement efforts, it is necessary to know the cost of incremental reductions in the discharge of pollutants from all sources.

While our knowledge is not complete, there has been a substantial amount of research and study of operating municipal wastewater treatment systems. These studies have included both the conventional physical-chemical treatment processes and land application methods (EPA, 1976; Van Note, et al., 1975; Young, 1978). Much less is known about the ways that farm and forest managers may reduce the pollutants coming from their operations. If wise decisions are to be made which have the support of citizens in this country, it is extremely important that studies begin soon to provide information on what the costs will be for reducing pollution coming from farm and forest lands.

Much of the pollution coming from farms enters streams via runoff from fields. Topsoil eroding from cropland carries chemical fertilizers and pesticides with it, depositing a portion of the silt and the chemicals in lakes and streams. To this point in time the major effort to reduce pollution from field runoff has been to apply Soil Conservation Service farm planning techniques to design structures, such as terraces and grassed waterways, and cropping systems with a greater proportion of cover crops, rather than row crops. While such plans will likely reduce the amount of soil eroding from farmland, there is evidence that the same objective frequently can be achieved at lower cost. White and Partenheimer (1978) studied farm plans prepared by the Soil Conservation Service in Pennsylvania and found frequent instances in their study where the same soil loss

objective could be met with less expenditure for structures and less reduction in farm income. This was achieved primarily through the use of minimum tillage methods of corn production. Further studies of this nature are needed to insure that programs to abate pollution coming from farmland and forests use the least costly method.

Another problem that impedes determining the cost of water pollution abatement is the uncertainty about the fate of soil, fertilizers and pesticides that erode from fields. Some of these pollutants, such as pesticides can be found in streams and lakes and be attributed to farmland erosion directly. What is not so certain is that all of the soil and chemicals eroding from a field eventually are deposited in a stream or lake. It is widely recognized that some, or perhaps even most, of the soil that washes off of a hillside may be deposited on the more level land below the hill. In some cases, only a small fraction eventually reaches the stream. While some might consider this difference between field loss and stream loading a desirable margin of safety, it is achieved at a cost that is unknown. Until better measures are available to determine the relationship between field loss and stream pollution, farmers will be justifiably suspicious of expensive soil erosion control programs that purport to improve stream quality.

Until better techniques are developed to determine the impact of farming activity on water quality and the least costly ways of meeting pollution abatement goals are developed, water quality planners will have great difficulty defending the economic efficiency or social justice of further efforts to reduce pollution. Better information is needed about all sources of pollution in a watershed to improve the regional water quality plans now being formulated. Studies to obtain the needed information must

be started soon to insure acceptable programs that allocate pollutant discharges to agricultural and nonagricultural sources.

III. Methods to Achieve the Socially Optimal Level of Pollution

The preceding sections of this paper have addressed some issues which must be resolved in order to determine the best policy—that is, the most economically efficient policy—for reducing the pollution of surface waters. In this section, attention is directed to a few of the issues concerning how pollution reduction policies should be implemented. The techniques chosen for putting a policy into effect can have a major impact on the effectiveness of government action and, thus, must be chosen with care and forethought.

Regulation is the technique for implementing environmental quality policies that is most widely used at present. Standards are set for the air or water body and these are related to permitted discharges from each source of pollution. In some cases, particular equipment for pollution abatement is required; more frequently, a facility receives a permit which approves the pollution reduction equipment chosen by the discharger and requires that it be used in a specified manner. Failure to abide by the provisions of the permit may result in fines or imprisonment of responsible individuals.

That there are other ways to implement environmental policy is widely known. Many economists have favored greater reliance on market systems through the use of taxes per unit of pollutant discharged or marketable licenses to discharge a specific amount of pollutant into a stream or airshed. Recently, Baumol and Oates (1979, p. 218) have classified

approaches to environmental policy to include moral suasion, direct regulation, taxes on environmental damages, subsidies to reduce pollutant emissions or to build abatement facilities, licenses, refundable deposits against environmental damage, allocation of property rights to facilitate individual recourse action against damage, and government investment in pollution abatement facilities, regenerative activities, research and information. They analyze experience with each of these techniques and their conclusions support that of other authors--that no one policy instrument is ideal and that a variety of instruments should be used, varying with the nature of particular pollution policies.

When designing programs for water pollution abatement that involve both agricultural and nonagricultural sources, it is highly desirable that enabling legislation and agency policy encourage the use of whatever technique is most appropriate for the problem. Greater reliance on market mechanisms and individual initiative will stimulate continued analysis and improvement in ways to achieve environmental quality. A more varied approach will also be more likely to provide efficient solutions where the costs and benefits of changes in water quality are considered.

IV. Achieving Equity

Even after an efficient level of pollutant discharges is determined for each source of pollution, both agricultural and nonagricultural, and a varied set of policy instruments is designed to best implement the program, problems may still remain requiring consideration by Congress and governmental agencies. Here I am referring to the problems of equity or justice. It is likely that an efficient solution to the water quality

problems of our surface waters will not call for equal sacrifice from each individual. Nor, is it likely that the unequal sacrifices will be judged by most people to be fair. In such a setting justice requires some redress for those unfairly imposed upon. It is highly likely that Congress will be expected to address itself to solving that problem.

I do not propose to discuss the advantages and disadvantages of various ways to solve the equity problems arising from water pollution control policies. It is important to mention, however, that whatever equity improving policies are selected must not counteract the incentives for pollution abatement contained in policy instruments designed for that purpose. It is likely that general fiscal policies will be needed, perhaps including compensation from general revenues to those judged to be unfairly damaged. Careful attention must be given to deciding whether compensation ought to come through the federal treasury or from state or local funds. Consideration will need to be given to occupational and consumption pattern factors as well as geographic location. The details to be considered and the proper programs to implement must be worked out along with the pollution abatement policies. My purpose here is to call attention to the eventual need for considering the equity issue and to counsel early analysis of this aspect of the problem.

V. Conclusion

I have attempted to outline briefly the issues to be faced in establishing policies to improve the quality of surface waters in the United States. We must determine with greater precision what we are willing to give up in order to have better quality water in our lakes and streams. It is also necessary to improve our knowledge of how agricultural and

and silvicultural practices may be modified, and at what cost, to reduce the pollution coming from those sources. More innovative policy methods must be employed to achieve the efficient level of discharge from each source of pollution, agricultural or urban. Finally, early consideration should be given to policies and programs to make the burden of achieving better water quality be shared equitably among all people.

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Testimony for the U.S. Congress

Regarding

Urban Waste Applied to Agricultural Land

7-11-79

This testimony was prepared primarily from interviews with Drs. Andrew Chang, Albert Page, Walter Farmer, Parker Pratt and Henry Vaux, all members of the Department of Soil and Environmental Sciences at the University of California, Riverside. Certain identified material was provided by Christine Harris, public affairs officer for the Los Angeles-Orange County Wastewater Solids Management Program. Information was compiled and written by Janet White, senior public information representative at UCR.

EXECUTIVE SUMMARY

Each American produces an average of 100 gallons of wastewater per day. Fifty to sixty percent of this waste is collected. It is carried by fresh water from lakes, rivers, and underground to sewage treatment plants, and it is eventually emitted in the forms of treated wastewater--95 percent of the total--and the solid component sludge. Americans generated 3.6 million metric tons of sludge in 1970. That figure is projected to double to 7.3 by 1985, when the Clean Water Act mandates full secondary treatment for all domestic wastewater. UCR scientists estimate we are about halfway there.

Total wastewater and sludge have a statistically small impact if applied to farmland nationwide. If all the wastewater generated in the San Francisco Bay Area were applied to San Joaquin Valley farms, it would satisfy only 17 percent of the current overdraft of water (1.5 million acre feet), let alone dent the valley's annual water use of 12 million acre feet. If all present-day sludge were applied to farmland, it would cover a fraction of one percent of the nation's total. By 1985, it would cover .5 to 2 percent, depending on the available nitrogen in the sludge.

However, the land application of sludge and wastewater will have locally intensified impacts, particularly in densely populated areas and seacoast cities which have dumped sludge in the ocean. (EPA has taken steps to ban ocean dumping, and encouraged land application of sludge and wastewater. In Los Angeles, ocean dumping has accounted for 15 percent of sludge disposal.) In a densely populated, small state such as New Jersey, the sludge produced would cover one-quarter of all farmland.

Wastewater is a potential source of irrigation in regions like the Southwest with low rainfall and limited groundwater. Farmland often depends on irrigation for productivity. Wastewater may also irrigate city landscapes: greenbelts, golf

courses, parks and highway plantings. However, application must be limited by potential hazards to public health and soil productivity. Economic feasibility is limited, especially when pumping water from largely coastal treatment plants to inland farm areas. Wastewater must sometimes compete with the water priced artificially low through Bureau of Reclamation water projects.

The farmland disposal of sludge recycles another resource, nitrogen, and solves a problem of where to put waste. But this solution must also be applied within safe limits for public health, productivity of land, and while minimizing new costs to the public and farmers.

UCR scientists believe farmland disposal has merit within the bounds of these restrictions.

"We know the hazards of applying waste to farmland. We know the benefits. The technology already exists. All we are lacking is the government incentive to proceed," said Andrew Chang, agricultural engineer at the University of California, Riverside.

Because sludge contains many of the most undesirable constituents of wastewater in concentrated form, this paper will address sludge problems first. Many apply to wastewater in a lesser degree, and one--trace elements--is not a significant problem in wastewater.

SLUDGE DISPOSAL: Introduction

The practicality of sludge land disposal is partly a matter of dollars and cents and partly a matter of intangible values. Possible benefits to the environment, resource conservation, and quality of life are difficult to quantify but no less significant.

It now costs society between $30 and $80 per ton to dispose of sewage sludge, depending on the degree of treatment. If sludge were applied to farmland, society could recover a small percent of the cost in the value of the recycled nitrogen, about $3 per ton. (Available nitrogen in a ton of sludge is 1.5 percent at minimum, or 30 pounds. Nitrogen currently sells for five to ten cents a pound.) To oversimplify, a 30-ton truck of sludge could transport sludge at an average cost of $90 per trip to break even.

The value of conserving nitrogen, a product of scarce fossil fuels that is likely to escalate in price, is hard to estimate.

The costs of alternative land disposal systems, encouraged by the EPA, are comparable, as illustrated by figures developed at Los Angeles/Orange County Wastewater Solids Management Program. The LA/OMA project plans for disposal of sludge for 8 million people in the two-county area.

Including the capital costs of new facilities as well as maintenance and operation expense, LA/OMA estimates that pumping sludge 4,000 feet up to a desert site 88 miles away would cost $45 to $47 million a year, amortized over 40 years. Disposal at a landfill site closer to existing facilities would cost $38 to $39 million annually for 40 years. The city of Los Angeles is already spending $23 to $24 million a year for ocean disposal.

These figures offer a rough cost perspective only. They derive from proposed disposal systems that would concentrate large amounts of sludge in very small

areas. This may or may not represent the transportation picture in a plan to sell sludge to farmers for fertilizer.

(Notably, such concentrated dumping may not even be feasible, partly for political reasons. The desert dumping program mentioned drew protest from 500 area residents at public hearings, leading to the scrapping of the plan.)

Furthermore, such concentrations of waste deposited at one site can magnify the pollution and health hazards discussed next, and raises the issue of whether we wish to remove some land from production in perpetuity.

SLUDGE DISPOSAL: Hazards

The hazards of sludge disposal result from four categories of sludge contents: trace elements including heavy metals, trace organic compounds, pathogens and nitrogen. Of these, trace elements and organic compounds present the most unknowns and the most hazards. Sludge containing high quantities of either one is probably unsuitable for long-term application on farmland. Pathogens and nitrogen can be largely controlled through sewage treatment and proper procedures of application and irrigation. The latter would require substantial reeducation of farmers.

One pathway of contamination by sludge is cracks or fractures in the soil that allow materials to be carried by rain or irrigation water to fresh groundwater. If the soil becomes saturated, contaminants may be carried by surface runoff to freshwater lakes and streams. This potential exists for every category of hazard to be addressed. Underground fissures cannot be located or quantified ahead of time; there is no systematic way to do so. However, the number of such pathways is likely to be quite small, and proper irrigation practices can keep runoff to a minimum.

Since sludges are generally low in primary plant nutrients, applying them to satisfy the nitrogen or phosphorus requirements of plants may result in excessive trace elements in soils.

Trace elements. Trace elements are the most serious problem in sludge application. There are 11 of them commonly found in sludge, and the acute toxicity of all has been established. Chronic toxicity to humans has been established for cadmium, lead and mercury.

Both cadmium and selenium are absorbed by plant roots into edible portions of vegetables, but selenium is not known to pose a chronic health hazard.

Even in trace amounts cadmium poses a health hazard when applied to farmland. Like all trace elements, it lodges in the soil indefinitely. Scientists have found that 99 percent of cadmium remains in the top meter of soil for at least 10 years. Cadmium's steady accumulation in soil can lead to dangerously high levels of cadmium in produce.

Certain crops absorb particularly high levels of cadmium, such as leafy vegetables like lettuce or Swiss chard. Grains absorb the metal to a lesser extent, but form a larger part of the diet. Cadmium ingested in excessive amounts over a period of time could cause chronic kidney damage in middle age. The background levels of cadmium in the environment as a whole are increasing, and some scientists estimate that the male teen's daily intake of cadmium is already near the tolerable level recommended by the World Health Organization, 70 micrograms.

Trace metal accumulation in soil can also reduce the productivity of the land. Scientists disagree about how long these metals actually remain available to plants for absorption. It seems to depend on soil chemistry, such as soil acidity which increases trace metal absorption by plants.

Trace elements control. Trace elements may be removed from waste at the industrial source or at the treatment plant with existing technology. Alternately, sludge containing high concentrations of trace metals could be excluded from farmland application, at least on a long-term basis. It is probably not feasible to apply cadmium only to nonedible crops, since most farmland is subject to crop rotation.

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EPA has mandated additional control of hazardous substances at industrial sources and sewage treatment plants. It has requested pretreatment standards from local sewage districts within two years. Such standards could minimize the presence of trace metals in sludge. The rigor of pretreatment standards will depend on opposing forces, the incentive of local communities to attract industry with minimum regulations, and the incentive of local communities to meet the approval of EPA.

Trace organics. While trace metals are known and quantifiable, the number of potential organic compounds is infinite, and the amount known about them is impressively small. (As a beginning, EPA recently listed 185 hazardous organic compounds.)

Depending on their individual characteristics, organic compounds may become pollutants of the air, the groundwater,or the soil. Many which cause concern are those which persist in the environment, such as the halogenated organic compounds. These compounds consist of carbon chains linked to chlorine, fluorine and bromine. Like the now-banned DDT, these substances may enter the food chain. They accumulate in ever greater concentrations in the fatty tissue of mammals higher and higher on the chain. The results of this accumulation are not completely known, although DDT is believed to have caused thin and breakable eggshells, and depressed reproduction, in some birds.

If such compounds are volatile, changing into gas form, they may leave the soil and be carried in the air to plants, animals or humans. This process could be enhanced by surface application of sludge to farmland. The well-publicized contamination of beef in Louisianna took place over a period of years during which cattle were exposed to the volatile hexachlorobenzene through contaminated forage and the air. This waste had been improperly deposited on surface soil rather than buried.

Most organohalogens bind to soil particles, although some percolate through the soil and may contaminate groundwater. Those that bind to the soil may come into

direct contact with animals or workers, or they may contaminate produce. They are absorbed by root vegetables.

Organohalogens may become a hazard to groundwater if they eventually saturate soil particles, after repeated sludge applications. If there are no soil particles to bind with additional organohalogens, they will rapidly leach to the groundwater. The exact period required for saturation is dependent on many factors: Characteristics of the soil, application rate, the compounds in question, and the contamination level of the sludge.

Chang said, "The overall concentration of hazardous organic compounds in domestic sludge is low, but high quantities could exist in some sludges, such as those from the solvents, pesticides or chemicals industries. More research is needed in this area. Little is known about the interactions of organics with soil. Nor do we know what will happen to them in the soil over a long period of time."

Pathogens. Pathogens are disease-causing organisms including bacteria, viruses and parasitic worms called nematodes.

Through a combination of disinfection (during sewage treatment) and proper farm practices, pathogens are largely controlled. However, it is theoretically impossible to remove 100 percent of all pathogens. For instance, composting technology may remove 99.9 percent of all bacteria from a sludge. It is common to find one million bacteria per gram of sludge, so that would leave 1,000 bacteria per gram remaining. Only a fraction of those are pathogenic to man.

The level of bacteria is reduced still further after sludge is applied to the land because the soil environment is naturally unfavorable to pathogens. Many human pathogens, adapted to survival inside the human body, die after two weeks in the soil. They don't compete well with soil-adapted organisms and they don't propagate once they are in the soil. The soil proves an especially hostile environment if it is in an area with severe winters.

Composting sludge for two to six weeks destroys more than 99 percent of disease-causing organisms. The digestion of organic material by microorganisms creates temperatures of 150 to 160 degrees Fahrenheit (65 to 70 degrees Centigrade), destroying pathogens.

Composting is expensive but not prohibitive. It is largely an unapplied technology because there has been little market among farmers or urban dwellers for composted sludge.

The most likely pathway for pathogens to contaminate food or water is through rainfall or irrigation following too soon after sludge application. Such water could carry pathogens to freshwater sources such as a river or the groundwater, particularly over surface soil or through cracks in the earth. Proper irrigation practices and runoff barriers are partial controls.

There are fewer pollution pathways if farmers apply sludge with a subsurface injector rather than a sprinkler system. However, the injector is more than double the cost of the sprinkler system.

There is no existing way to conclusively prove the hazard or safety of sludge for its pathogen content. Although sludge disposal has been linked in time to bacteria-caused disease nearby, there is no way to prove that the bacteria in question came from the sludge rather than some other source.

Of the three pathogens, bacteria are the best known and the easiest to control. Viruses, not considered life forms since they can only reproduce through a host cell, are eventually "inactivated" in soil. They lose their ability to cause disease. Too little is known to assess their hazard.

Nematodes, or parasitic worms, are a particular problem in warm areas where there is no severe winter. They exist in sludge as eggs and can survive for long periods in a hostile environment. Composting, because of the high heat, eliminates most of them.

Pathogens are not absorbed by plant roots but they may be passed by direct contact with produce, especially root vegetables. Field workers are at greatest risk of infection by direct contact, grocery shoppers much less so.

Nitrate pollution. Whether the farmer applies sludge or chemical fertilizer, he wishes the end result to be the same, the addition of the plant nutrient nitrogen to the soil. Recent studies at UCR revealed that excessive use of fertilizer and excessive irrigation promote inefficient plant use of this essential nutrient. Such practices accelerate the movement of nitrogen in the nitrate form toward the groundwater. Nitrates are harmful to human beings and can cause the "blue baby syndrome" in infants less than 6 months of age. Public health agencies limit nitrates in drinking water to less than 10 parts per million.

Nitrate levels may be controlled by adjusting sludge application and irrigation to the natural rate of groundwater recharge from freshwater sources.

SLUDGE DISPOSAL: Economic considerations

While the technology for sludge application exists, it may not be reasonable to expect individual farmers to absorb the cost of additional equipment needs, as well as slightly higher labor costs.

Sludge application would increase labor costs 10 to 15 percent because it requires several passes over the same area that could be covered by one pass of a chemical fertilizer applicator. The machinery for sludge application could cost as little as $2,000 or as much as $30,000 to $40,000. Depreciated over a 20-year period, a $40,000 sludge applicator would cost the farmer of 320 acres $336 per month per acre, assuming a 10-percent interest loan. That amounts to $4,032 a year -- possibly a prohibitive cost to a farmer seeking a $20,000 net profit.

Sludge application carries an extra cost burden if the farmer must also maintain traditional fertilizer equipment. Although it wuld be more economical for a farmer to convert completely to sludge fertilization, this might not be possible. Sludge application might be limited because of trace elements, trace organic compounds, pathogens, or nitrogen.

Government incentives. "We need a set of government incentives for sludge disposal on farmland that are directed toward waste-generating communities. Sludge is a burden on them. Some communities already sell sludge to farmers. In some cases the city applies the sludge for the farmer as part of a package," said Chang.

As an example of government incentives he cited the Clean Water Act which provided 75 percent federal funding for upgraded sewage treatment facilities.

WASTEWATER APPLICATION

The hazards of trace organic compounds, pathogens and nitrogen exist for wastewater, but to a lesser degree than for sludge. Trace elements settle out of wastewater during sewage treatment and are generally not a problem. Samples of California wastewater have shown that most of it could meet the trace element requirements for both public water supply and continuous crop irrigation (as recommended by a National Academy of Science and National Academy of Engineering Joint Committee.)

In addition to the management imperatives associated with undesirable trace organic compounds, pathogens and nitrogen, wastewater has a relatively high mineral content and can adversely affect soil by increasing salinity. Improperly managed, saline wastewater can significantly lower groundwater quality. Minerals may include nitrates, making the groundwater unsuitable for drinking (if nitrate concentration reaches 10 parts per million or higher.) Saline soil is not suitable for many salt-sensitive crops.

Only continuous irrigation management can prevent salt buildup. The flow of water, and salts, through the soil must be regulated according to the natural recharge of groundwater to avoid excessively high salt concentrations. On California cropland, it might take nitrates and other minerals 10 to 50 years to travel from the surface to the groundwater. Irrigation practice can vastly speed up or slow down the process. Drip irrigation minimizes movement of minerals to almost zero, whereas flood irrigation hastens the movement of minerals toward groundwater.

"The efficient control of minerals rests with farmers. The problem is how to make sure everyone follows the best management practices. If they are not followed, the result is a pollution situation that is prohibitively expensive and technically impossible to control," said Chang.

Economic feasibility. Several circumstances detract from the feasibility of wastewater application to farmland.

In the Southwest, where semiarid to arid farming regions provide a market for reclaimed wastewater, most large sewage treatment facilities are located on the coast, miles distant and thousands of feet below inland farming regions. Matching wastewater to farmland would entail capital costs of building a pipeline and ongoing costs of pumping. The energy situation makes the availability of energy uncertain and its cost highly unstable.

LA/OMA figures (from Public Affairs Officer Christine Harris) illustrate the high cost of pumping just 10 percent of the wastewater generated annually in the two counties to a site 88 miles away. The 48-inch pipeline would reach a maximum elevation of 4,025 feet and the effluent would flow at 71,255 gallons per minute. Pumping 122,500 acre-feet per year would require about 730 million kilowatt hours of energy. At three cents per kilowatt hour, that would cost about $22 million per year. Pumping situations will vary greatly; the Los Angeles area has discarded this pumping proposal because of excessive cost. These figures reflect a single disposal site of the end of the pipeline; farmers would require wider dispersal of wastewater. They also would want to moderate the flow depending on fluctuating crop needs. (Too much wastewater at certain times will deliver additional nitrogen to plants and spur growth when farmers do not want it.)

Wastewater as an irrigation source must also compete with water priced artificially low in some areas due to water projects subsidized by the Bureau of Reclamation.

Wastewater application near an urban area. A more promising prospect is the use of wastewater on urban landscapes: parks, greenbelts, freeway plantings, golf courses, and firebreaks that are downhill from some mountain cities.

Perhaps the most significant drawback is the capital cost of building pipeline to distribute the wastewater. Mixing it with the fresh water carried in existing pipelines would be unacceptable. The cost per foot of pipeline is higher in an urban area than in a rural area, according to LA/OMA. Capital cost of a 24-inch diameter pipeline in the city is $74 per foot; in a rural area, $60.

In California, public acceptance of recycled wastewater is increasing except in the case of wastewater recycled for personal uses. While wastewater has a detectable smell, it may be unnoticed and is not generally considered intense or obnoxious.

Other uses of wastewater in urban areas include recreational purposes, and industrial cleaning or cooling use. The cost of pipeline construction and pumping could be significantly lowered depending on the recycled use.

"Local initiative and imagination could reduce recycling cost and produce more benefits, but this has to happen on a local level. Successful recreational reuse, for instance, is very site-specific," Chang concluded.

CONSEQUENCES OF SOIL EROSION

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Erosion writes the history of nations indelibly on the earth, creating a permanent record of successes and failures. Our past is full of both good and bad examples of man's stewardship of the land which sustains him. Entire civilizations have failed because of soil erosion, whereas control of erosion has allowed other civilizations to prosper for thousands of years (6). Neglect, greed, and ignorance are primary causative factors for accelerated erosion. Since the beginning of time, man seemingly has considered himself to be "at war with the elements". In some cases, man has had to "scratch out an existence from the earth with his bare hands". However, in most cases in this country, the living has been bountiful and man has taken full advantage of the harvest. In the process, all too often he has raped and pillaged the land and left his mark wherever he went. In too many cases, that mark has been gullies too deep to cross and lands too eroded to produce.

Our very existence on the earth, and that of all humans, rests in the final analysis on soil productivity. In fact, the livelihood of the generations to follow will depend on the productivity of the same soils that we have the opportunity of utilizing today. These facts place great importance on proper use and management of our soil resources and give us continuing need to be aware of the consequences of soil erosion.

Soil erosion may be divided into two categories--water and wind. Erosion may also be classified as natural or geologic and as accelerated or man-induced (2). In most cases, accelerated erosion is the focus of attention for control programs, but man can also slow geologic erosion in many situations. Water erosion may be further divided according to type

into raindrop erosion, sheet erosion, rill erosion, gully erosion, and channel erosion (1). Water erosion is a problem throughout the country, whereas wind erosion is limited to certain dry regions.

Consequences of soil erosion for purposes of this discussion will be divided into three major categories: natural resource consequences, economic consequences, and social consequences. This discussion will deal in part with all three, but will dwell mainly on natural resource effects. This report does not propose to provide an exhaustive listing of all soil erosion effects--rather to point out a few of the most important consequences. Comments will be directed mostly toward erosion of agricultural lands.

Natural Resource Consequences

There is much discussion about whether or not soil should be classified as a renewable or a non-renewable resource. This seemingly unimportant academic exercise of classifying resources is based on the need to understand whether or not damage done to soils is permanent and irreparable. Such an understanding is necessary in planning control strategies. Generally, soil scientists have recognized that soils form very slowly. Factors influencing soil formation are parent material, climate, relief, organisms, and time. For many types of parent materials in many climates, hundreds and even thousands of years are required to form a few inches of soil material. On flood plains where deposition of already weathered soil materials takes place, less time is required. However, for soil materials to be deposited in flood plains, another soil somewhere must have been damaged. Soil scientists generally agree that hundreds of years are required for a soil to recover naturally from severe erosion. However, depending on the parent material, some soils may never recover. With modern technology, equipment, and other resources, we can speed the healing process on eroded soils greatly.

However, this is an expensive process and energy intensive. With increasing problems with shortages of fossil fuels, our alternatives for aiding natural processes likely will become more and more expensive and limited. We, therefore, may recognize that even though soil resources are renewable in terms of eons, in our short-term perspective, soils are virtually non-renewable. Such a realization amplifies the need for soil conservation.

One of the greatest losses associated with soil erosion is that of productivity reduction. Topsoil is that material which separates us from starvation. The impact of the loss of a given unit of topsoil varies. For a soil with a thick topsoil layer, the loss of an inch of soil is of less consequence than on thin-surface soils. Also, loss of the first inch of topsoil is of much less consequence than the loss of the last inch. For soils with uniform textures throughout, the impact of the loss of topsoil is much less than for those where the topsoil is underlain by materials less suitable for seedbed preparation, plant establishment, and plant growth. Some subsoils are unsuitable for cultivation.

Various authors have described attempts to quantify soil erosion impacts on soil productivity. Stallings (9) summarizes several. He indicates that yield reductions increase with successive losses from 15 percent for 2 inches to 75 percent with a 12 inch loss. Recently, efforts have been made to provide better methods of evaluating this relationship recognizing the need to be as specific to individual soil properties as is possible. Work continues on this relationship.

Valuable nutrients and recently, expensive herbicides are also lost along with sediment. Considering nutrients alone, and using fertilizer costs that are approximately 50 percent of present costs, it has been estimated that annual nutrient losses from erosion amount to $6.8 billion (1).

Considerable quantities of organic matter are also lost. Such a loss has a deleterious effect on soil physical conditions.

Sheet erosion will remove a relatively uniform amount of topsoil from an entire field, whereas rill and gully erosion concentrate erosive processes in channels across the soil. Land cut by gullies may be reduced to a non-productive status even though soils between the gullies retain their potential productivity. Average conditions across such a field might suggest relatively high yield potential for a given crop, but in a practical sense, no potential exists. Hockensmith and Steele (5) report that 33 percent of the cropland in the United States is level or nearly level soils subject to little damage by water erosion. Yet many reports use average soil loss per acre for all cropland as an indicator of control needs. Such reports are misleading and suggest little appreciation for where the real problems exist. In some areas, soil loss rates boggle the imagination, but averaged in with over 120 million acres of virtually non-erodible soils, conditions do not appear too bad. Soil loss averages should be used with caution and understanding.

Wind erosion preferentially removes fine soil particles and "winnows" soil. Fryrear[1] indicates that in desert environments fine sand is the material moved; however, in cultivated fields wind erodes sand, fine silt, and clays. This process removes much of the available water-holding capacity and nutrients from topsoils. Wind-eroded fields commonly have exposed subsoil in places with dunes of sand in other places within the same field. These differences lead to productivity losses through direct crop damage,

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[1] D. W. Fryrear. Long-Term Effect of Erosion and Cropping on Soil Productivity. Presentation of the February 1977 Meeting of American Association for Advancement of Science, Denver, Colorado, and for publication in the Proceedings (unpublished).

seedbed preparation difficulties, harvesting problems, and other related mechanical difficulties. Research has shown that in the Texas High Plains, grain sorghum yields have in some cases been reduced by 65 percent since 1908. Forage sorghum yields have decreased by 41 percent during the same period.[1] Other researchers in the Great Plains report similar erosion-related yield reductions.

Erosion also has a direct linkage with water quality. Recent governmental actions such as Public Law 92-500, Section 208 and the Clean Water Act of 1977 have focused attention on what is called "nonpoint source pollution". Non-point source pollution is defined to include materials entering streams through erosion processes from both agricultural and non-agricultural lands. Currently, there is much debate about whether all sediment in water should be considered as "pollution". Some have suggested that there is a difference between "clean sediment" and "dirty sediment". They point out that many streams have a naturally occurring high level of suspended sediment. They further argue that additional contributions of sediment into such systems could hardly be termed as detrimental to that stream system and certainly do not affect the "fishable, swimmable" status. However for certain streams which normally are clear, addition of sediment has been shown conclusively to have detrimental affects on the biotic components of the ecosystem. For such streams, large quantities of sediment may have a dramatic impact in causing the starvation of certain fish, destroying spawning beds, and other deleterious consequences.

Sediment eroded from urban landscapes and agricultural fields may also

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[1] D. W. Fryrear. Long-Term Effect of Erosion and Cropping on Soil Productivity. Presentation of the February 1977 Meeting of American Association for Advancement of Science, Denver, Colorado, and for publication in the Proceedings (unpublished).

be contaminated with pesticides or adsorbed nutrients which are carried "piggy-back" into the receiving waters. Toxic chemicals and elevated nutrient levels have a deleterious effect on the receiving water systems and associated biota.

Very little information is available about the direct effects of suspended sediment on health (7). Clays and organic colloids suspended in water through erosion processes may not be of direct concern to the health of people but may have adsorbed toxic materials or pathogens associated, which would be of definite concern. There is also some concern that acicular or fibrous materials may be carcinogenic. Even though these minerals are relatively rare in terms of their geographic occurrence, erosion processes which would contribute large amounts of these types of minerals to streams would be of concern from a health standpoint.

Another common consequence of soil erosion is the reduction of the diversification potential of soils. Frequently, topsoils are underlain by materials which are not as well adapted to particular cropping systems as is the topsoil. In such cases, the subsoils may be too clayey, too stoney, too saline, too acid, or have other problems which reduce the opportunity for use of the eroded soil for certain crops. Where rainfall is a major limiting factor for crop production, the mere reduction of the thickness of the soil is enough to prevent that soil's use for production of some crops. Hence, erosion limits cropping choices.

Erosion may have dire consequences for wildlife. In addition to the impacts indicated above on fresh water fisheries, erosion may also cause problems with upland birds and animals, as well as estuarine systems. A general reduction of the productivity of upland soils makes food scarce for wildlife. Large amounts of sediment delivered to estuaries may cause direct

problems for fish and other organisms, interfere with reproductive processes, and alter other life-related systems. An estimated one billion tons of sediment reaches tidewater annually (5).

Erosion has a direct relationship to sedimentation processes. One of the consequences of erosion, whether from urban or rural sources, is that sediment is delivered to receiving water where it settles and creates problems. Mud, sand, and other debris choke stream channels, increase flooding problems, fill reservoirs, choke drainage pipes, cover roads, destroy productive agricultural lands, kill crops and other vegetation, increase costs for water supplies, decrease water power potentials, and generally becomes a nuisance. Problems created by deposited sediment is the second cutting edge of the double-edged sword of erosion. Many highly productive agricultural soils are reduced to being marginally productive when a thick layer of sediment is deposited over the topsoil.

Flooding increases as a consequence of erosion for several reasons. Erosion naturally forms channels which conduct water as efficiently and quickly as possible from upslope position to streams. The formation of rills and gullies accelerates the movement of water downslope. In a severely eroded landscape, almost all of the water which falls on upwatershed slopes moves very rapidly to the lowest point in landscape. Therefore, large quantities of water swell streams soon after the rain falls. In contrast, on landscapes with grass or other vegetation and deep soils, the flow of water is slowed. Much more infiltrates into the soil thus reducing the speed and total amount of water which moves into the drainageways.

The impacts of drouths are also increased by erosion. As indicated above, erosion increases the rate at which rainfall is removed from the landscape. This reduces the amount of effective rainfall received on the

landscape. Rainfall is considered to be more effective if it enters the soil and becomes available to plants. Erosion also increases drouthiness by removing topsoil and decreasing the overall available water-holding capacity of the entire soil by decreasing soil depth. For those years in which annual rainfall is deficient in marginally productive areas, a relatively small amount of available water-holding capacity can mean the difference between some production and no production. Vast acreages of cropland in the United States are located in such marginal zones. Hence, climatic fluctuations coupled with wind erosion can have a large impact in certain regions.

In some areas, erosion produces gullies that are deep enough that they intersect groundwater and therefore effectively lower the water table. Such an impact may be of importance from the standpoint of water supplies both for livestock and humans and also on ephemeral streams in the vicinity.

Wind erosion has a dramatic effect on air quality in some regions. Blinding dust storms hamper vehicular travel, induce pulmonary health problems and cause other difficulties and inconveniences. In fact, erosion was allowed to continue in the United States for nearly two hundred years without any federal government efforts at control and landowner assistance until the massive dust storms of the 1930's focused enough attention on erosion for actions to be taken. Wind erosion can have dramatic effects regionally as well as locally.

Economic and Related Consequences

Demands for food, feed, fiber, and now energy production have placed a strain on croplands. The push for increased national production has brought some lands into row-crop agricultural uses which are unsuitable for such uses. Some of these soils are located such that they cannot be adequately protected against erosion. Relatively recent governmental actions

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issued an almost fatal blow to many conservation programs and systems which had developed over decades, when the push was made for "all out" agricultural production. Such a single-purpose economic drive is unconscionable if we have more than an annual perspective. In many similar cases, economic pressures from short-term demands on farmers and ranchers force the abuse of land resources. Included in such outside pressures are government programs, bankers and lending institutions, landowners, and others who are in a position to make direct demands on land operators. It is a sad fact that farmers must operate on short-term capital, whereas quality conservation programs have long-term payback. Land operators have difficulty in economically justifying emplacement of some conservation practices since the duration of the benefits may far exceed his expected tenancy on that land. All too often, non-resident landowners are unwilling or apathetic toward land resource protection.

Conversions of land use often are made unwisely. Frequently, the folly of such a decision is felt financially and the conversion is short-lived. However, even during a few years, resource damages may occur which are irreparable. Soil erosion which occurs during untenable land uses may result in financial ruin and bankruptcy for the land operator.

Dr. John F. Timmons indicates that ultimately soil erosion will lead to higher food prices and reduced exports (10). He suggests that considering our situation in the world today, such an eventuality will greatly hamper our capacity to hold inflation within tolerable limits and stabilize the value of the dollar.

The public has an abiding interest in erosion that occurs on private lands. It has been shown by numerous research studies that the public derives direct benefits from soil conservation practices. As increased demands and stresses are placed on croplands and rangelands, it seems appropriate that public

expenditures should increase to support the adoption and use of needed conservation practices. Unwise land management decisions and improper land use conversions will greatly increase the need for expenditures for erosion control. Obviously, as public expenditures increase so must taxes also increase. Such a linkage demonstrates that we all must pay, not only in the short run, but in the long run for soil erosion.

It has been estimated by Robinson (8), that over 4 billion tons of sediment are moved from land surfaces into streams and lakes on the average annually. Hockensmith and Steele (5) report that of 4 billion tons of sediment produced by erosion in the United States, 2 billion are washed into streams. In either case, millions of dollars are spent each year to dredge channels and remove sediment from lakes, streams, reservoirs, roadside ditches, drainage systems, roadways, and other areas. It was recently reported that sediment removal costs exceed 250 million dollars annually (11). In addition to those direct costs of sediment removal, there are also substantial economic losses associated with shipping and navigational limitations.

Necessarily, the cost of crop production increases with increases in soil erosion. Frequently, rills and gullies cut into farmland must be smoothed and levelled to allow for passage of farm equipment. This land shaping requires expensive special purpose machinery, substantial energy, and much time. In general, those expenses are accompanied by lower productivity, higher general farming expenses, and consequently, less net return per acre.

Social Consequences

The American food production machine has operated so efficiently that the public has almost ceased to be concerned about having enough high quality food. In fact, if it were not for the miracles of mass communication, the

majority of the American public would not even know hunger still exists in our world today. Soil erosion threatens eventually to reverse our bountiful harvest. The soil on which we depend to satisfy human needs may soon be stressed beyond its capacity to produce enough for all. As a consequence, spiraling prices will restrict the quantity, quality, and diversity of the diet of many Americans and other people. Even our keeping of animal pets eventually may become limited.

As soil erosion reduces overall production of agricultural products, exports will be reduced. Such a reduction in the food availability worldwide will result in widespread hunger. The United States is one of the few countries of the world so richly blessed with an abundance of highly productive agricultural resources in combination with a favorable climate to allow for production of excess food, feed, and fiber products. We have the opportunity to make important contributions to world food needs. Present projections of possibilities for expanding United States croplands (3) do not indicate any immediate crisis; however, long-term consequences suggest differently.

Pressures on natural resources increase as the standard of living increases. The corollary to this well established principle may be that as the quality and quantity of natural resources decrease, there will be a consequent decrease in the standard of living for those who depend on those resources. This means that our reckless use of resources today can only lead to problems in the future. Those conveniences and low prices for food which we have come to enjoy may be painfully stricken from us in the future. As soil erosion robs us of our own productivity, we may be forced to import greater quantities of certain commodities. Such a change will create an uneasy dependence on other countries.

One of the long range effects on mankind of soil erosion is the reduction of the potential population which the earth can sustain at any given time. The maximum number of people which can live on the earth is necessarily controlled by the amount of food available. As soil erosion occurs throughout the world, necessarily the capacity of the earth to sustain human and other animal life is reduced. To needlessly cause a reduction of this limit is unconscionable.

One trend which seems universal in areas where economic stress occurs, whether in response to erosion or other factors, is the general increase of non-landowner land operators. This situation frequently results in further increases in soil erosion. Tenants are not as careful with land that they do not own. Non-resident landowners tend to be more apathetic and have less concern and knowledge about land than those who own and operate land.

Presently, soil erosion and sediment deposition are causing review of rights and liabilities associated with land ownership. Increasingly, injunctions and demands for compensatory damages are sought for injuries to properties of one landowner by the uncontrolled or accelerated erosion from the land of another. Cox and Walker (4) have reviewed some of the statutes applicable in this regard. Projected to an extreme, this form of damage recovery could place many landowners in an untenable situation regarding the continued use of their land in such a way that erosion is excessive.

Possibly, one of the most serious consequences of soil erosion is the necessity for governmental action. One of the cornerstones of our American society is the individual freedom associated with land and the bundle of rights associated with land ownership. Seemingly, once government assumes control of previously existing individual citizen rights, those rights are virtually forever removed from the individual. This situation is considered

by many to be so severe that the erosion of liberties may be more important and costly than erosion of soil. Any governmental program should allow for maximum individual freedoms where possible.

Conclusions

Soil erosion is a natural process; a process which is responsible for the very existence of many of our productive soils. However, man's misuse of certain soil resources leads to excessive or accelerated soil erosion. Consequences of accelerated soil erosion are great and far-reaching. Erosion in many cases is so great that the soil resource is irreparably damaged. In other cases, repairs of damages can be made but only by expensive and energy-intensive operations. Very few agricultural soils are not damaged by erosion processes.

It is improper to view a national average soil loss in comparison with acceptable soil losses to arrive at an estimate of the magnitude of soil erosion problems. Soil erosion occurs on almost every acre of agricultural land in the United States. However, substantial problems with soil erosion are present on only a relatively small portion of that acreage. "Critical areas" have been and will continue to be identified by the Soil Conservation Service and others for program focus.[1] Those are the lands which are in danger of being irreparably damaged and which contribute excessive levels of sediment and accompanying pollutants into our stream systems. Those are also the areas which demand public as well as landowner attention so the soil erosion problems may be controlled.

In most cases, in those years when farmers can least afford conservation practices, those practices are needed most.

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[1] R. M. Davis, Administrator, USDA Soil Conservation Service. Doing the Things that Count. Speech delivered at the Annual Conference of SCS State Conservationists, San Diego, California, September 12, 1977.

Seemingly, government programs dictate whether or not farmers and ranchers can afford conservation practices. Since the programs vary from year to year, long-term conservation practices cannot be economically adopted. One bad decision by government costs the American people millions of tons of sediment in their water and untold millions of tons of food, feed, and fiber production potential for future generations. Such an impact may be taken far too lightly.

Research and educational programs necessary for development of conservation programs are of necessity, long-term in nature requiring several years of data collection, study, and work. Such efforts are presently poorly funded. The present focus on short-term research will cost Americans in the long run. Education programs in the area of soil conservation must of necessity be expanded. Public school, university, adult education, and extension programs must express a renewed enthusiasm and interest in the subject of soil conservation.

Unfortunately, the American public reacts mainly to crisis situations. Very few governmental programs are based on long-range goals with well-planned immediate steps. Erosion control demands long-term continuing dedication by all. Once a crisis stage of soil erosion occurs the damage has already been done. The value of our soil resources is such that anything less than well-planned, well-funded strategies for protection is not good enough.

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AGRICULTURE COMMITTEE;

SUBCOMMITTEE ON NATURAL RESOURCES AND THE ENVIRONMENT,

SCIENCE AND TECHNOLOGY COMMITTEE;

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

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July 15, 1979

AGRICULTURAL AND ENVIRONMENT GOALS:

COMPATABILITIES, TRADEOFFS, CONFLICTS

Currently there is excessive attention to conflicts, inadequate awareness of inescapable tradeoffs, and too little knowledge of the compatability of modern agriculture practices and environmental goals. For over 100 years the agricultural sector carried, almost single-handedly, the responsibility to assure an adequate supply of high quality food at reasonable cost.

About ten years ago other sectors of Universities, non-agricultural groups and new governmental agencies became interested in food production strategies, and they have increasingly become involved in both research

and decision-making that affect agricultural practices.

The transfer of a significant portion of decision-making in farming practices from farmers and their local sources of information to non-agricultural groups, interjects strong, oftentimes decisive, inputs from persons who have legitimate concerns, high levels of interest and strong convictions but limited technical and scientific expertise and understanding of the food and fiber production complex. Technical issues were, in the past, debated and resolved in scientific journals. Scientists had extensive training in how to evaluate data: examine the experimental techniques, consider the nature of the soils and climate, envision the results of applying the new technology in commercial agriculture, and arrive at a balanced assessment. The issues have changed and so have the participants.

It is disquieting to note the extent to which descriptions in the news media of individual farmers opinions and surveys of differing approaches to food production, are being equated to carefully conceived and conducted scientific research. Agricultural science is being challenged by persons without adequate credentials to deal with technical issues. Just as "man bites dogs" is highly newsworthy, so is an article about anyone who attacks conventional agriculture and claims to have developed a viable alternative that has no undesirable environmental effects. Farming without chemicals is currently the hottest topic. The need for effective communication between the traditional agricultural sector and newcomers to decision-making in food and fiber production strategies is increasingly urgent.

I shall deal mainly with matters which have received inadequate attention; discussing concepts that are already well accepted seems to be unnecessary. Focus will, therefore, be centered on the impacts of agricultural practices on the achievement of five societal goals:

- An adequate supply of high-quality food at reasonable price.
- Preservation of the productive capacity of land.
- Preservation and/or improvement of water quality.
- Preservation of wildlife and recreational areas.
- Energy efficiency.

The missions of agriculture to produce food and preserve the soil and of other agencies to protect the environment and assure food safety must be complementary rather than competitive.

1. Food Supply, Quality and Price

In spite of recent outcries over rises in food prices in grocery stores, the production sector of our food system is the envy of the world. Over the past ten years, only 13 percent of the increase in food costs occurred on the farm; 87 percent occurred in processing, storing, transporting and merchandising after the raw materials left the farm gate.

Fresh fruits and vegetables are available on an almost year-around basis nearly everywhere. They are fresher and more attractive than ever before. In some products, for example tomatoes, peaches, cantelopes, a tradeoff has been made in loss of flavor and in firmness at the time of harvest in order to allow them to be transported long distances without excessive loss due to spoilage.

The nutritional value of conventionally grown foods with respect to vitamins, minerals, proteins, etc. has been challenged by some persons but this is not supported by scientific research.

The significance of chemical residues that are within World Health Organization safe limits will be debated far into the future. Regulatory agencies are, of course, charged with the responsibility for establishing reliable standards and assuring compliance. Residues at some level are

an inescapable tradeoff if food and fiber are to be produced at present levels.

Dr. Philip Handler, President of the National Academy of Sciences, has said that reasonable people will take "moderate risks for great benefits, small risks for moderate benefits, and no risk if there are no benefits." Irving S. Shapiro says that: "Anyone who tells us to do it without risk is really telling us -- don't do it -- and any protestation to the contrary adds up to attempted deception of the public."

A statement of risk by itself is no basis for decision making. A prestigious committee of the National Academy of Sciences put it this way:

> "The concept of acceptability needs to be given its proper place among consideration of cost, efficiency and the other components of social decisions so that, for instance, it becomes commonly understood how a thing can be unsafe but perhaps unavoidable for the time being, or how a thing can be quite safe but nevertheless undesirable on other grounds."

The notion is prevalent that high-yielding germ plasm is fragile and thus requires more fertilizers and pesticides (and in some cases irrigation). That is generally untrue. High-yield germ plasm is more responsive to treatment, hence it pays to use more fertilizers, pesticides and water. But the typical improved variety in the so-called Green Revolution outyields prevalent native varieties even without additional fertilizer, pesticides and irrigation.

A related misconception is that diversified cropping systems are always less susceptible to pests hence require less pesticides than systems based upon only one or two crops. But farmers have long known that some weeds, notably perennials, are worse in a system that includes hay and pasture crops than in continuous row crops. A Cornbelt study found

that 6 insects were worse in a rotation that included hay and pasture crops, whereas 2 (including the very serious rootworm) were worsened by continuous corn.

Modern agriculture, founded upon USDA and Agricultural Experiment Stations research has been eminently successful in producing enough food. Some persons challenge its quality, especially in relation to possible effects of chemical residues. In response to that, I shall cite only data associated with the dread disease cancer. Because death statistics are influenced by the effectiveness of treatment, only statistics on the incidence of cancer provided by the National Cancer Institute will be used. The so-called chemical age in agriculture began in the late 1940's to early 1950's, thus the latency period from exposure to diagnosed malignancy in humans has expired for many agricultural chemicals. When lung cancer (credited by the NCI mainly to smoking) and colon cancer (believed to be influenced by type of food, including amount of fiber, rather than chemical constituents at the time of harvest) are subtracted, other major age-adjusted cancer incidence has declined per 100,000 population in all except black males from 1937 to 1969: White Male - 124 down to 114, White Female - 191 down to 155, Black Male - 94 up to 161, Black Female - 205 down to 171. This decline does not agree with the perception of the U.S. public, and perhaps not your perception, but it is a fact nevertheless.

To paraphrase a statement by Peter Yankwich, Vice President of the University of Illinois: "Pesticides is an area in which information conveyed to the lay public has incited its fears beyond its reason." (Frontiers in Genetics Research Workshop. Balmoral Woods. March 3-4, 1978. Yankwich referred to genetics research.)

It is often asserted that predicating when, where, and how to produce food upon economic criteria, means putting dollars above the health

interests of people. I shall not deal with all aspects of that subject, but wish to call attention to an important overlooked consideration. Wise and prudent use of all available technology, which results in relatively low-cost food, increases the chances of low-income families being able to afford a nutritious diet with money left over to purchase health-related services. I submit, therefore, that agricultural technology which produces food in an optimum economic framework has positive health implications which, for proper perspective, must be considered when assessing potential negative effects of pesticides and antibiotics.

2. Preserve the Productive Capacity of The Soil Resource

Maintainting the soil resource is obviously indispensable to the future of mankind. Many persons are asking what is modern commercial agriculture doing to this precious resource? The answer can only be framed in response to another question "Compared to what?".

Compared to the virgin condition, most farmland has lost at least 40 percent of its organic matter and reserve of nitrogen. Our forefathers survived by growing crops with the plant nutrients released when organic matter (humus) was destroyed. The destructive process has slowed dramatically because: 1) the most readily destroyed humus is already gone, and 2) contrary to popular notion, modern high-yield agriculture returns vastly greater amounts of crop residues than did less intensive, but lower-yielding systems of earlier periods. Intensive corn and soybean production in the Cornbelt, for example, returns more than twice as many residues as did the corn-small grains-hay system in 1950 or 1920.

Intensive tillage (characteristic of row-crops such as corn, soybeans, sorghum, and vegetable crops) accelerates the destruction of soil organic matter. But nitrogen fertilizer balances the low nitrogen status of

residues and favors the buildup of humus. In the Great Plains region, nitrogen fertilizer has become a highly positive factor in maintaining soil organic matter.

The most serious problem in maintaining the productive capacity of U.S. soils is water and wind erosion. Erosion is the only factor that leads to permanent loss of productivity in many soils. Organic matter can be rebuilt, plant nutrients can be replenished (though there are finite limits especially of economically available sources of phosphorus), and even a surface covering of concrete can be removed in a time frame of 100 to 1000 years. But if a highly desirable silt loam mantel over clay or bedrock is removed, productivity is likely permanently impaired.

What is the record of modern agriculture in relation to soil erosion? There are three answers. Not good enough. Better than you may think. We've got to do better. Others will discuss answers one and three, so I'll address number two; 'Better than you think'.

In spite of a rise in row crops in the central Cornbelt from about 50 percent to 85 percent, soil loss actually declined during the past forty years. Why? Mainly because of the dramatic increase in yields which not only protected the soil during the growing season, but, as stated previously, returned far greater amounts of residues to the soil after harvest. This effect was supplemented by modest application of special soil conservation measures such as contour farming, strip cropping and terracing. Leaving crop residues on the surface has been vital in the Great Plains region, and adaptations of the practice are growing rapidly in the midwest.

A relatively free, highly competitive agriculture has resulted in crops and livestock systems being located where they are best suited. From a national viewpoint, this has generally minimized erosion and damage to

the productivity of the soil resource and to water quality. The total sediment load delivered to lakes and rivers is least, for example, when corn is grown intensively on the deep, dark, level to slightly-rolling land of the midwest, and feed grains are shipped to the northeast and middle Atlantic states so farmers in those states can specialize in dairying, and keep a higher proportion of their steeper, more erosive land in small grains, hay and pasture.

Intensive production of corn and soybeans in the Cornbelt is possible only because of adequate use of commercial fertilizers. Suggestions that each farm become more self-sufficient by shifting rotations to provide more homegrown nitrogen (alfalfa, clover, lespedeza) and increasing the amount of livestock, is counterproductive to national goals of minimizing erosion and sedimentation of rivers, lakes, and reservoirs.

Though the absolute amount of erosion is of prime concern, it is worth noting in passing that, since total agricultural production has about tripled while the amount of soil loss remains about the same, commercial agriculture now produces about three times as much food per unit of soil loss as it did thirty to fifty years ago.

There is at the present time no widespread buildup in soils of any toxic chemical used in commercial agriculture. Most modern pesticides are biodegradable within a few weeks and nearly all within one or two years. The amount of persistent chlorinated hydrocarbons in the soil peaked about 1970 and has since declined at least two thirds.

The phosphorus and potassium status of most cropland is actually better than it was before farming began because of regular fertilizer additions.

3. Preservation and/or Improvement of Water Quality

The goals for water quality were established by PL92-500 (Water Quality Amendments of 1972), but we do not yet know which are achievable at any price, and which can be reached at a publicly acceptable cost.

Compared to the practices of fifty to one hundred years ago, producing current levels of food and fiber by present methods results in only a fraction as much sediment pollution, biochemical oxygen demand, and both total and soluble phosphorus in surface waters. This is mainly because high acre yields allow food and fiber to be grown on far less land. This helps in two ways: 1) less acres are exposed, and 2) cropland can be confined to the level to gently-rolling soils and minimized on steep, erosive hillsides.

About ten years ago great concern was generated for the increase in nitrate content of rivers which was alleged to be caused by nitrogen fertilizer and to pose a grave threat to health. This volatile issue has now been largely defused in spite of a doubling in the use of nitrogen fertilizers. I have studied the trend in nitrate content of all of the major streams in the U.S. for which long-term records are available. The rise that appeared to be so dramatic during the 1960's has about levelled off in many cases. There are about as many rivers in which nitrates are declining as there are in which it is rising.

The explanation is likely that the upward trend in row-crop acreage has about run its course, and larger crop yields effectively utilize more nitrogen leaving less to leach into waters. Compared to 1955-1965, an increase of more than 50 percent in aggregate crop production has been achieved in the midwest, the region of greatest concern for nitrates (except for California), with little increase in nitrates. If a 50 percent increase had been achieved through the growing of more legumes,

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application of more manure, and farming more land, nitrate levels would likely be higher than they are.

The phosphorus status of lakes, ponds and reservoirs (though not of flowing waters) is of concern because of its role in eutrophication and excessive algal growth. With respect to phosphorus inputs to surface waters, modern agriculture has a mixed record. Most of the phosphorus contributed by agriculture is attached to sediment and, as has previously been pointed out, sediment from agricultural land though unacceptably high is about stable. Increased use of phosphorus fertilizer has raised the content of the plow layer with the result that one ton of sediment now carries substantially more phosphorus than a ton of sediment did fifty years ago. The phosphorus that is most active in reducing water quality is not that attached to sediment, but rather that which is soluble or is contained in organic matter. In many regions this latter form is less in surface water where intensive row cropping (corn and soybeans in the mid-west for example) is practiced than where mixed cropping systems prevail.

The water quality component in which modern conventional agriculture is inferior to earlier systems is in pesticides contributed to surface waters. Nearly all of the pesticides that reaches surface waters from agricultural land are carried piggyback upon sediment. The first line of attack, then, appears to be to reduce erosion. But there is an incompatability with the most widely suggested approach, namely to leave crop residues on the surface. This practice complicates control of certain pests with the result that greater amounts of pesticides are needed. Therein lies another tradeoff: less sediment pollution for more pesticides.

Incidently, researchers at the Missouri Water Resources Research Center found that optimum fertilizer application increased the crop canopy and reduced soil erosion, hence would reduce pesticide runoff. They also

report that pesticides in field runoff are much less than those found in laboratory and field simulation studies.

The number of major new pesticides increased from 2 in the 1930's to 20 in the 1960's. Based upon the record thus far during the 1970's, it will decline about two-thirds in this decade. The chances of developing a marketable product declined from 1 in 4000 in the 1950's to 1 in 16,000 by 1975. (Mullison. Proceedings 30th North Central Weed Control Conference. 1975.) This is an alarming situation and is a threat not only to efficient production but also to a universally supported concept as stated in a recent Office of Technology Assessment report to Congress: "Effective integrated pest management is impossible in the absence of well-designed chemicals for careful application at the most vulnerable stages of pests."

4. Preservation of Wildlife and Recreational Areas

Intensive commercial agriculture reduces the amount of suitable habitat for wildlife on cropland. But, fortunately, there is a desirable tradeoff in that intensive farming on the best soils reduces the overall area of cropland, hence maximizes the area left for natural habitat and for recreation. For each 1 percent increase in yield on the best suited land, nearly 1.5 percent of the poorest land can be returned to wildlife habitat and/or to recreational uses. This is a dimension that has generally been overlooked.

Constraints on the use of available, proven agricultural technology in hopes of achieving certain environmental goals, therefore, involves a tradeoff with other environmental goals. There is no denying that occasional harm to non-target species has occurred. But it has been difficult to gain proper perspective because of the lack of scientific objectivity and emotionalism surrounding this issue, especially associated with such

chemicals as DDT, PCB's, PPB, and Kepone.

Contrary to conventional wisdom, farmers in the aggregate would benefit from regulations that restrict the utilization of proven technology. This is because a 1-percent decline in production, when supply and demand are about in balance, causes a rise of 2 to 4 percent in the price of farm products.

5. Energy Efficiency

There is much loose talk on how to reduce the energy needs of agriculture. Modern agriculture, is, indeed, energy intensive per acre of cropland, but the proper criterion to use in evaluating performances is energy per unit of food produced. When primitive systems are fully charged for their enormous demands on human labor and, in some cases, animal power, U.S. agriculture is competitive, even superior, to most.

For proper perspective, it is important that we remind ourselves that the primary goal of agriculture is food and fiber production. Energy saving, though it has high visibility at the present time, is still secondary. Furthermore, the total fossil fuel energy used to mine the minerals, manufacture the machinery, run the tractors and combines, build the livestock shelters, and deliver all crops and livestock products to the farm gate is only 3 percent of national consumption. It is, of course, a vital 3 percent and must be available at precisely the right time and place because in much of the United States there is only one right time in each year to sow and to reap.

Agriculture is a powerful solar energy machine. The ability of food, feed and fiber crops to capture solar energy has more than doubled in the U.S. during the past fifty years, and in many sectors, it has at least tripled. Furthermore there is no end in sight to continued progress

provided adequate resources are made available to support promising research. The number of researchable concepts is still increasing. Genetic engineering of plants, for example, is an elegant approach that is in its infancy. It is, of course, simply another tool for plant breeders (and other similar disciplines), but it will eventually open up exciting new avenues for improvements in food production strategies.

While we wait for dramatic results from such exotic tools as genetic engineering, we must remind ourselves that many small improvements in strains of crops, fertility practices, water management and utilization, pest control, and in harvesting to reduce losses, have resulted in an aggregate capability to capture solar energy that has risen rapidly in the past and holds promise of continuing indefinitely. Though less dramatic than genetic engineering, the continuous progress through many small, interrelated improvements is the backbone of the food and fiber system.

From a national point of view, far greater savings in energy can be made by improving cropping and livestock systems through research on better strains, better fertilization, pest control, and livestock that utilize feed more efficiently than in tampering with crop rotations and livestock systems in hopes of reducing energy needs on individual farms through less purchased fertilizers and pest control chemicals which can be applied in environmentally acceptable ways.

APPENDIX II

Agriculture and the Environment—The Issues
A Public Policy Issues Study Report

Prepared by The American Society of Agricultural Engineers Task Force on Environmental Quality

July 1979

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SUMMARY OF ISSUES

- Maintenance of soil productivity is the primary environment issue in agriculture.

- Soil conservation practices for wind and water erosion are the best ways to maintain soil productivity.

- The quality of water resources is of increasing concern in agriculture, especially the quality of ground water and irrigation water.

- An adequate supply of useable water for agricultural production is becoming more difficult to obtain.

- Urban and other demands for agricultural lands are removing highly productive crop land.

- Utilization of livestock waste via refeeding is a promising avenue for resolving animal waste management problems.

- Odors and their control are a major nuisance and problem in agriculture.

- New equipment is required for the safe application of concentrated pesticides.

- Energy intensive agricultural practices such as tillage can be modified to reduce both energy use and erosion.

- Intensive production and utilization of biomass energy may present a new set of environmental issues in agriculture.

- The agricultural environment is seriously impacted by conventional energy development and utilization. Acid rain problems and surface mining are immediate concerns.

SECTION 1
PROTECTION OF THE AGRICULTURAL ENVIRONMENT

The major environmental question is how can we most fully utilize our land, air, and water resources without abusing them to the point where serious environmental damage is evident. This is of particular concern in agriculture where the quality of the environment is linked to the productivity of the land. The situation is complicated further by the impacts non-agricultural elements can have on the rural environment. Air and water pollution from towns and industry seriously impact rural area. Therefore, the basic issue is at one point does utilization of our resources precipitate a significant deterioration of environmental quality.

Assuming that use of our resources will at some point be curtailed, the development of environmental regulations will be required. Because environmental problems are very complex and often poorly understood, environmental regulation is a constant issue with regard to environmental protection.

In this report, some major environmental issues identified by the ASAE Task Force on Environmental Quality are examined with regard to nature of problem, regulation and possible approaches for resolution.

SECTION 2
ENVIRONMENTAL AND PRODUCTIVITY ISSUES

Conservation of the land resource base is our primary insurance for a continuing supply of food and fiber to meet the basic needs and necessities of society (Lowdermilk, 1953; Bennett, 1939; Brown, 1978; Dasmann, 1969; Pimentel et. al., 1976). The importance of conservation to the public interest for maintaining a productive land resource base also has been expressed by legislation. Soil erosion as a menace to agriculture in the United States received national recognition when Congress adopted the Buchanan amendment to the Agriculture Appropriations Bill (P.L. 70-769) on February 16, 1929. Numerous laws since enacted have resulted in agency and institutional commitments to avoid deterioration of the land through misuse of soil, water, and related resources. The Resources Conservation Act of 1977 (P.L. 95-192) reaffirmed the national commitment to the conservation of soil, water, and related resources. The purpose of this act was to ensure that conservation programs administered by the Secretary of Agriculture respond to the Nation's long-term needs.

SOIL PRODUCTIVITY

Soil productivity is not a permanent asset, and it is a factor affecting the permanent economic welfare of the Nation. Productivity is affected by physical soil property deterioration, deficiencies in organic matter and nutrients, and the rate of soil loss by erosion.

One issue that must be addressed is the development and availability of technology to maintain high level productivity and minute soil degradation. Systems and techniques for intensive utilization of farmland will be required to satisfy future food and fiber production needs and such intensive approaches will place additional stress on our land resource. Traditional systems for intensive agricultural production, such as those practiced by the Chinese, illustrate some of the avenues for increased utilization of our land resources. These Chinese systems include multicropping, inter-cropping, transplanting and use of marginal areas by benching, terracing and developing even very small areas. However, these systems are labor intensive and are difficult to adapt to our highly mechanized system.

In the past, the effect of soil erosion on the productivity of land has been somewhat masked by other factors. New and more productive crop varieties, improved tillage, better pest management, and the addition of fertilizers have generally increased yields even though high rates of soil erosion were ocurring. However, the full extent to which these forms of technology can contribute to productivity increases may have been reached. In recent years, yields of major crops have not risen as fast as they did in the fifties and sixties (Jorling, 1978). In some cases, the yields have leveled off and in others, there have been decreases (Brown, 1978). It is becoming increasingly clear that current technologies have developed if production is to increase. Since a productive soil base is necessary to produce food and fiber, new and/or improved crop production technologies must be aimed at reduced erosion while improving the soil base. These new methods should also consider the increasing cost and probable shortage of fossil energy sources and the increased demand on our land resources for the production of biomass energy.

Many of the known technologies for reducing soil erosion while maintaining and/or improving crop productivity have not been used by individual operators or have been only partially used for several reasons. Among these reasons are:

Lack of farmer acceptance.
Added cost and less profit.
Method not adapted to existing equipment, and
Lack of concern for maintaining the productive soil base.

The primary reason is one of economics in the short term, since the farmer must make a profit in order to continue to produce food and fiber products. Based on 1975 price averages in the Palouse area, Harker and Michalson (1977) found reduction of soil loss from 9 to 8 tons per acre reduces the farmer's net profit by $0.75 per acre, from 6 to 5 tons reduction in net profit is $2.95 per acre; and from 5 to 4 tons profit is reduced $7.79 per acre. Similar examples have been noted in other farming regions (Pimentel et al., 1976). Other studies in the Palouse area, however, have shown that with changes in cropping patterns, additional conservation practices may reserve this trend (Palouse Cooperative River Basin Study, 1978).

There are many examples of practices that decrease soil erosion while maintaining or increasing the level of crop production (Pimentel, 1976; Langdale, 1978). Some practices increase production by better utilization of soil moisture, improving the crop climate conditions, and increasing the plant nutrient supply. Some practices create problems. Minimum tillage and no-tillage practices with high surface residues are excellent for soil erosion control, but have given problems in stand establishment, crop climate, and weed and insect control. Since no-till requires chemical control of weeds and insects, more chemicals are needed with this method.

There are promising areas where we should seek to expand our knowledge and improve technology so that reduction of erosion may be realized without sacrificing crop productivity. Areas to consider are:

1. Soil Hydrodynamics. An increase in soil infiltration will reduce erosion since the water will enter the soil rather than runoff on the surface. In some cases, adequate subsurface drainage will decrease surface erosion. Methods are needed that will maintain infiltration, reduce compaction and maintain good soil structure with a minimum tillage of the soil.

2. Topographic Alteration. Needed are new methods for decreasing slope and length while controlling runoff. Development of depositional areas within fields is a possibility.

3. Soil Fertility. Adequate plant nutrients help reduce erosion by providing better plant growth and cover. There are still excellent opportunities for improving soil fertility levels which could help lower erosion rates and improve soil productivity.

4. Plant Breeding. Plants that develop better canopy cover, more intense root systems, and more residue are possible. For example, the development of new plant varieties that an adequate canopy early in the season to protect the soil from erosion is one possible new research direction in this area.

5. Economic Factors. The economics of the agricultural system are closely related to erosion control. The demand and price for crops will usually determine the intensity and scope of cropping and the erosion potential. More cost-effective practices should be developed.

6. Governmental Factors. The extent and amount of cost sharing, tax incentive, technical assistance, and credit in installing conservation practices is an important aspect of erosion control.

7. Sociological Aspects. Operator attitudes and acceptance of erosion control practices are very important. Development of a sense of responsibility for saving and preserving the soil should actively be encouraged.

8. Climate Control. The ultimate factor for erosion control would be some manipulation of the weather so that rainfall would occur in a non-erosive manner. Most erosion occurs from excessive rates of rainfall or high winds which occur when the soil has the least protection and is in the most erodable state.

SOIL CONSERVATION

The 74th Congress enacted Public Law 46 in 1935 to establish a National Soil and Water Conservation Program. The emergence of conservation districts throughout the country provided impetus for private land users to plan and apply conservation resources and practices in accordance with sound principles of land use and treatment.

Initially soil conservation practices were rapidly adopted by private land owners. Between 1935 to 1940 investments in land treatment totaled 3 billion dollars; by 1945 it had reached $7 billion; and by 1955 nearly $20 billion. These capital investments in land treatment (in 1972 dollars) are shown in Figure 1 (after Pavelis, 1978). Nineteen sixty-seven data from the National Inventory of Soil and Water Conservation Needs estimated that adequate conservation use and treatment had been attained on 37 percent of the non-federal lands of the U.S. by 1967. The percentage of land needing treatment in 1967 by land use were 64% of the cropland, 69% of the pastureland, 67% of the rangeland, 62% of the forest land, and other 28%.

The National Erosion Inventory identified the following conservation treatment needs in 1977 for the above land use: cropland, 58%; pastureland, native pasture, and rangeland, 75%; forest land, 67%; and other, 28%. Thus, in this ten year period conservation treatment of highly managed lands (e.g., cropland) has significantly improved while less managed lands have a greater need for conservation treatment today than in 1967.

The loss of topsoil reduces the productivity of the soil for present and future generations and contributes to the pollution of our air and water. In the last 200 years an estimated one-third of the topsoil has been lost from U.S. cropland. It was estimated in 1935 that erosion had ruined 100 million acres for practical cultivation and in another 100 million acres, H. H. Bennett (1939) estimated that from one-half to all the topsoil had been lost. Thus, soil erosion had ruined or seriously impoverished for crop growth some 200 million acres in the U.S. by 1940. Since then some 2 billion tons of sediment a year are washed into our streams (USDA, 1970) and perhaps another billion tons of soil are transported annually by wind (SCS, 1978).

Estimates of the average loss of soil annually from agricultural cropland vary from about 5 to 14 tons per acre (see Figure 1). The rate estimated from the 1977 SCS National Erosion Inventory is 4.8 tons per acre per year from all U.S. cropland. Topsoil loss adversely affects crop productivity because of (1) loss of plant nutrients and organic matter, (2) removal of finer soil particles causing soil compaction and poor tilth, (3) loss of topsoil, and (4) increased water runoff reducing the availability of moisture for crops (Pimentel, et al., 1976).

Nationwide losses of plant nutrients due to erosion are alarming. Wadeleigh (1968) calculated that more than 50 million tons of plant nutrients (nitrogen, phosphorus, and potassium) are lost annually from cropland. The U.S. Department of Agriculture (1965) estimated the annual cost of replacing the nitrogen, phosphorus, and one-fourth of the potassium lost by soil erosion at 7.75 billion dollars.

The rates of erosion when less suitable lands are used for crops can be high. The 1977 National Erosion Inventory estimates show nationwide rates for row crops on Class VI land to be 15 T/acre/yr. The use of less suitable land may be part of the reason for high rates of erosion in Iowa in 1974, the highest in 25 years. Four and a half million acres eroded at rates exceeding 10 T/acre/yr. Gross erosion of 40 to 50 T/acre/yr was not uncommon and levels as high as 200 T/acre/yr occurred in some areas (Alt and Heady, 1977). Thus, careful attention to soil conservation needs must be given when managing these lands.

Cropland in need of treatment for these less suitable lands, by capability class e subclass, are shown in Table 1.

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SHEET AND RILL EROSION (CROPLAND)

Figure 1

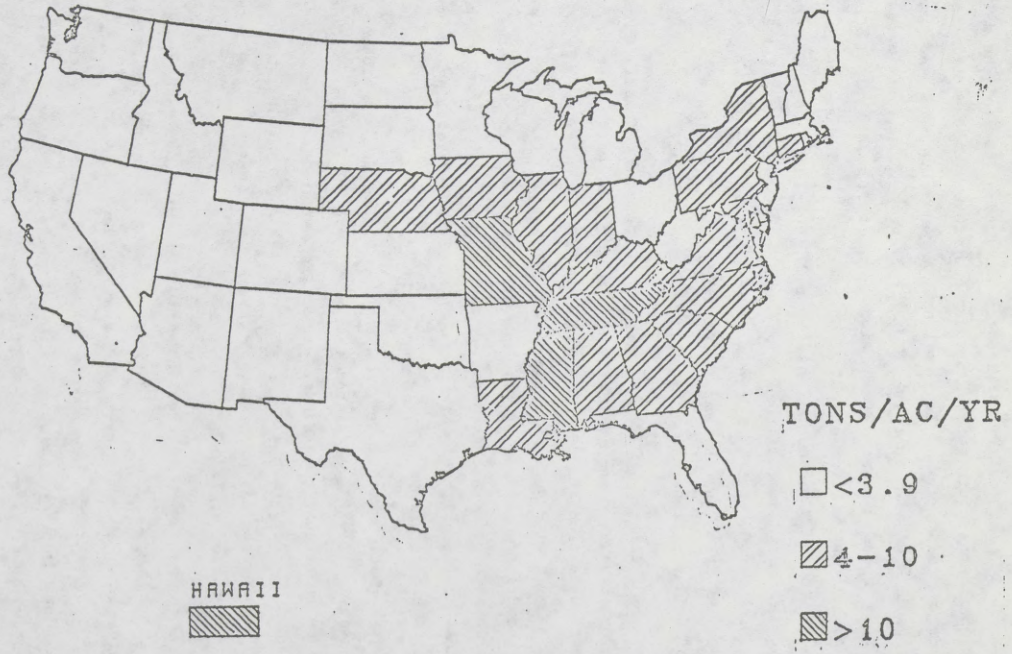


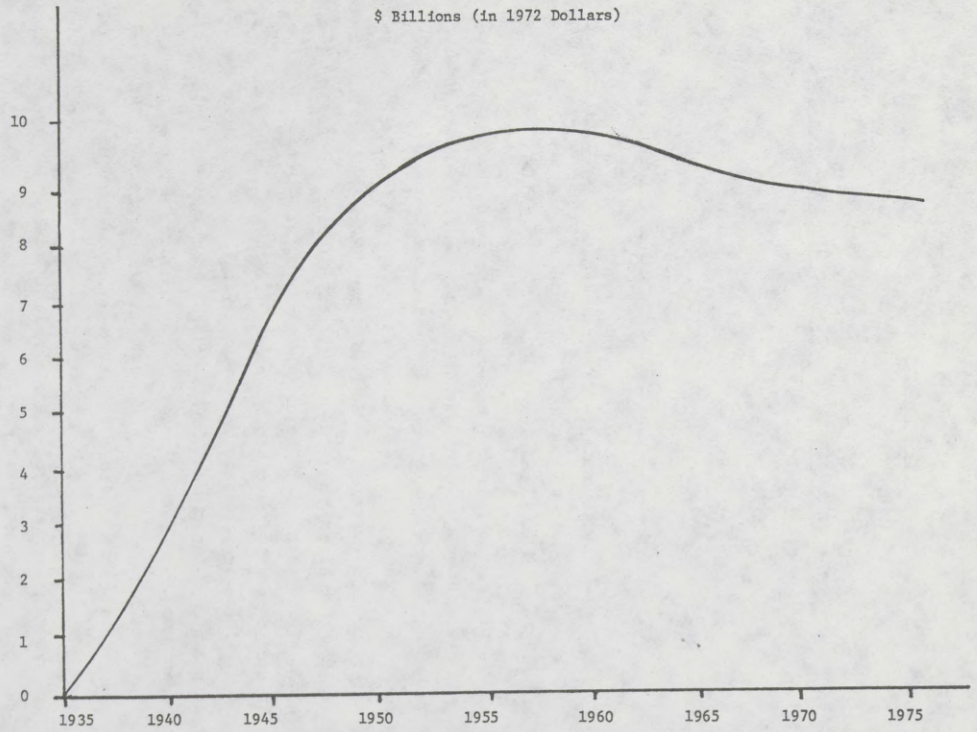
Table 1. Percent Cropland Needing Treatment by Capability Class and e Subclass

Classification	Needing Treatment	
Classification	Acres (million)	Percent
IIe	56	63
IIIe	52	65
IVe	20	67
VIe	7	78
VIIe	2	67

The higher percentages of lands in the e subclass needing treatment reflects the greater complexity of problems in achieving adequate land treatment on sloping erodible soils.

The continuing need to produce the food and fiber to meet growing demands at home and abroad resulted in more intensive land use. Changing technology, larger equipment, increased size of farms and other factors complicate the problem of maintaining conservation practices on the land. Many practices previously applied have become incompatible with modern equipment. Also, some types of practices designed for a given lifespan become inadequate unless reinstalled or adapted to changing needs. Changes in land ownership, fluctuating demands for food and fiber products, and lack of available conservation investment capital further affect the needed level of practice maintenance. Pavelis (1978) notes that declines in the value of general soil and water conservation facilities have been severe (Figure 2). Their peak value of $9.9 billion was reached in 1955. Their value in 1975 was done to $7.9 billion. The average annual rate of decline between 1955 and 1975 was 1.1% or about $100 million per year on the project. From 1970-75 the average drop was nearly %155 million per year. Much of this decline may be attributed to failure to adequately maintain existing conservation practices.

Figure 2. Capital Investment on the Land Value of General Soil and Water Conservation



SURFACE AND GROUND WATER QUALITY AND AVAILABILITY

Crop production, erosion control, and disposal on the land all may have an impact on the land resource. Lands may be enhanced or destroyed. Each practice must be carefully evaluated to determine the proper management system to insure proper protection and enhancement of the land resource.

These management systems also have a direct impact on water quality -- surface and ground water. Sediment, pesticides, and fertilizers are readily transported into waters through runoff. The impacts on these waters must be carefully evaluated in any planning done for long-term use and protection of resources.

Section 208 of the P.L. 92-599 aim at improving water quality by eliminating the discharge of pollutants onto U.S. waters from non-point sources.

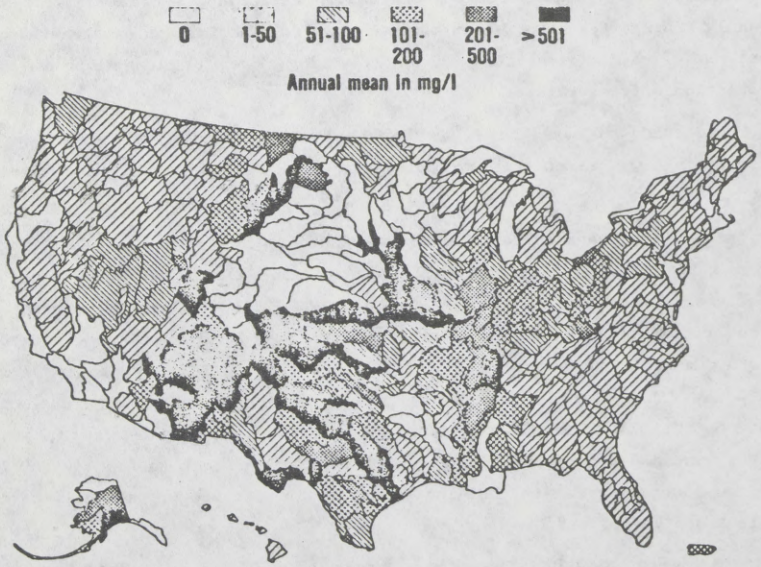
Irrigated agriculture causes suspended sediments and salt in irrigation return flows. Non-irrigated agriculture contributes soil erosion, pesticides, fertilizers, and livestock wastes. Silvaculture and aquaculture also contribute to non-point source pollution. In areas where the nature and extent of the water pollution is significant, BMP must be utilized. BMPs may differ for different parts of the country. Many BMPs are synonomous with such time-honored conservation practices as terraces, grass waterways, and conservation tillage. BMPs for livestock wastes may involve lagoons, settling basins, holding ponds, and prescribed spreading practices (Frank and Taylor, 1978).

Several new BMPs have been proposed. These include vegetative filters to control feedlot runoff and statewide programs on Integrated Pest Management. However, BMPs are developed and evaluated from a water quality standpoint rather than from an agricultural production standpoint, although sometimes these goals are mutually inclusive.

Figure 3 identifies suspended solids concentration in various river basins throughout the U.S. It is in the agricultural areas of The Great Plains and Southwest that the highest concentrations are found.

Figure 3

Mean Concentrations of Suspended Sediments at NASQAN Stations during the 1977 Water Year



Source: CEQ analysis of U.S. Geological Survey, National Stream Quality Accounting Network, data.

Contamination of the water by chemicals is also very evident in the major agricultural areas of the U.S. Pesticides (Fig. 4) and salts (Fig. 5) are serious water pollutants that are associated with agricultural operations.

Leaching of pollutants into the ground water is an increasing problem. Wastes of urban or industrial origin are often the cause of such contamination. However, irrigation and other agricultural practices often contribute to the contamination of ground water in a given region or are major causes (Fig. 6).

As important as the quality of water is its availability. Growing urban and industrial demands for water complete with agricultural requirements for this resource and deficiencies are prevalent throughout the U.S. but expecially in the West (Fig. 7).

The development of effective approaches for control of non-point pollution and the adoption of more efficient water utilization techniques are two major environmental objectives in agricultural engineering.

AIR QUALITY

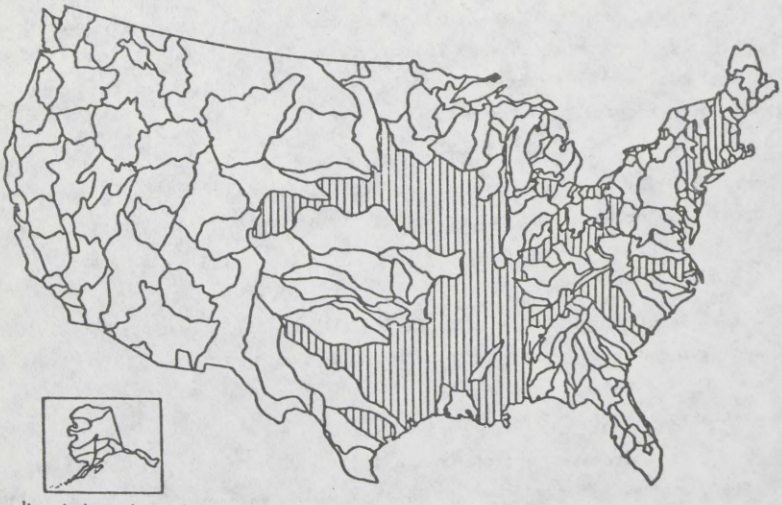
Farming operations cause air quality problems. Dust from cultivators and farm harvesting operations are usually of short duration and generally not of lasting concern. Wind erosion, however, can create serious air quality problems.

Wind erosion results from a turbulent wind stream blowing across a soil surface. Surfaces which are smooth, bare, loose, dry, and finely granulated are eroded more easily. Soil particles start to move when wind forces exceed those static forces active to keep the soil in place. Typically soil will begin to disappear at windspeeds exceeding 13 miles per hour at a height of 1 foot. Once in motion, the soil particles are transported by three mechanisms -- suspension, saltation, and surface creep. Once this erosion begins, the soil particles will abrade the surface, wearing away clods, crop residues, and also living vegetation.

Figure 8 shows those states with serious wind erosion problems. Table 2 lists the wind erosion estimates for these states. Although wind erosion is prevalent in other areas, the more significant impacts arise in

Figure 4

Basins Affected[1] by Pesticides from Nonpoint Sources 1977

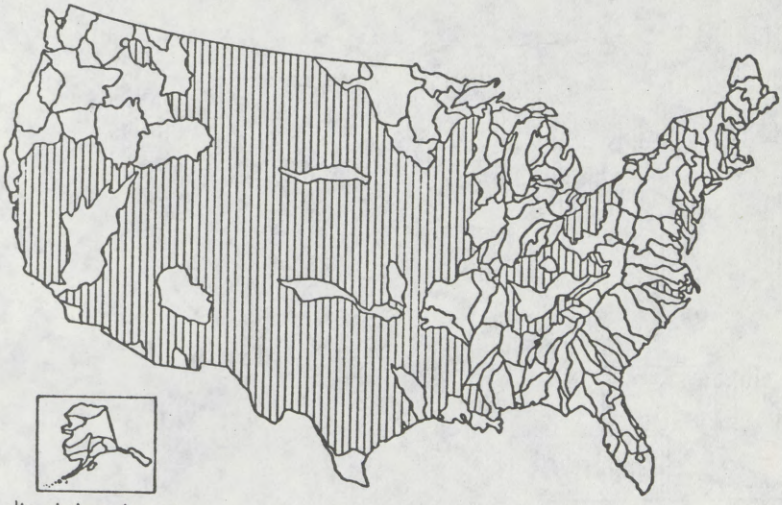


[1]In whole or in part.

Source: U.S. Environmental Protection Agency, *National Water Quality Inventory: 1977 Report to Congress* (Washington, D.C.: U.S. Government Printing Office, 1978).

Figure 5

Basins Affected[1] by Excess Salinity from Nonpoint Sources
1977

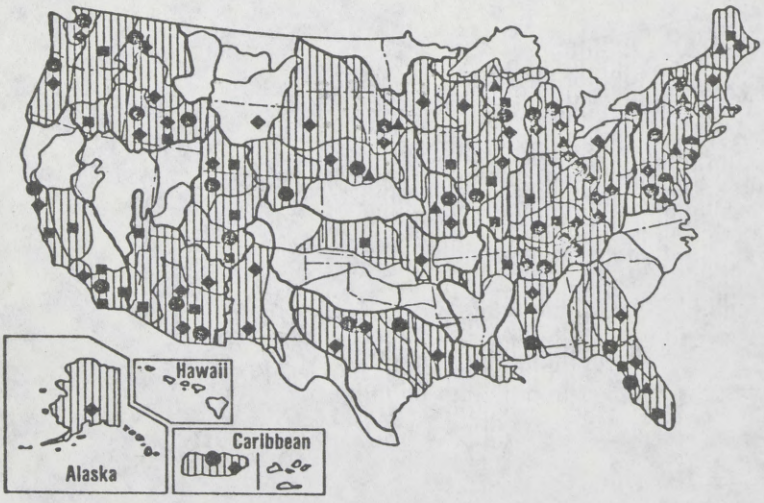


[1]In whole or in part.

Source: U.S. Environmental Protection Agency, *National Water Quality Inventory: 1977 Report to Congress* (Washington, D.C.: U.S. Government Printing Office, 1978).

Figure 6

Ground Water Contamination 1977



Areas with greatest total impact: areas that have ground water contamination

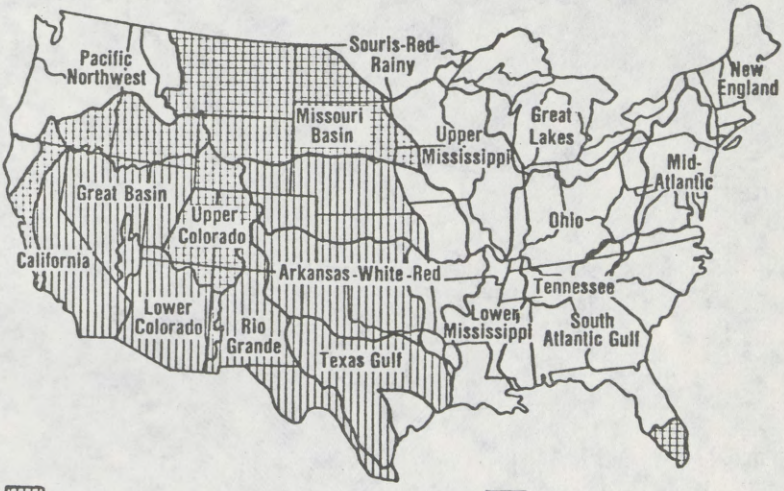
Location of specific impacts

- Contamination resulting from toxic industrial wastes
- Contamination resulting from leaching of municipal and industrial wastes, from waste runoff through oil and gas fields, and from other excavations
- Contamination resulting from leaching of wastes from land fills
- Salt and other chemical contamination of aquifers from irrigation and other agricultural activities
- Inadvertent contamination from well drilling, harbor dredging, and excavation for drainage systems

Source: U.S. Water Resources Council, "Preliminary Water Resources Problem Statements" (St. Louis, Mo.: Harbridge House, Inc., 1977), National Conference on Water, May 23-25, 1977, program materials, p. 13.

Figure 7

Water Supply Deficiencies by Watershed Region



Current problems

Arizona, New Mexico, Texas, Oklahoma, Kansas, Nebraska, Nevada, Southeastern Wyoming, Central and Southern California, Eastern and Central Colorado, Western Utah

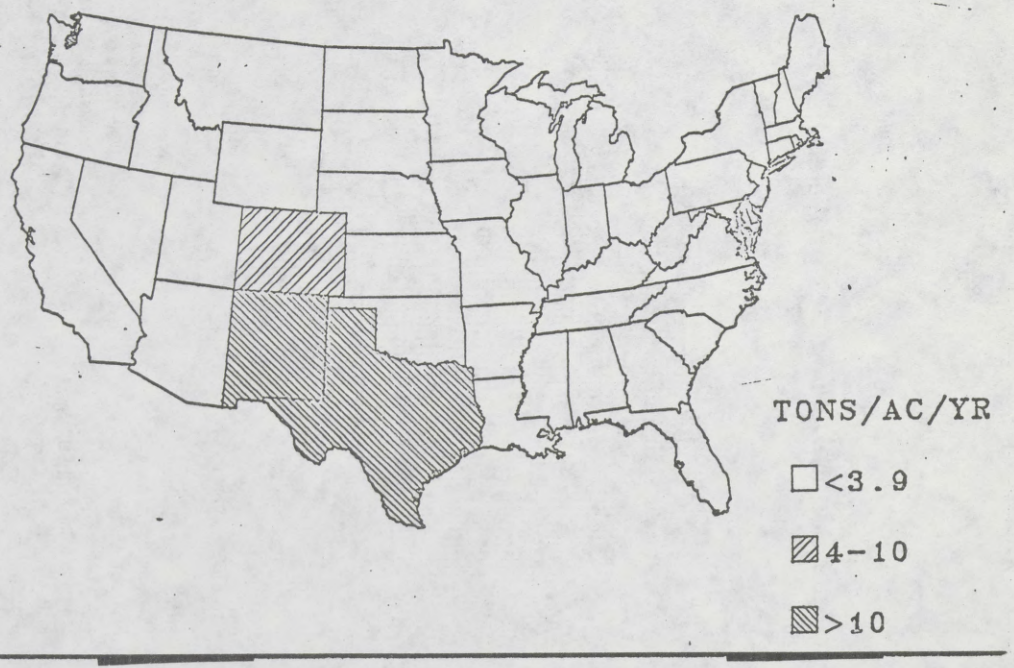
Future problems

Montana, South Dakota, Wyoming, Southern Idaho, Southeastern Oregon, Southern Florida, Northern California, Eastern Utah, Western Colorado, Western North Dakota

Source: U.S. Water Resources Council, *1975 National Assessment* (Washington, D.C., 1978).

WIND EROSION
IN THE GREAT PLAIN STATES
(CROPLAND)

Figure 8



the Great Plains Region. The estimated average annual movements of soil per acre of cropland in the more severely affected states range from 8.9 to 14.9 tons/acre. As would be expected in these states, the wind erosion problem is most common on "e" soils.

Soil conservation needs to be practiced to protect the land from wind erosion. One of the more common practices -- the use of tree windbreaks -- has been declining. The high costs of land and the need to produce as much crop as possible, makes it economically unattractive to use this land for erosion control. Thus, more economic measures are required.

Table 2. Estimated Average Annual Wind Erosion, By State

State	All Cropland	
	1000 T/Yr	T/acre/yr
Colorado	99,179	8.94
Kansas	84,760	2.94
Montana	58,450	3.81
Nebraska	25,903	1.25
New Mexico	26,139	11.49
North Dakota	47,317	1.76
Oklahoma	35,091	2.97
South Dakota	53,730	2.96
Texas	453,906	14.92
Wyoming	7,152	2.41
TOTAL	891,627	5.29

THE LAND RESOURCE BASE

The total surface area of the United States is about 2.35 billion acres. Of this, about 32% (760 million acres) is federal owned land, and 4% (98 million acres) consists of water areas more than 40 acres in size and streams greater than one-eighth of a mile wide. The remainder is under non-federal ownership and contains nearly all of our agricultural lands.

Land Use of Non-federal Lands

According to the 1977 SCS National Land Erosion Inventory, 413 million acres (28%) is cropland, 54 million acres (36%) is pastureland, and rangeland, 370 million acres (25%) is forest land; 95 million acres (6 %) is used for urban, built-up, and transportation, and 81 million acres (5%) is in other uses (Figure 9).

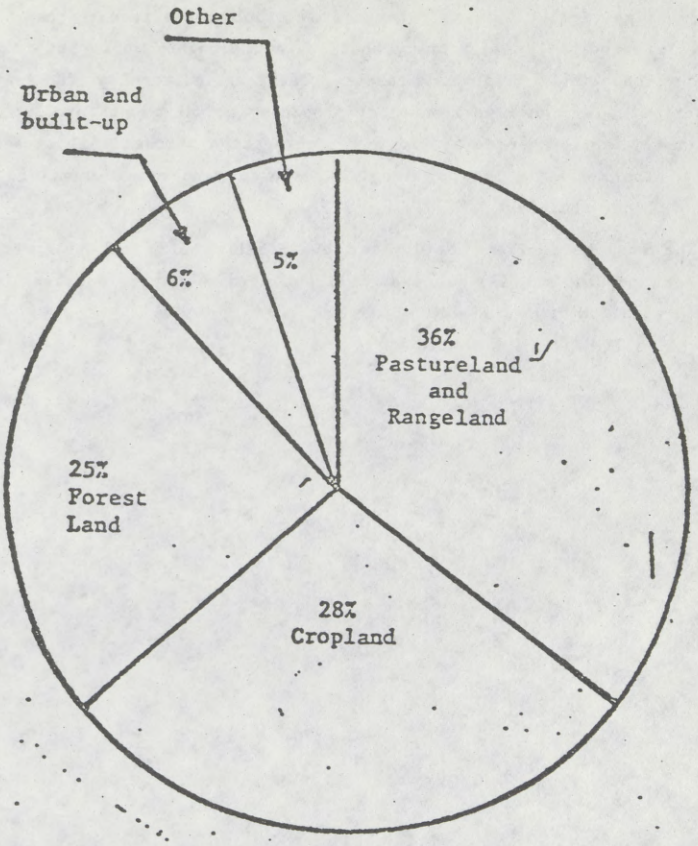
Data in Table 3 reflect projected changes in land use from 1977 through 2030. Losses of cropland acreage to highways, urbanization, etc., and compensating of land use conversions from cropland reserves and other uses are considered in predicting the 432 million acres of cropland shown in the table.

Table 3. Projected Nonfederal Agricultural and Forest Land (Million Acres)

	Year					
Land Use	1977	1990	2000	2010	2020	2030
Cropland	413	432	432	432	432	432
Pastureland	133	132	131	130	129	128
Rangeland	408	398	394	391	387	380
Forest land	370	363	360	355	354	352
Total	1,324	1,324	1,317	1,308	1,302	1,292

A 1975 potential cropland study by SCS showed that 18 percent of the 1967 cropland shifted to other uses in 8 years. Some rangeland, forest land, pastureland, and land in other uses were brought into crop production, which partly offset the cropland losses. Thus, any interpretation of the total acreage or trend in cropland use must be examined with the awareness that this use is everchanging.

Land suited for agriculture, or readily available for such purposes, is limited. When evaluated in terms of an extended period of time (1977-2030), it becomes evident that not only could there be a leveling off of agricultural land use for cropland but there could be more use of marginal



1/ Includes native pasture

Figure 9.--Use of Nonfederal Land in the United States in 1977.

land or near marginal. That is, the loss of cropland may require that some low-yielding erodible, wet, stoney, shallow, and droughty soils be brought into crop production. Trying to achieve greater agricultural production in this setting could cause environmental problems including water pollution, higher energy, and water uses, and soil degradation through soil erosion. It might also mean the loss of fragile resources and other amenities so important to our society.

The long-term effect of limited availability of cropland combined with rising population will place significant stress on our land resources currently used for crop production.

SECTION 3
WASTE MANAGEMENT CONSIDERATIONS

The major waste management problem in agriculture results from livestock. Americans depend to a great extent upon livestock products, including poultry products, for protein in their diets. Figure 10 gives per capita consumption information (USDA, 1978). The demand for these products results in huge numbers of livestock grown in the U.S.A., and there has been a trend toward concentrated raising of livestock to increase production efficiencies at the farm-site. Manure (livestock excrement plus associated materials such as bedding, hair, feathers, soil, etc.) is a by-product of livestock production and contains nutrients, organic matter, and odor-producing substances. In addition, there may be disease organisms that can be potential health hazards, as well as the manure attracting insects and rodents. The manure must be managed in such a way as to not deteriorate the environment of air, water, and soil. Serious waste disposal problems have resulted from concentrations of livestock in the U.S.A.

Other waste management problems arise in agriculture. Disposal of urban sludge waste on agricultural land is widely practiced and can adversely affect crop and soil quality. Agricultural chemicals must be used and applied wisely, otherwise, wasteful utilization will precipitate chemical contamination of the environment. For the above waste, responsible approaches for their management need to be encouraged.

LIVESTOCK WASTES

It has been estimated that about 2 billion tons of manure, wet basis, are produced per year in the U.S. (Wadleigh, 1968; Taiganides and Stroshine, 1971). Assuming 15% dry matter, this is about 300 million tons, dry basis, of which about 50% is collectable. Cattle account for about 80% of the total, but less than 50% of the cattle manure is recoverable. Virtually all the poultry waste is collectable (see Table 4)(Van Dyne and Gilbertson, 1978). The amount of manure produced per retail, consumer-ready product is given in Table 5 (Jeschke, et al., 1972). The large amount of cattle manure per pound of retail beef is partly because cattle utilize large amounts of low quality feed compared to non-ruminant animals resulting in a larger amount of manure.

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Table 4. Livestock Manure Production and Amount Collectable in 1974 (Van Dyne and Gilbertson, 1978)

Class of Animal	Thousands of Tons of Dry Waste	
	Production	Collectable
Beef cattle (range)	52,057	1,897
Feeder cattle	16,428	16,000
Dairy cattle	25,210	20,358
Hogs	13,360	5,538
Sheep	3,796	1,700
Laying hens	3,374	3,259
Turkeys	1,251	983
Broilers	2,086	2,434[a]
Total	111,562	52,169

[a]Includes litter.

Table 5. Manure Produced Per Consumer-Ready Product (Jeschke et al., 1972)

Swine	8 Lb Manure per Lb Pork
Pork = 50% market wt.	
Sheep	65 Lb Manure per Lb Lard
Lamb = 35% market wt.	
Beef	110 Lb Manure per Lb Beef
Beef = 43% market wt.	
Dairy	4 Lb Manure per Lb Milk
Milk = 1300 Lb./cow-year	
Poultry	4 Lb Manure per Lb Eggs
Eggs = 240/hen-year	

The major forms of manure utilization include use for plant nutrients, soil builders, animal nutrients, and fuels. It can be shown that spreading manure onto cropland for its fertilizer and soil-building value is the most economical and energy-saving method of waste management (Economic Research Service, 1974; Kim and Day, 1975). Such analyses, however, do not assign any value to having suitable access to cropland. Competitive land-use demands, as well as concerns for environmental quality and regulations resulting therefrom offer justification and opportunity for manure re-use as a feed ingredient at the feedlot site, thus bypassing the historical land-plant-animal waste recycle method. A comparison of the value of manure produced per year in the U.S. used as fertilizers or as feed ingredients is shown in Table 6, showing that manure is more valuable as a feed nutrient than as a fertilizer (Yeck et al., 1975). It should be noted, however, that the crude protein equivalencies of manure is not all in a digestable form, and that rations cannot accomodate all the manure that is produced. Therefore, use as a fertilizer and other uses such as for producing biogas will continue to be important in addition to using manure as a feed ingredient.

ENVIRONMENTAL IMPACTS OF REFEEDING

Manure recycled judiciously as a feed ingredient can have a desirable impact on animal agriculture. Ruminants will play a significant role because of their unique ability to use non-protein nitrogen and cellulose (Hodgson, 1976). Although ruminants are best suited to utilize manure nutrients, especially the non-protein forms of nitrogen and fiber, other livestock can also utilize manure to a lesser degree. There has been considerable research of feeding dried poultry waste to poultry (Surbrook et al., 1971). Also, the nitrogen in manure can be upgraded to protein quality through the aerobic fermentation of an oxidation ditch. This material has been successfully fed to non-ruminants such as swine and poultry (Harmon and Day, 1975). Energy requirements for drying and aerobic treatment, however, make these methods less competitive than less expensive methods of processing that are adequate for feeding to ruminants. Also, heat drying of manure results in increased nitrogen losses (Fotenot et al., 1971). The nutritive value of manure has been reviewed by many researchers (Anthony, 1970; Bhattacharya and Taylor, 1975; Smith and Wheeler, 1979) and is well documented in scientific literature. Poultry manure contains the highest concentration of nutrients and cattle manure the least. Poultry manures are rich sources of nitrogen, phosphorus,

Table 6. Annual Production of Manure in U.S., Value as Fertilizer Compared to Value as Feed (Yeck et al., 1975)

2 BILLION TONS OF LIVESTOCK EXCRETA.

CRUDE PROTEIN EQUIVALENCY = 40 MILLION TONS, AFTER 2/3 LOSSES = 13 M.T.

12 M.T. OF SOYBEAN PRODUCTION.

AS FEED = $2.5 BILLION.

AS FERTILIZER § $2.50/TON = $1.7 BILLION.

MANURE IS MORE VALUABLE AS FEED THAN AS FERTILIZER.

Table 7. Distribution of Nitrogen in Feces and Urine for Livestock (Smith, 1973)

	% of Total N	
Species	Feces	Urine
Beef cattle	50	50
Dairy cattle	60	40
Sheep	50	50
Swine	33	67
Poultry	25	75

and other minerals, which can correct deficiencies in high forage type rations for ruminants (Othjen and Dinius, 1976). Using some of the manure as feed ingredients, however, will reduce the amount used as fertilizers and thus will affect fertilizer needs.

Manure must be collected often (daily or perhaps weekly) to preserve nutrients, especially nitrogen, and avoid losses to the surrounding environment. Figure 10 is an example of volatilization losses showing 35% of the total N was lost by the second week and 50% was lost by the tenth week (Adreano et al., 1971). The 50% loss represents the amount of N in the urine, as shown in Table 7 (Smith, 1973). It is apparent that about half the nitrogen is in the urine in a volatilizable ammonia form emphasizing the need for frequent and total collection to avoid losses to the environment.

ASSOCIATED COSTS OF REFEEDING

The costs of equipment for various methods of processing wastes is not well known due to limited use of utilizing wastes as feed ingredients. However, the majority of methods use conventional equipment that is regularly used in feeding operations.

Smith and Wheeler (1979) reported the following in a summary of the nutritional and economic value of manure:

> Animal excreta products contain 48 to 73% TDN, 20 to 31% crude protein, 13 to 20% crude fiber, .9 to 8.8% calcium, 1.6 to 2.5% phosphorus, .4 to .9% magnesium, and .5 to 2.3% potassium. The products range in value as sources of plant nutrients from $24 to $39 per metric ton of dry matter. Their value as a feedstuff ranges from $113 to $173 per metric ton when soybean meal costs $221 per metric ton of dry matter and $116 to $254 when soybean meal costs $369 per metric ton of dry matter. In both nutritional and economical terms, poultry litter had the highest value and cattle excreta the lowest. The nutrient content of animal excreta limited their use from 15 to 34% of the total dietary dry matter for selected classes of ruminants.

REGULATORY STATUS

In a 1967 policy statement, the Federal Food and Drug Administration (FDA) annou ced that it did not sanction the feeding of poultry litter to

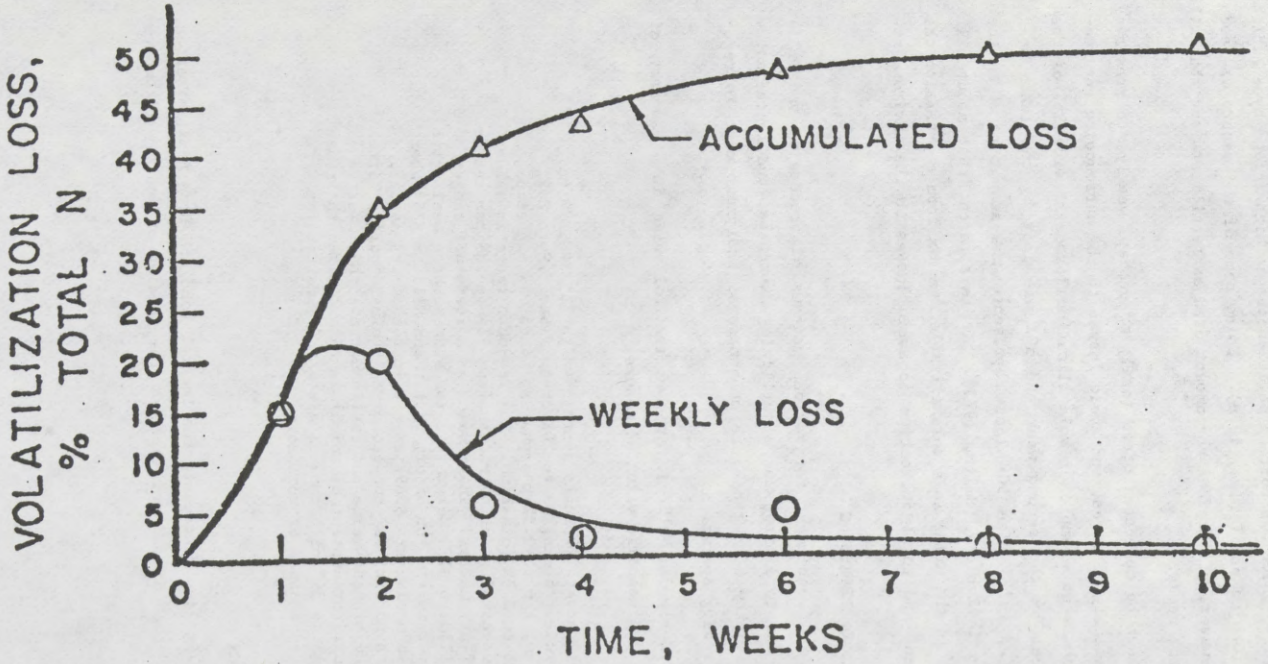

Figure 10. Example of volatilization nitrogen losses of cattle manure versus time after excrement. (Calculated from Adriano et al., 1971).

animals (FDS, 1977). The agency has since informally extended the scope of its statement to include wastes from other animal species, although it has restricted enforcement of the announced policy.

In 1972, the United States Department of Agriculture (USDA) formed a task force with scientists from USDA, FDA, and the Environmental Protection Agency (EPA) to update the earlier policy position in view of technological advances in the processing of animals waste and recent research findings regarding its nutritional value. While beneficial and favorable results were concluded, the earlier FDA policy position was not changed due to lack of sufficient supportive research to disprove health-related concerns.

A committee of the American Association of Feed Control officials (AAFCO) has drafted model regulations for processed manure intended for use as a feed ingredient (Minyard, 1977). The AAFCO regulations would apply only to commercial sale of manure-containing feedstuffs, but would exempt on-farm recycling. Seven types of "processed animal waste products" are defined in the draft regulations. Specific quality control criteria are specified for each product, together with general prohibitions pertaining to extraneous materials, pathogens, parasites and residues. While AAFCO has not yet adopted these regulations, they have been published for general distribution and are available from the AAFCO Treasurer (c/o Donald H. James, Consumer Protection Division, West Virginia Department of Agriculture, Charleston, West Virginia 25305).

FDA made an additional request for data, information, and views on aminal waste refeeding in the Federal Register of December 27, 1977 (FDA, 1977). Responses are presently being studied.

A multidisciplinary task force of the council for Agricultural Science and Technology (CAST 1978), of which ASAE is a member society, responded to the FDA request. Fontenot (1978) reported a summary of the CAST report. The CAST report confirms that animal waste has substantial nutritional value, especially for cattle and sheep, which can digest fiber and utilize nonprotein nitrogen. Some other conclusions were as follows. Poultry manure possesses the highest nutritional value

and cattle the lowest. The nutrients supplied by manure seem to be used just as efficiently as those supplied by other feed ingredients in rations without manure if the rations contain equivalent amounts of the various nutrients. The main safety concerns about feeding animal waste are its potential for transfer of harmful residues of pesticides, drugs, minerals, toxins, and disease organisms. Research shows no adverse effect on the quality of animal products as a consequence of feeding animal waste at nutritionally sound levels. The palatability of the products has not been affected. The report concluded that there is reason for exercising continuing caution, but it noted that problems have not developed in practice despite widespread use of animal manure as a feed ingredient for the past several years.

ENVIRONMENTAL CONTROL TECHNOLOGY REQUIREMENTS

Arndt et al. (1979) reviewed advantages and disadvantages of various processing methods including: drying, composting, ensiling, chemical treatment, aerobic production of single cell protein, and liquid-solid separation. Ensiling and chemical treatment are the most promising for processing manure to be included in cattle rations. The type and arrangement of production facilities may need special design attention to collect and utilize manure.

Major climatic considerations involved in the selection of livestock-housing and waste-management systems are temperature, precipitation, evaporation, wind direction and velocity, and solar radiation. Ideally, the livestock facility should be located in an agricultural area, downwind from nearby residential areas, and on sufficient land to permit adequate treatment of the wastes and disposal of surplus matertials if necessary. Facilities for emergency storage of some raw manure may be required for pollution control, as usually only up to about half of the manure from cattle can be refed back to the same animals. Standby electrical power may also be needed during power-outages if mechanical manure removal and feeding are used.

ENGINEERING NEEDS

The extensive research on manure refeeding during the past 15 years has dealt principally with nutritional properties and ration formulation and, to a lesser extent, with residue problems. There is a need for information on equipment and systems for efficient, reliable processing of manure as a feedstuff at commercial operations. To realize the full economic potential of manure refeeding, agricultural engineers need to work with animal scientists and veterinarians to develop integrated systems of feedlot design, manure collection, ingredient mixing and processing, processed feed storage and delivery that will more nearly optimize the beeding program.

LIVESTOCK ODORS

Odors are a major unresolved problem associated with livestock and poultry waste. All livestock production and processing operations produce some odor, but the amount emitted and potential problems caused vary greatly from one operation to the next. The odors are noticable primarily because of their public nuisance potential. Inside the animal production unit itself, however, odorous gases such as hydrogen sulfide and ammonia may be produced at concentrations that deleteriously affect animals and/or human health. The gases emitted rapidly dissipate and are not toxic at concentrations that would exist downwind of the facility.

The extent to which an environmental pollution problem exists depends upon the degree of exposure of downwind neighbors. Exposure can be quantified in terms of odor frequency, intensity, duration, and offensiveness. It can also be quantified in terms of the number of people affected and the number of complaints received by agencies.

For example, 45% of the air pollution complaints received by the Texas Air Control Board between September 1974 and August 1976 involved odors. Livestock feeding operated accounted for 14% of the odor complaints and agricultural product processing plants results in 15% of the complaints. The remote location of most livestock feeding operations leads to comparatively few complaints but also makes source identification comparatively easy.

Urbanization of traditionally rural areas, subdivision of agricultural land and rising public expectation for clean air have created increasingly greater pressures on livestock producers and processers to control odors. The number of odor nuisance suits, public and private, appears to be steadily increasing. Basic technology exists to significantly reduce livestock waste odors. The basic approach to odor control is aeration: either keep solid manure dry through rapid drainage or add oxygen to liquid manure through mechanical means. Most of the available proven solutions require higher costs and greater energy consumption than conventional livestock waste management practices. To a limited extent, odor control technology may be justified in terms of greater animal production rates, such as in the case of controlling ammonia emissions in confinement hog buildings (Curtis et al., 1978).

In many cases, such as open cattle feedlots, available solutions are imperfect at best. When it rains, for example, odors will be intense and offensive for several days until natural solar drying can occur. In such cases, positive year-round control would require redesigning the feedlot to collect all manure in a liquid form for mechanical aeration. Obviously, such a drastic solution would be costly, would entail greater energy consumption, and would cause dislocation in the livestock feeding sector.

Technology also exists for measuring odor intensity. The principle of odor measurement by a vapor dilution is universally acceptable. This entails diluting odorous air with odor-free air down to the point where half of the odor panelists detect it and half do not. However, technical debate continues over unbiased procedures and equipment for presenting odorous air to the odor panel and for eliciting their response.

Meanwhile, the application of available odor measurements technology to enforcement of nuisance provisions of state clean air acts has been sporadic. Reluctance for aggressive adoption of odor measurement technology and numerical odor emissions limits is traceable primarily to the following factors:

a. General lack of familiarity on the part of lawyers and environmental scientists with odor measurement technology.

b. Inability of air pollution control officials to correlate odor intensity with public response pattern (i.e. complaints).

c. Nervousness by industry over the possible spectre of unannounced on-site odor measurement inspections by air pollution control officials even in the absence of complaints.

NATURE OF THE ODOR PROGRAM

Approximately 45 specific odorous compounds or odorants have been identified in the gases and vapors released from livestock wastes decomposing under anaerobic conditions (Miner, 1974). These compounds are listed in Table 8. Concentrations of selected odorous compounds at which characteristics and perceptible concentrations of certain of these odorous compounds are given in Table 9. Importantly, most of the odor gases listed have threshold limit values that exceed the perception threshold by at least an order of magnitude. For example, methyl mercaptan is detectable at 1.1 parts per billion (ppb) but is safe for workers at 20 ppb. The threshold limit value for acetaldehyde is 90 times higher than the perceptible concentration. For these compounds, human sensory perception gives an "early warning" that the compound is present.

Major manure gases with potential human health consequences includes ammonia hydrogen sulfide. Ammonia has a distinctive odor discernable to most observers at concentrations of approximately 0.037 mg/l. Ammonia acts as an irritant to the eye, nose, and throat of animals and humans at concentrations of 0.3 to 0.5 mg/l. At very high concentrations, it acts as an asphyxiant (Miner, 1974).

Curtis et al., 1978, established three major facts about atmospheric ammonia in the pigs environment:

1. At 50-75 ppm, it hinders the young pig's ability to clean bacteria from the lungs.

2. Between 75-100 ppm, it depresses the rate of goiter.

3. At 100 ppm it exacerbates the effects of early stages of ascaried infection.

Table 8. Compounds Identified in the Air from the Anaerobic Decomposition of Livestock and Poultry Manure

Alcohols (1,8)	Carbonyls (1,3,8)	Esters (1,2)
Methanol (1,8)	Acetaldehyde (1,3,8)	Ethyl formate (1)
Ethanol (1,8)	Propionaldehyde (1,3,8)	Methyl acetate (1)
2-Propanol (1,8)	iso-Butyraldehyde (8)	iso-Propyl acetate (1)
n-Propanol (8)	Hexanal (3)	iso-Butyl acetate (1)
n-Butanol (8)	Acetone (3)	iso-Propyl propionate (1)
iso-Butanol (8)	3-Pentanone (3)	Propyl acetate (2)
iso-Pentanol (8)	Formaldehyde (8)	n-Butyl acetate (2)
	Heptaldehyde (8)	
Acids (6)	Avaleraldehyde (8)	Fixed gases
Butyric (7,6)	Octaldehyde (8)	
Acetic (6)	Decaldehyde (8)	Carbon dioxide
Propionic (6)		Methane
iso-Butyric (6)	Sulfides (2,6)	Ammonia
iso-Valeric		Hydrogen sulfide
	Dimetyl sulfide (2)	
Amines (1,2,4,5)	Diethyl sulfide (2)	Mercaptans (2,6)
Methylamine (4)		
Ethylamine (2,4)	Nitrogen heterocycles (6)	Methylmercaptan (2)
Trimethylamine (2)		
Triethylamine (4)	Indole (6,1)	Disulfides (6)
	Skatole (6,1)	

NOTE: Numbers in parentheses refer to the references below in which identification was reported:

1. R. M. Bethea and R. S. Narayan, 1973.[54]
2. R. K. White, et al., 1971.[37]
3. L. D. Hartung et al., 1971.[56]
4. J. R. Miner and T. E. Hazen, 1969.[6]
5. J. Fosnaugh and E. R. Stephens, 1969.[53]
6. W. E. Burnett, 1969.[35]
7. R. H. Deibel, 1967.[48]
8. J. A. Merkel, 1969.[36]

Table 9. Characteristics and Perceptible Concentrations of Various Substances in Air (Sheeby, et al., undated)

Substance	Odor Characteristic	Concentration causing faint odor 10^{-9} g/l
Acetaldehyde	Pungent	4
Ammonia	Sharp, pungent	37
n-Butyl mercaptan	Strong, unpleasant	1.4
Carbon disulfide	Aromatic odor, slightly pungent	2.6
Ethyl mercaptan	Odor of decayed cabbage	0.19
Hydrogen sulfide	Odor of rotten eggs, nauseating	1.1
Methyl mercaptan	Odor of decayed cabbage or onions	1.1
Propionaldehyde	Acrid, irritating odor	2
Propyl mercaptan	Unpleasant odor	0.075

Hydrogen sulfide causes concern relative to livestock wastes because of its toxicity to humans and animals as well as its objectionable odor. The National Institute of Occupational Safety and Health (NIOSH) and OSHA recommended a maximum concentration of 10 ppm of H_2S for up to an 8-hour exposure time ()American Conference of Governmental Industrial Hygienists, 1971). Above this level, eye irritation begins. (One part-per-million or ppm, may be compared to 1 drop of water in 16 gallons.) Hydrogen sulfide can be detected by its characteristic rotten egg smell at between 0.0001 and 0.7 ppm, well below dangerous concentrations, but continued exposure dulls the sense of smell and prevents detection. Higher concentrations cause headaches, dizziness, nausea and excitement. NIOSH recommends persons be evacuated when the H_2S concentration exceeds 50 ppm. Prolonged exposure to concentrations of 50 to 250 ppm causes respiratory irritation, with pneumonia sometimes occurring after exposure to 250 to 600 ppm for one hour. Levels of 500 to 800 ppm are regarded as "dangerous," and death may occur rapidly with exposures above 600 ppm. H_2S concentrations above 1000 ppm cause diaphragm paralysis upon first inhalation followed by rapid asphyxiation. Agitation of liquid manure storage pits has produced hydrogen sulfide concentrations of 800 and 1000 ppm for swine and poultry manure, respectively.

FEEDLOT ODORS

Peters and Blackwood (1977) measured certain odorous gases at two cattle feedlots in Texas with the following results:

Feedlot	Ammonia	Total Sulfides & Mercaptan Mg/m^3
A	104	27.5
B	120	5

Researchers with the USDA-Agricultural Research Service and the University of California at Riverside monitored ammonia levels around large and small dairies in the Chino Valley of Southern California (Luebs et al., 1974). For a 600-cow dairy, ammonia levels decreased 97% (from

540 $\mu g/m^3$ to 18 $\mu g/m$) in just 1/2 mile distance downwind. Nighttime ammonia levels were 70 to 75 timnes higher than mid-afternoon levels. Over an area of distillable N in the atmosphere was between 20 and 30 times greater than at a central site outside the dairy area.

The evolution of ammonia, hydrogen sulfide, and odorous volatile gases was investigated as a function of beef cattle ration at Oregon State University (Miner, 1976). Measurement of the ammonia evolution rate from surface within and around the livestock production facility provided an accurate reflection of anaerobic biological activity and a means for comparing the effects of odor control treatments. Ration had a major effect on hydrogen sulfide and ammonia evolutions rates as shown in the Table 10. Ammonia evolved at a rate 1000 to 10,000 times faster than hydrogen sulfide.

Table 10. Effect of Type and Amount of Grain on Hydrogen Sulfide and Ammonia Evaluation from 50% Cattle Feces, 50% Urine Mixtures (Miner, 1976)

% Grain in Ration	Means Gas Evolution Rates, g/hr					
	Hydrogen Sulfide*			Ammonia**		
	Corn	Milo	Barley	Corn	Milo	Barley
25	0.390[a]	0.489[a]	0.616[a]	3038[ab]	2926[ab]	3107[a]
50	1.121[a]	0.741[a]	0.653[a]	3467[ab]	2855[ab]	3921[a]
75	4.96[b]	4.531[b]	4.870[b]	3189[ab]	2325[b]	3833[a]

[a]Means with common superscripts in the same column are not singularly different (PL0.05).

[b]Means with common superscripts are not significantly different (P 0.05).

Length of storage time also had a marked effect on ammonia release (Miner, 1976). The ammonia evolution rate peaked at 2900 Mg/hr after 25 days of liquid cattle manure storage under anaerobic conditions, and then decreased sharply to only 30 Mg/hr after 10 days of storage.

Narayan (1971) determined that waste management practices markedly influenced the concentration and number of odorous gases emitted. Daily

removal of manure by washdown or scraping gave much better odor control than infrequent or no cleaning. USDA researchers (Hutchinson and Mosier, 1978) in Colorado measured emissions of ammonia, amine compounds and volatile fatty acids from a cattle feedlot surface in 1977. Ammonia emissions averaged 1 to 5 kg/ha/hr during daytime. This represents about 1/2 the rate of nitrogen deposition in urine, or 1/4 the rate of nitrogen deposition in both feces and urine. Ammonia volatilized from the surface of a 125,000-head feedlot would be enough to fertilize 20,000 hectares at the rate of 100 kg/ha/ yr (100 lbs/acre/yr).

Ammonia emissions ranged from 225 to 1200 g/m^3 at 1.5 m above the feedlot surface and 170 to 580 g N/m^3 at a height of 8.8 meters. Lowest NH_3 emissions occurred when the feedlot was wet just after precipitation. Peak NH_3 emissions occurred as the feedlot surface dried after a rainfall, which agrees with the data of Miner (1975). Except for precipitation, environmental variables had little effect on NH_3 evolution. The constant rate of NH_3 evolution suggests that its primary source is freshly-deposited urinary N rather than biodegradation of fecal material (Hutchenson and Mosier, 1978; Miner, 1976).

Of the 7 amine compounds detected, trimethyl amine was dominant and averaged 6 gm/ha/hr. These 7 compounds together amounted to less than 1% of the ammonia emissions.

Concentrations of 5 fatty acids and 5 volatile sulfur compounds were also measured above the feedlot surface. Of these, only butyric acid and $(CH_3)_2S_2$ were detected above reported odor threshold levels.

These 10 compounds individually make no major contribution to feedlot odors, but their unknown synergistic effects could conceibably contribute to an odor problem.

RESOLUTION OF ODOR PROBLEMS: LEGAL

Private regulation of odors comes about through the common-law concept of nuisance (Sweeten and Levi, 1976). Nuisance is broadly defined as anything which unreasonably interferes with the normal use and enjoyment of property. Cattle operations are often the target of nuisance complaints resulting from odors, flies, dust, noise, or water pollution.

A private nuisance is one affecting only a few persons from enjoyment of private property. By contrast, a public nuisance is one that affects a considerable number of people from enjoying rights of the public as a whole. Public nuisance suits are usually brought by state or local agencies to the courts, wherein relief may consist of a moderate fine, specific corrective measures, and/or an injunction.

A private nuisance suit may involve a request for an injunction, for damages, or for both an injunction and damages. If the suit is for an injunction, the court seeks to be fair to both parties. The court weights (a) the plaintiff's allegations that the operation makes living conditions intolerable, is a hazard to health, and/or lowers the value of the land, versus (b) the defendant's assertions that sizeable investments and perhaps jobs for the community would be lost if the injunction were granted. The party found to have the greatest interest will win the lawsuit. To the extent that injunctive relief or monetary damages are granted, the operator is subjected to private regulation of his business.

Questions of degree are crucial: How many people are affected? How bad is the nuisance? Is it temporary or permanent? Can it be corrected? Evidence supplied to answer these questions will have a large bearing on the outcome. The mere threat of a lawsuit under the "nuisance law" may affect conduct of the operation, with regard to materials handling, processing, production, waste management, pollution abatement, etc., in an attempt to avoid litigation. This changed conduct is in itself an informal yet effective form of private regulation of pollution.

SOME RECENT NUISANCE CASES -- EXAMPLES

The case law is informative but not conclusive on the subject of nuisance. As a Massachusetts court said in 1914, "The law of nuisance affords no rigid rule that can be applied to all instances" (Stevens vs. Rockport Granits Co., 216 Mass. 486, 488, 104 N.E. 371, 373 (1914).

This spring, a Nebraska jury awarded a farm family -- themselves cattle producers -- about $50,000 in damages for odor, rodent, and dust related nuisance allegedly created by a nearby 10,000 head feedlot. In March 1979, the Texas Court of Civil Appeals (Summers, 1979) upheld a trial court decision that livestock pens, built 80 years ago to receive, sort, and ship livestock, are producing odors "by processes other than natural." Further, the court stated that concentration of livestock "would not now be normal in this vicinity," since homes and businesses have sprung up around the livestock facility. An El Paso District Court closed down an old feedlot in 1975 that had been engulfed by residential, commercial, and industrial property (Marquez, 1975).

On the other hand, a large new Texas meat packing plant was successfully defended last year against claims of property value reduction brought by an adjacent farmer who "was there first" and who allegedly suffered nuisance from odors and flies (Klinke vs. Iowa Beef Processors, Inc.).

In a famous nuisance case, the Arizona Supreme Court decided in 1972 that Spur Feedlot should be closed but that the opportunistic land developer had to pay the feedlot "for a reasonable amount of the cost of moving or shutting down." Payment to Spur was necessary because the developer had brought homeowners into a previously agricultural area (Chatwin, 1972).

A Kansas court held in 1958 that a residential landowner may not have relief if he knowingly came into a neighborhood reserved for industrial or agricultural endeavors and has been damaged thereby (Dill vs. Excell Packing Co., 183 Kan. 373, 525, 526, 331, P. 2d 539, 548, 549 (1978)). Similarly, would-be land developers tried unsuccessfully to claim damages for reduced property value attributable to odors and flies from two established feedlots in Taylor and Hood Counties, Texas.

With the uncertainty of the outcome and the sure expense of defending against nuisances, cattle producers need to understand certain technical principles and practices involved in abating nuisance conditions.

FEDERAL LAWS AND REGULATIONS ON ODORS

At the Federal level, the U.S. Environmental Protection Agency (USEPA) has no regulations or standards applicable to odors. The USEPA did consider applying standards of odors for new rendering plants (Prokop, 1977). Their studies and analysis, however, established the fact that rendering plant odors are objectionable pollutants to the public welfare, but are not harmful to the public health. Therefore, the USEPA judgement is to leave this area of odor regulation to state and local agencies. The USEPA decision is based on the concept that only those gases that are hazardous or toxic require a separate specific abatement regulation. For according to Summer (1971), ". . .medical opinion views air pollution by smells as nothing worse than a molestation, unless the ingredients are toxic."

ODOR REGULATION IN STATES AND MUNICIPALITIES

In the public sector, odors and dust are usually prosecuted under nuisance provisions of state clean air acts. Fly and rodent problems in many states are handled by separate agencies as a public health nuisance, often regulated by local government. Water pollution problems are seldom handled as nuisance suits, but rather under state and federal water quality laws that prohibit discharge without a permit. State agencies try to work with the producer to help solve his problem, but in the final analysis will bring suit if a severe problem incapable of permanent solution persists.

A recent evaluation of odor control regulations of state and local government in the U.S. was provided by Leonardos (1974), who categorized the regulations of 50 states and 2 local agencies as follows:

a. No specific regulations (16 agencies).

b. Air pollution/nuisance regulations (17 agencies).

c. Specific criteria for determining objectionability of an odor in ambient air (6 states).

d. Scentometer measurements of ambient air odors by control officials (7 agencies). Violations occur if stated dilutions to threshold (D/T) are exceeded, usually within specified time periods.

e. Mandatory adoption of highest and best practicable, reasonable and/or suitable control system at the source (9 states).

f. Source emissions standards specifying odor concentrations (as odor units/ft^3 or odor concentration units) that are not to be exceeded (3 states). These are based on the syringe dilution technique.

g. Regulations based on instrumental analysis at the source or in ambient air ("several" states and agencies; specific as to compounds).

h. Control regulations that serve as statements of policy for handling odor problems (2 states).

i. Both source and ambient standards specified (2 states).

Many of the agencies surveyed by Leonardos (1974) have incorporated more than one of the above listed categories into their regulations.

Leonardos (1974) stated that the existing regulations all stem from 5 technical papers published from the mid-1950s to the 1960s. Apparently, recent technical advances in odor measurement (e.g. dynamic olfactometry) have not found their way into contemporary regulatory use. Thirty-three of the agencies covered in his review rely explicitly or implicitly on the public nuisance concept to handle odor pollution problems.

Odors can be characterized according to their frequency, intensity, duration, and offensiveness (the so-called "FIDO factors"). Nuisance complaints result when these characteristics exceed reasonable limits.

Odor intensity criteria have ranged widely, from 1 to 127 dilutions to threshold (D/T) or odor units (Leonardos (1974). Experience has shown that an odor intensity above seven dilutions to threshold (D/T) will cause nuisance if it persists (Huey et al., 1960). Cattle feedlots rarely get below 7 DT. By comparison, in El Paso County, Texas, the 120th District Court ordered a maximum odor limit of 7 D/T at the property line of a feedlot located alongside residential/commercial neighborhoods (Marquez, 1975). Odor intensity is usually measured using a scentometer (a portable, plexiglass, hand-held device costing about $150) which established different dilution ratios of odorous air to odor free air. The human nose is used to select the highest dilution at which odors can be detected.

Odor quality or offensiveness standards have been adopted by several state and local agencies (Leonardos, 1974). These standards are ordinarily stated in terms of the percent of a given number of people interviewed who find the odor "objectionable," rather than specific laboratory technique to judge offensiveness. In these standards, the number of people polled ranges from 9 to 30, and the allowable percentages range from 15% to 75% who must find the other objectionable.

Two other criteria that have been used in odor regulations are (a) the number of complaining persons, and (b) the location of the plaintiffs relative to the odor source. For example, a Cedar Rapids, Iowa, regulation says there must be only one complaint, whereas Milwaukee County, Wisconsin stipulates more than 3 complaints (Leonardos, 1974). Similarly, an Iowa regulation states that "for a complaint to be actionable, it must be filed. by 3 or more citizens from different households within a 5-mile radius of the odorous substance source. . ." (Iowa Air Quality Commission, 1976).

Another type of specific odor criterion is odor occurrence, i.e. the frequency and duration of odors at a given location. The choice of odor frequency and duration values that divide "reasonable" vs. "unreasonable" situations is clearly arbitrary, regardless of how carefully an agency studies the situation. Regulations adopted by the Iowa Air Quality Commission (1976) indicate that for a complaint to be "actionable," the odor must occur at a frequency of 10 or more days per 30-day period for a duration of 12 or more hours on each of these days. This implies a record-keeping responsibility on the part of the complaining parties.

OTHER APPROACHES TO ODOR NUISANCE REGULATION

Some innovative approaches designed primarily or in part to regulate feedlot odors and dust include:

a. Agricultural zoning by counties (Nebraska)

b. Construction permits for new feedlots (Texas)

c. Construction permits for lagoons (Iowa)

d. Property line odor intensity limits (Colorado)

e. Objectionability criteria (Iowa) -- number of people affected, frequency, duration, etc.

In 1978, the North Carolina legislature passed a law (HB 481) that states: "No agricultural operation or any of its appurtenances shall be or become a nuisance, private or public, by any changed conditions in or about the locality thereof after the same has been in operation for more than one year, when such operation was not a nuisance at the time the operation began; provided, that the provisions of this subsection shall not apply whenever a nuisance results from the negligent or improper operation of any such agricultural operation or its appurtenances." In another important section, this law invalidates "any and all ordinances of any unit of local government now in effect or hereafter adopted that would make the operation of any such agricultural operation or its appurtenances a nuisance in the circumstances set forth. . ."

The Alabama legislature previously had enacted a similar bill to protect against encroachment of nonagricultural land uses.

RESOLUTION OF ODOR PROBLEMS: TECHNICAL APPROACHES

Odor control methods are imperfect to say the least. But livestock and poultry producers can and should strive to minimize odor frequency, intensity, duration, and offensiveness. Some odor control methods are specified in ASAE Engineering Practices EP 379 (see Appendix).

Separation of the odor source (feedlot) from the receptor (neighbors) is the best method of odor control. Odor concentrations diminish rapidly with distance downwind of an odor source. Odors from a ground-level source are calculated to undergo 99 percent reduction in odor concentration over a distance of one to two miles, depending on atmospheric stability class. But, experience has shown that odors can drift for several miles at low yet detectable intensities. So distance alone is not the answer.

Prevailing winds can be determined fronm hourly observations recorded at major U.S. Weather Service installations. For example, the wind direction frequency data for Amarillo shows that there is only an 11 percent chance of wind out of the quadrant Northeast to East-Southeast. But, the wind blows 48 percent of the time out of the South-Southwest quadrant. In this instance, feedlot location could make a lot of difference to both neighbors and juries.

The second basic approach to odor control is to keep manure dry as much of the time as possible. Odorous compound formation is generally the product of bacterial decomposition of manure. Offensive odors are released when manure is allowed to undergo anaerobic (or septic) decomposition. This occurs when oxygen is excluded. By maintaining a manure-covered surface in a relatively dry condition (less than 40 percent moisture) anaerobic decomposition at the feedlot surface is halted.

Intense, offensive odors are most prevalent when pens are drying out after rainfall, when water stands on the feedlot surface, or when runoff holding ponds contain relatively fresh solids.

A strategy to lessen the intensity and duration of feedlot odors after rainfall consists of these steps:

1. Maintaining rapid pen drainage -- pen slopes should be 2-3 percent ideally with no potholes.

2. Keeping manure solids out of runoff holding ponds -- runoff collection ditches should empty into an easily-maintained settling basin or channel (0.1-0.3 percent slope) to capture settleable solids before liquids are drained to holding ponds.

3. Water trough maintenance to prevent overflows and leaks.

4. Maintaining dust control systems to prevent leaks, nozzle stoppage, and low pressure that cause wet spots around sprinkler nozzles.

The third basic approach is to keep a minimum quantity of manure and wastewater on hand. This involves:

1. Rapid dewatering of runoff holding ponds.

2. Prompt removal of settled solids from debris basins and channels.

3. Frequent collection of loose surface manure which soaks up rainfall and delays recovery from rainfall.

4. Maintain an undisturbed manure pack two to three inches thick just above the soil surface to seal off infiltration and to maximize surface runoff.

5. Maintain markets for manure to limit the manure inventory and limit the size of the working face of stockpiles.

6. Haul manure to fields immediately after stacking in pens.

Manure spread on cropland produces temporary odors until drying occurs. Ways to avoid odor complaints from land application include:

1. Select a field downwind of neighboring residences.

2. Spread manure in the morning to allow maximum drying time.

3. Spread manure when the wind speed exceeds 9 mph for maximum dispersion and do not spread when wind is less than 5 mph.

4. Flow under surface-spread manure to control odors and conserve nitrogen.

Confinement livestock feeding facilities with liquid manure management systems have different types of odor control problems, but control technologies are available nonetheless. Special manure handling methods must be used to keep animals clean and dry and prevent anaerobic conditions. Successful practices to minimize odor in the buildings include daily scraping, hydraulic flushing, use of absorbant bedding material or litter. Covered manure storage tanks control the release of odorous gases generated by anaerobic decomposition of stored manure. Where the soil is suitable and neighbors are close, direct sol injection is a valuable technique for liquid manure disposal. Aerobic systems, such as mechanically aerated lagoons, can be effectively used to maintain low odor intensities where treatment is required and odor control is important. Anaerobic lagoon systems, where permissible to install, need to be designed with adequate capacity and managed carefully to avoid overloading which is accompanied by fly and odor problems.

Some additional practices worthy of consideration include (1) landscaping to enhance appearances and to shield feeding and waste management facilities from the public view; and (2) spot treatment of wet areas on feedlot surfaces with oxidizing chemicals such as potassium permanganate or hydrogen peroxide, odor absorption chemicals such as zeolite, or bacterial/enzymatic products (digestive deodorants). Odor control chemicals are

widely available. From limited data, their effectiveness has appeared promising in some instances and disappointing in others (Miner and Stroh Day, et al., 1979).

THE FUTURE

Many unresolved problems regarding nuisance will be carried forward into the 1980's. Agricultural engineers have an enormous stake in deciding issues such as establishment of agricultural zoning or enactment of odor intensity standards. Broad protections against nuisance suits afforded by new laws in Alabama and North Carolina look appealing.

Unhappily, one thing is certain -- legal developments are far more likely to occur than technical breakthroughs at the present pitifully low levels of research funding on odors. Basic research is needed to unlock secrets of how odors are generated and how they can be affordably controlled. Applied research to evaluate these discoveries in the field could swiftly follow. Reliable information on odor transport and safe separation distance could be rapidly gotten and is sorely needed. Understanding the complexities of molecular interactions that transform odors will take more time.

Lately, leading odor researchers have agreed that complex odors such as manure vapors can best be measured by human perception. Several useful devices are available now to achieve this. Debates over exactly which instrument and set of procedures to choose may run into the 1990's. It would seem ill-advised for agricultural engineers to wait for universal acceptance of odor measurement technology, or for EPA to dictate the methodology, technology, and perhaps even standards, before proceeding with odor research. The task ahead seems clear and pressing. Unfortunately, funding for basic and applied research to lead the way does not appear eminent.

LAND APPLICATION OF SLUDGE AND SEPTAGE

Currently (1978), about 4.3 million tons of sludge as measured on a dry basis is generated by some 18,500 publicly-owned wastewater treatment plants across the country each year. Origin of the wastewater producing this sludge is approximately 75 percent from residential and 25 percent from industrial sources. Through implementation of required secondary

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treatment, the volume of sludge produced will probably increase by 25 percent by 1990. Additionally, about .7 million dry tons of septage is produced by on-site facilities annually. This is projected to increase to nearly 1.0 million dry tons by 1990.

While not universally true, most septage and sludge generated from residential wastewater does not contain concentrations substances harmful to soils or crops. Sludge generated from wastewater which includes industrial waste is likely to contain harmful concentrations of toxic substances. A majority of the 18,500 publicly-owned treatment plants serve primarily residential areas. However, well over half of the sludge produced comes from treatment plants serving more densely populated, industrial areas. It is estimated that as much as 70 percent of the heavy metals reaching wastewater treatment plants comes from the 50,000 to 55,000 individual industries believed to be dischargers of greatest concern.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, and the Clean Water Act of 1977, Public Law 95-217, require EPA to encourage recycling of sewage treatment plant effluent and sludge through land application.

The Resource Conservation and Recovery Act of 1976, Public Law 94-580, requires EPA to define hazardous wastes and establish a permit program for its management. Sludge with potentially harmful concentrations of toxic substances may be considered a hazardous waste. EPA must also publish regulations and guidelines for solid waste management including all other sludge.

Current sludge landfilling practices are generally questionable and may be contributing to degradation of ground and surface waters with heavy metals, toxic organic materials, pathogens, and nitrates. Control technology indicates that in many cases such landfill sites should be lined, the leachate collected and treated, and monitoring systems installed.

Current landfilling costs of $20 to $30 per dry ton for small communities will probably double when appropriate control practices are installed. Costs for larger cities are somewhat higher.

The land application option can offer an opportunity for beneficial use of sludges with low levels of heavy metals, pathogens, and toxic organic materials. Use of such sludges can be made with minimal risk through sludge stabilization, site and crop selection and management, proper pH, and controlled application rates and volumes. Data on the interrelationship of soils, crops, and sludge characteristics is limited as is precise information on risks involved. This limited knowledge has resulted in a lack of agreement on potential environmental and public health hazards which contribute to a general reluctance of the public to accept land application of sludge.

Current land application costs range from $42 to $58 per dry ton of sludge for small communities. For larger cities these costs may be double because of remoteness of acceptable sites.

Communities are just beginning to have their sludge analyzed for beneficial nutrients and hazardous materials. Some estimates indicate that possibly one-half of the sludge currently generated is acceptable for beneficial use through proper management. It is hoped that analysis of sludge will lead to identification of those sources which are contributing excess levels of heavy metals and toxic organics, and that those sources can pretreat their wastes to reduce levels to a point where sludge from many more communities will be acceptable.

Sludge with low levels of hazardous materials can be used to add organic matter and improve soil structure, increase available moisture, and provide major and minor nutrients for crop growth. It appears that federal and state programs will encourage use of such sludge in production of food and forage. To that end the opportunity exists for beneficial use of acceptable sludges by individual farmers and ranchers. Sufficient controls will be imposed to insure environmentally sound management of land application sites.

Sludge with higher levels of hazardous materials will require more positive site control by responsible public entities. Opportunities exist for use of such sludge in non-food chain crop production, land reclamation, and on turf grass, parks, etc. In some cases, dedication of disposal sites to preclude future use for purposes other than disposal will be required. This may often involve ownership of the site by a responsible public entity.

Disposal of urban and industrial wastes on agricultural lands can be done in an envronmentally sound fashion that can benefit crop production. Additional studies related to soil, hydrologic, and biologic phenomena associated with such practices are needed.

AGRICULTURAL CHEMICALS

A wide variety of agricultural chemicals are a vital part of agricultural production. These materials range from fertilizers and soil amendments, to pesticides for animal and crop protection, as well as materials used to enhance crop harvesting and processing. The successful use of these chemicals involves considerable planning and technology to assure that they are applied in the proper amounts, the proper place, at the proper time in the proper manner, under suitable environmental conditions and with due consideration for the environment. Failure to properly carry out any one of these aspects will likely not only result in reduced production and lessened environmental protection but would also represent a direct economic loss in terms of energy and time expended.

The continued development of sophisticated and reliable technologies surrounding the uses of these materials is essential. Also, as agricultural chemicals are closely related to decreasing energy supplies and rising energy costs, development of more efficient and effective delivery systems must be continued and be consistent with the needs of the the user and the environment. The industry must be alert to new trends so that adequate lead time is provided to allow the development of new delivery systems.

For example, new energy efficient tillage systems may require new methods and machines for proper fertilizer and pesticide application and placement. The increasing use of higher analysis, more concentrated fertilizer and pesticide products (to save shipping costs and trips over the fields) requires a new generation of precision metering and application equipment to accurately meter and distribute the lower rates. The use of granular formulations for some pesticides rather than liquid sprays has already created a need for adequate equipment to meter and place them. The techniques of pesticide micro-encapsulation and controlled-release require the development of new methods and machines and delivery systems to properly deliver and utilize them.

A new technology area involving the planting of germinated seeds to speed emergence and expedite harvesting is also requiring a new generation of precision planting equipment capable of handling germinated seed and gel mixtures and planting the germinated seed precisely spaced along a row. Likewise new concepts involving the application of chemicals to drying forage products for binding and retaining leaves to speed drying and to prevent forage quality loss requires new equipment development.

The search for more efficient and reliable systems seems unending. There is, however, a continuous need for efficient production tools. Because of the evolutionary nature of development that must also keep pace with evolving production practices, the process must be a continuous one where the needs and goals are reviewed and revised.

The lack of an adequate support industry for development of low market demand equipment for chemical applications has additionally hampered equipment development. Reliance has been and will likely continue to be on state and federal research agencies to provide concepts and prototype hardware for the industry.

Developments have frequently been hindered by regulations and there are numerous examples. If there is no equipment available to apply a new product, there is no need for developing the product; and there is no need to undertake development of a new piece of equipment when there is no product to apply. Many industries are hesitant to invest resources in developing products and equipment for a limited market. Here the end user (the farmer, generally) is left to his own devices and frequently lacks the knowledge, skill, technology, capital, and/or time to develop adequate equipment for his needs. This approach generally results in reduced environmental protection and economic benefits.

ECONOMIC BENEFITS

The agricultural aviation industry is an example of where a very small support industry exists to develop and refine application equipment. The aircraft industry has accepted only the responsibility for developing agricultural aircraft (mostly from parts of other commercial

aircraft) and have put little development effort in the dispersal equipment used with their aircraft. Thus it has been the end user (the commercial applicators) using mostly trial and error procedures to develop systems that under many operational situations are not adequate for the task. The failure of aircraft delivery systems under many conditions to apply agricultural chemicals, with acceptable uniformity and precision and to keep the material within an intended treatment area is a result of not considering the aircraft and the delivery equipment as one entire system. Thus desperately needed for this entire industry is a systematic approach to develop more effective, efficient, and reliable equipment that is consistent with both the needs of production agriculture and environmental protection.

The equipment used today in production agriculture to distribute agricultural chemicals is essentially the same equipment that has been in use for 20 to 30 years with refinements in terms mostly of improved materials of construction. Rather than developing new types of equipment, the main activity has been in refining existing equipment and this has lead us to a point where not much else can be done with these systems. Furthermore, the equipment has generally not quite kept up with the technology. For example, rate dispensing equipment originally designed to deliver material at rates from 200 to 400 lbs. per acre cannot easily and accurately be adjusted to deliver more concentrated materials at rates of 10 to 20 lbs. per acre.[2] In recent years there has been a nationwide decrease in the engineering SMY devoted to these tasks. Thus many new concepts and techniques have not been seriously and thoroughly examined to date that would feature designs to allow precision application with improved reliability and safety.

The American Society of Agricultural Engineers has sought to identify environmentally safe procedures for the application of agricultural chemicals. The Society's Standards Committee has developed and issues several standards related to aerial and land application of chemicals.

The tasks which lie ahead in the area of agricultural chemical concerning the identification approaches that enable the maintenance of a high level of production without adverse effects on the environment.

Among these are (1) the fostering and enhancement of improved support industries for agricultural chemical application, (2) encouraging improved communication between the different segments of the industry viz, the chemical manufacturers, the shipping container manufacturers, the application equipment manufacturers and the public research and extension agencies, so that problems, such as safe handling and transfer of pesticides, can be attacked from an entire system standpoint, rather than piece-meal, (3) stimulation and expansion of the basic research efforts to formulate and develop new ideas and concepts for both ground and aircraft application equipment and techniques. Increased activity is needed in the areas of safety in handling and transfer of pesticides and in used container disposal, in the development of electrostatics and other new application concepts, in the development of integrated dispersal systems for aircraft, in the development of low-rate metering systems for liquid and dry chemical application, among others, (4) development and implementation of education systems and programs to inform with the chemical user and the general public of the relative importance of effective chemical use and the economic and environmental penalties associated with misuse. As increasing urbanization occurs and these groups are brought into closer contact, this activity becomes increasingly important. Thus, wide ranging educational programs are a vital link in successful implementation of this technology.

SECTION 4
ENERGY AND THE ENVIRONMENT

There are many questions surrounding the effects energy utilization and production have on the quality of the rural environment. Impacts can arise not only from agricultural operations but from other, non-agricultural sources. The solution of energy-related environmental problems is complex with subtle factors determining the interrelationships between environmental quality and energy. There are several situations which illustrate the complexity of the problem. These situations concern the energy intensiveness of agricultural production, biomass energy, and conventional energy development, and utilization.

ENERGY INTENSIVENESS

The energy intensiveness of agricultural production is frequently a cause of pollution. Conventional cultivation, fertilization, and pesticide application not only require a large energy input but increase erosion and add unwanted chemicals to the environment. A major conclusion of the ASAE Public Policy Issues Study on energy states: "The impressive yields of modern agriculture have been made possible largely by substituting from oil and natural gas for human and animal energy expenditures."

Conventional gas production is tillage intensive. It includes the practices of plowing, disking, harrowing, and cultivating. No-till systems provide essential seedbed preparation with a no-till planter and weed control with herbicides. Between the no-till and conventional tillge systems are numerous systems that eliminate or reduce tillage in comparison to conventional practice. These are commonly referred to as reduced or minimum tillage systems (FIEI, 1978).

In some sectors, reduced tillage is termed conservation tillage since, by leaving more standing plant cover and creating less surface disturbance, sol losses from water and wind erosion will be significantly reduced compared to conventional tillage approaches. Various forms of reduced tillage are becoming more popular. The USDA has estimated that, while 10% of the total cropland was farmed with reduced tillage methods in 1974, this could grow to about 82% by the year 2000. If true, this will

come about as farmers become more familiar with reduced tillage farming methods and can manage their operations to maintain yields. The erosion reducing aspect of reduced tillage will most likley aid in its acceptance level (FIEI, 1979). Tillage is performed primarily to control pests, the most important of which are weeds.

Reduced tillage increases the need for pesticide use. When the total energy use for a cropping cycle is considered, including the energy needed to produce the pesticides, no-till showed only a very modest savings (3%) over conventional tillage in studies made in Nebraska. Other studies have shown energy savings from 2.5 to 6.7 gal/A (diesel fuel equivalent) from no-till.

Minimum tillage systems are highly crop-, and/or geographical-area-specific. No one system is a universal answer, and yield reductions may result from their use in some situations.

A complementary situation can therefore exist between energy conservation (e.g., reduced tillage) and environmental protection during agricultural production. By utilizing this energy conservation approach in agricultural tillage operations, it is possible to simultaneously save energy and retard soil pollution of water and air resources. By retaining the soil, one has also retained the soil nutrients, in particular, nitrogen and phosphorus. Retention of these nutrients means that they need not be replaced by additional fertilization. Thus, more energy can be conserved and fewer unwanted chemicals are put into the environment.

BIOMASS ENERGY

In addition to the traditional demands for food and fiber production, the agricultural sector is expected to supply, via biomass energy, a significant share of the future energy supplies.

Table 11 summarizes the amount of energy which various recent models have forecast as being potentially available from biomass.

The general consensus of these projections is that it should be quite reasonable to expect biomass sources to displace 2-4 quads of conventional fuels by the year 2000. The recently released Solar Domestic Policy Review projects that 5.5 quads of energy could be displaced by the use of biomass by the year 2000 (U.S. DOE, 1978).

Table 11. Projected Impact on Biomass Technologies by the Year 2000 (Quads)

	Basis for Projection								
Model Designation	Mitre SPURR NEP	Mitre SPURR RTS	SRI	SRI Sol. Emph.	SRI Low Dem.	SWG w/B.L.	SWG wo/B.L.	MOPPS	IEAPS
Biomass	.4	.1	1.0	5.0	1.0	2.1	2.4	1.66	1.18

	Basis for Projection						
Model Designation	NSF/ NASA	CONAES High Sol.	CONAES Low Sol.	Proj. Ind. BAU.	Proj. Ind. Acc. Sol.	ERDA 49	CEQ (Mid Point)
Biomass	5.12	3.5	.1	.7	15	3.0	4.0

SOURCE: Dunwoody and Atkins, 1978.

However, the production and utilization of biomass energy will place additional stress on the agricultural environment and necessitates a greater involvement by agricultural engineers to minimize any adverse consequences.

Utilization of agricultural, food processing, and forestry wastes as fuel sources can simultaneously provide energy and enhance environmental quality. Whole plant harvesting and extensive crop residue removal, however, will have to provide the bulk of the anticipated 2-4 quads per year of biomass energy. These harvesting practices can accelerate soil erosion and nutrient depletion, and mitigative measures need to be developed to maintain the productivity of the land.

Questions also arise concerning the environmental impacts associated with the conversion of various biofuels. For example, what would be the air quality impacts of large-scale gasohol use? This novel fuel is a blend of gasoline and ethanol fermented from various biomass sources (e.g., corn, molasses, etc.). Are more hydrocarbons produced during combustion of gasohol in an automobile's engine? Are hydrocarbon losses into the atmosphere during storage and transfer greater for gasohol than for gasoline? These are some of the end-use environment questions which could arise from biofuel use.

Another set of environmental concerns may develop for the fermentation industry that would be needed to produce the ethanol for gasohol. Waste management for this industry will be an important environmental issue. Stillage disposal, water quality, and odors are some of the problems which may plague the gasohol fermentation industry.

However, the most important questions for biomass energy may be socioeconomic. A principal objective of agricultural engineering is the production of food. For years, the U.S. has supplied food not only to its own citizens but to those of many other countries throughout the world. The demand placed on U.S. agriculture in 1974, for example, was to provide food for many drought-stricken areas of the world. The question at that time was centered more on food production than biomass energy production. Grain prices soared. Today the situation is different: grain prices are low and farmers are seeking new markets. At the existing price for corn, gasohol is a marginal venture. If an energy-oriented fermentation industry is developed, can it survive a period of high grain prices? Can the use of

U.S. corn and wheat for fuel production be justified if there is a world food shortage? What lands or regions are to be used for biomass energy production and which shall produce food? What will be the effect of extensive grain utilizastion for gasohol on the price of cattle, hogs, and dairy products? If the U.S. becomes dependent upon gasohol or other biomass energy sources as fuels, what would be the impact of a major city failure? These questions and others may pose the most series issues concerning biomass energy.

Current investigations by the U.S. Department of Energy on the environmental consequences of biomass energy production, conversion, and utilization focus on eleven major environmental issues:

Land and resource requirements for terrestrial biomass production.

Air and water quality effects from agricultural and silvicultural operations.

Depletion of soil organic content due to residue removal.

Impacts from combustion of biomass.

Gaseous, liquid, and solid residuals from thermochemical biomass conversion.

Disposal of sludge from anerobic digestion.

Competition of terrestrial biomass production with other uses of resources.

Ecological and climatological effects of ocean kelp farms.

Transportation of biomass and derived fuels.

Machinery noise from harvesting equipment.

Health of energy plantation workers.

These issues are to be assessed with regard to their impacts on eight areas: air quality, water quality, land use/solid waste, ecology, health and safety, esthetics, social/institutional, and resources.

Biomass energy is a renewable energy resource. Maintenance of environmental quality is necessary to ensure the productive capabilities of our lands, so that development of this renewable energy resource may meet current expectations.

ENERGY RESOURCE DEVELOPMENT

Perhaps the most significant impact of energy production on the agricultural environment comes from coal mining operations. Surface coal mining can destroy the productive capacity of the land. Public law 95-87, The Surface Mining Control and Reclamation Act of 1977, provides for the regulation of surface coal mining operations. Prime farmlands of the nation receive special protection under this law. Mine operators now must demonstrate their technological capability to restore mined prime farmlands, within a reasonable period of time, to equivalent or *higher* levels of yield as non-mined prime farmland in the surrounding area under equivalent levels of management. Regulations such as this can permit energy development to occur in an environmentally sound fashion on agricultural lands. It is still questionable, however, whether the land's productivity can be fully restored after mining and additional research is required to identify approaches, for removing, storing, and replacing the soil, which would result in equivalent or higher post-mining productivity.

It has been estimated that over 17% of the strippable coal reserve base of the United States lies under prime farmland (Harper, 1979). Table 12 gives estimates of the acreage of prime farmland and prime croplands (i.e. those prime farmlands on which row crop production occurs) in major strippable coal containing counties of U.S. and the underlying strippable reserves. From Figure 11 the immense amount of strippable coal under the prime farmland areas of the Midwest and Northern Great Plains is graphically depicted.

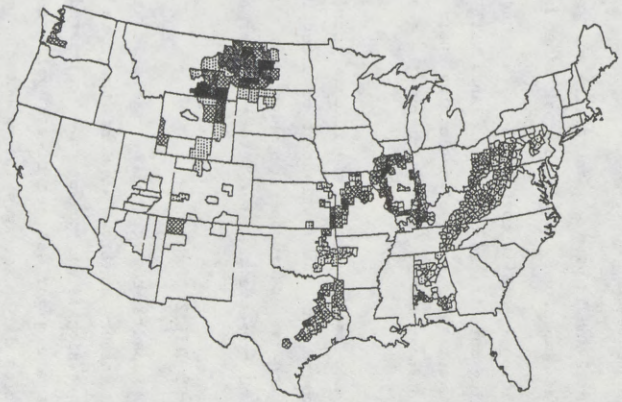
The need to develop our fossil energy resources is great, yet, our most valuable asset is our prime farmland. Proportionally more crops are grown on prime land than on other land classes. It is imperative that the productive agricultural base of the U.S. be irreversibly diminished by energy development.

Table 12.STATE ESTIMATES OF THE AREA AND THE STRIPPABLE RESERVES OF COAL COUNTIES, PRIME FARMLANDS AND PRIME CROPLANDS

State	Coal County		Prime Farmlands			Prime Croplands		
	Estimated Area (Acres)	Estimated Strippable Reserves (10^6 Tons)	Estimated Area (Acres)	Estimated Strippable Reserves (10^6 Tons)	Strippable % Reserve Impact	Estimated Area (Acres)	Estimated Strippable Reserves (10^6 Tons)	Strippable % Reserve Impact
Alabama	13,673,068	1,183.74	2,648,406	243.56	20.6%	942,837	96.91	8.2%
Arizona	25,371,524	350.00	42,896	.88	.3%	24,506	.61	.2%
Arkansas	3,082,273	231.30	426,072	34.41	14.9%	117,630	7.89	3.4%
Colorado	13,761,927	870.00	217,924	3.58	.4%	131,461	2.57	.3%
Illinois	16,384,152	12,222.86	9,526,130	6,518.33	53.3%	7,847,053	5,266.86	43.1%
Indiana	4,850,070	1,674.08	2,231,355	773.62	46.2%	1,688,177	559.53	33.4%
Kansas	4,494,942	1,388.06	1,580,925	599.03	43.2%	1,117,452	405.51	29.2%
Kentucky	12,356,321	7,354.08	2,353,124	1,629.09	22.2%	1,480,625	1,028.82	14.0%
Maryland	696,319	146.30	84,311	18.08	12.4%	37,604	8.73	6.0%
Missouri	11,848,587	3,413.66	3,988,627	1,218.75	35.7%	2,720,703	768.78	22.5%
Montana	24,549,253	42,561.93	2,850,902	3,741.37	8.8%	1,616,852	1,667.37	3.9%
New Mexico	9,431,040	2,258.32	89,555	36.26	1.6%	39,688	10.04	.4%
North Dakota	21,060,749	16,003.00	8,094,687	5,405.00	33.8%	6,143,401	3,975.13	24.8%
Ohio	8,327,593	3,653.89	1,477,112	461.71	12.6%	1,048,239	327.48	9.0%
Oklahoma	8,012,885	434.11	791,295	50.26	11.6%	471,697	20.82	4.8%
Pennsylvania	18,412,000	1,181.38	3,109,790	231.39	19.6%	1,342,559	103.80	8.8%
South Dakota	7,900,224	428.00	629,847	24.38	5.7%	339,276	11.59	2.7%
Tennessee	5,338,800	319.59	644,862	45.59	14.3%	301,770	12.09	3.8%
Texas	19,023,732	3,271.90	5,174,549	883.58	27.0%	1,210,568	251.69	7.7%
Utah	11,588,820	262.00	109,913	1.07	.4%	82,779	0.94	.4%
Virginia	1,724,880	679.24	43,971	10.47	1.5%	27,754	6.48	.9%
Washington	2,022,180	500.00	108,210	26.60	5.3%	43,379	10.70	2.1%
West Virginia	11,734,880	5,212.02	583,697	170.86	3.3%	303,916	76.52	1.5%
Wyoming	27,127,960	23,845.30	305.885	258.79	1.1%	240,191	134.53	.6%
Total	282,774,099	129,444.76	47,123,453	22,383.48	17.3%	29,319,353	14,755.14	11.4%

Estimated Strippable Coal Reserve Base under Prime Farmland, for selected counties in the U. S. Millions of Tons of Coal.

Figure 11



Another important part of the federal surface mining law is Title IV, which creates a fund to reclaim lands previously affected by past coal mining. A 1977 U.S. Soil Conservation Service inventory indicated that over 1 million acres of abandoned coal mined lands exist in the United States. Such abandoned lands chemically contaminate water resources and increase sediment load of local streams and lakes. Successful reclamation of these abandoned lands will not only correct these environmental problems but aesthetically enhance the landscape.

Figures 12 and 13 give a quantitative and graphic illustration, respectively, of the amount of abandoned coal mine lands throughout the U.S.

An additional benefit to farmers is that under Public Law 95-87 farmers currently owning unreclaimed coal mined lands will be able to share with the federal government the expense of reclaiming their lands. The recent SCS Rural Abandoned Mine Program will greatly improve the quality of privately held coal mined lands.

These new programs will significantly improve the quality of the rural environment, and the development of effective reclamation strategies will improve and prevent further degradation of land resources from energy development and preserve them for future food or biomass energy production.

OFF-FARM ENERGY UTILIZATION

Major impacts to agriculture arise from energy conversion and production in other sectors. One of the more serious problems related to energy conversion is air pollution. Coal-fired power plants and automobile exhaust are major sources of air pollution in rural areas. Acid rainfall affects large acreages throughout the country and can result in significant declines in productivity. Ozone, sulfur dioxide, and other combustion pollutants can adversely affect the development, physiology, yield, and chemical composition of plant tissues and harvested seed. The effects of these air pollutants are often poorly understood, particularly the effects of chronic low-level exposure of vegetation to such pollutants. Recently, much attention has been focused on the effects of acid rain on the quality of the streams and lakes. The low pH of acid rain which recharges these aquifers is seriously affecting their quality. Since expanded coal utilization is planned to satisfy future energy demand, the downstream impacts of coal conversion residuals may further degrade the agricultural environment.

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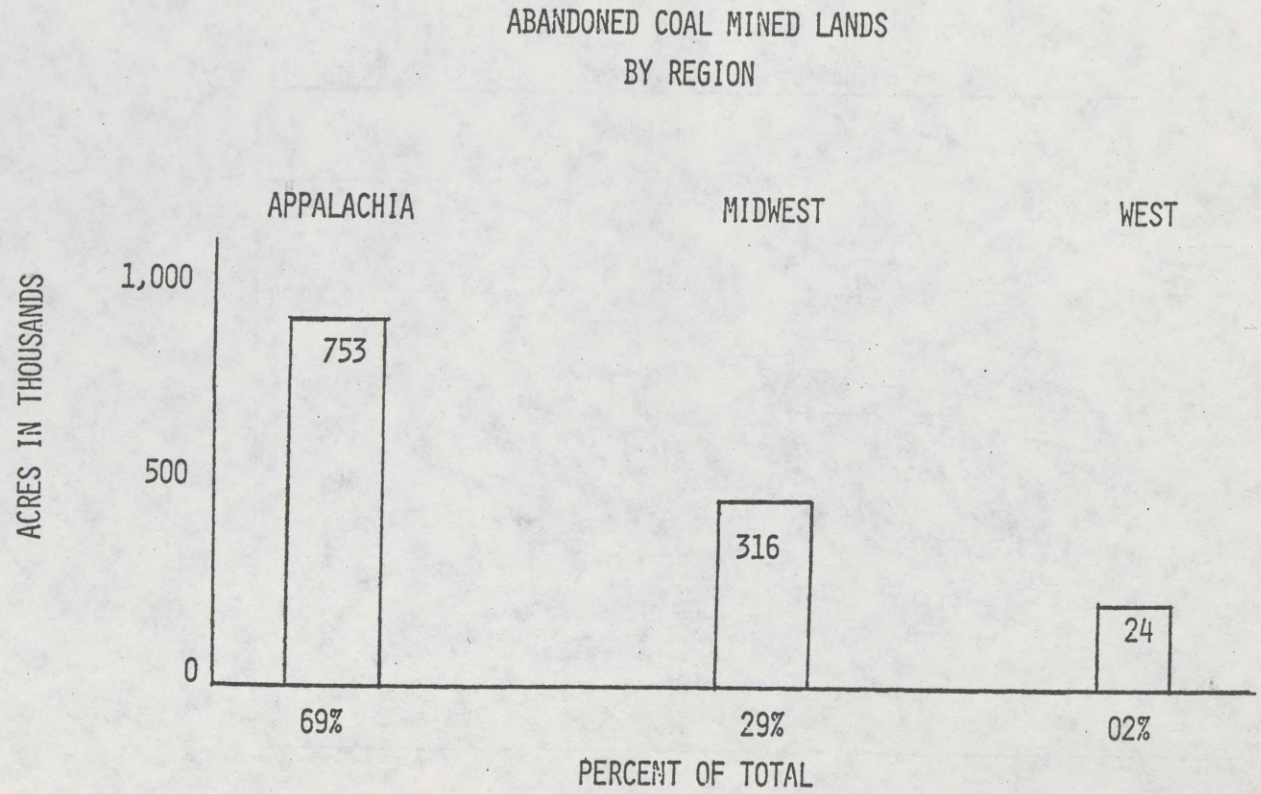

FIGURE 12. EXTENT OF ABANDONED COAL MINE LANDS BY REGION.

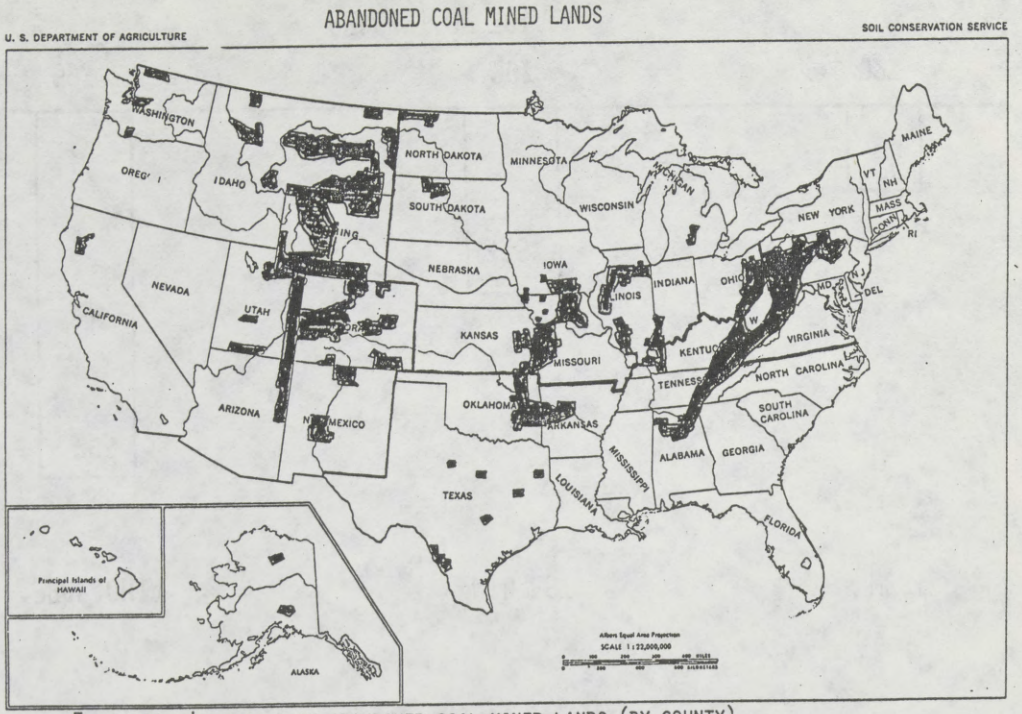

FIGURE 13. LOCATIONS OF ABANDONED COAL MINED LANDS (BY COUNTY)

Waste disposal of energy conversion by-products such as ash and scrubber residue place an additional environmental stress on land resources. Currently, researchers are focusing on ways to utilize these wastes as fertilizers or soil amendments. Special environmental control technologies for the removal of air pollutants from stack gases have been developed which yield a scrubber residue that has potential as a fertilizer. Questions still exist on the environmental consequences of using such by-products for food and feed production. The trace elements and heavy metals released by the burning coal are significant, and extensive uptake of these chemicals in the scrubber residue by the vegetation may occur. Thus, waste utilization approaches for these residuals, like fertilization with scrubber residue, are still in the development stages but could provide an environmentally sound outlet for disposal of such wastes and effect energy savings in agriculture by replacing certain fertilizers.

Reduced tillage, biomass energy production, acid rainfall, coal mined land reclamation -- many energy-related environmental problems are affecting agriculture and, as steadily rising petroleum prices indicate, energy demand is increasing. The impacts that energy utilization and production have on the agricultural environment will be of increasing concern. The central need is to preserve land capabilities for future food, fiber, and now, energy production, which requires that the quality of the rural environment be maintained.

SECTION 5
TRADE-OFFS OR SOLUTIONS

The underlying dilemma surrounding environmental questions in agriculture is whether a trade-off should be made or a solution should be implemented.

Trade-offs typically sacrifice environmental quality or exclude certain uses or practices. Often trade-offs are less than satisfactory. Neither environmental objectives or other needs are fully realized. Yet, in the absence of a definite technological solution of an economically realizable one, this is the only avenue for resolution.

The development of technological solutions to environmental problems can preserve environmental quality of our land and water resources, and permit their full utilization. This is the most satisfactory route but is the most difficult to achieve in an economic manner.

Agricultural engineers have approached the resolution of environmental problems on both fronts. Members have and will continue to provide their experience and knowledge to public and private groups seeking resolution of environmental trade-offs and will continue to develop economically and technologically feasible solutions to environmental problems. In this report some key environmental issues in agriculture which our membership are addressing have been identified. As yet, we cannot state what the perfect solutions are but it is possible to have workable alternatives and as a professional engineering society we feel it is our responsibility to assist in the resolution of these environmental problems.

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APPENDIX III

The Economic Milieu of Pest Control: Have Past Priorities Changed*

J. C. Headley**

Introduction

Secretary of Agriculture, Charles Brannan, in a foreward to the Yearbook of Agriculture in 1952 made the following statement:

> "We dare not think of any knowledge-least of all knowledge of living things-as static, fixed or finished."

He made this statement in the foreward of a book on insects after noting that even though the science of entomology had made great progress in the two decades prior to 1952, that the problems caused by insects seemed to be even bigger than ever.

Some 26 years later, these observations still carry meaning for people knowledgeable about the problems of pest control in agriculture. The combination of a constant pressure by pests on agricultural production, concerns for producing enough food and the concern for the effects of chemical pest control agents on humans and the environment constitute ample evidence to conclude that pest control problems are far from being solved once and for all. During those 26 years, however, many things have changed which suggest that new approaches to pest

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control problems may be needed. The technology applied to agriculture has changed, the pattern of farm ownership and operation has changed, consumer tastes have changed and the domestic and international economic climates have changed dramatically since the close of the Korean War.

It is the purpose of this paper to provide a detailed description of the changes in the economic milieu which surrounds agriculture and pest control technology. This description will provide a basis for (1) explaining the development of agricultural pest control and (2) providing insight into actions that are needed to improve pest control to meet social objectives.

Changes in American Agriculture

The observations of Secretary Brannan mentioned above, indicated that agriculture was a fast changing activity with significant pest control problems which seemed to be growing. A brief perusal of some data on U.S. agriculture indicate that these observations were accurate. Due to various forces, both inside and outside agriculture, the nature and scope of farming has changed significantly since 1952.

Table 1 displays selected characteristics of U.S. agriculture with comparisons between 1952 and about 1975. First, the number of people living on farms has declined by about 60% to a point where only one person in 25 now is classed as farm population. Farm numbers have been cut in half since 1952 and farm size has doubled.

While the cropland harvested has declined by about 20%, irrigated land has increased by about 40% representing a

significant increase in the input intensity on the land which is irrigated. Acreages of three important crops, corn, cotton and soybeans provide an interesting comparison over the 1952-1975 period. Cotton acreage declined by about 53% due to economic pressures from demand. As a result, many areas in the so-called "cotton south" reduced acreages by extremely large amounts. States such as Virginia and North Carolina grow almost no cotton now. Corn acreage has changed very little since 1952, while soybean acreage has increased by a factor of 3.7. The increase in soybean production has been in response to a strong domestic and international demand for oil and protein. Soybeans displaced cotton in the south and probably hay in the north central U.S. as livestock technology came to rely less on pasture and roughage and more on concentrates. In addition, the development of herbicides made weed control much more effective resulting in increased yields.

Farmers use of chemical technology has changed as well. In 1952 about half of the cotton acreage was chemically treated for insects. In 1971, 61% of the cotton acreage was treated with chemical insecticides of one kind or another. In 1952, 12% of small grain acreage was sprayed with herbicides for weed control, while in 1971, 37% of the small grain acreage was so treated. Finally, the use of nitrogen fertilizer, which has been important in increasing yields, has increased by more than a factor of 5.

These data demonstrate that, indeed the agriculture of the present is very different from the industry that existed during

the Korean War. Farmers spend over 1 billion dollars for pesticides in 1971, more than twice what they spent in 1966. Presently more than 1 billion pounds of active chemical ingredients are used by farmers, about twice the amount used in 1964. Chemical technology has been rapidly applied to agriculture during the last 20 years, especially in the control of insects, weeds and plant and animal diseases.

The Economic Context

Producing agriculture is an industry made up of 2.8 million individual firms. Most of the labor used by those firms is supplied by the owners of the firms or by persons within their family. It is an industry of price takers in the market. That is, it is not organized so that the industry can administer the prices which they receive for their products, neither can the firms in any way control the prices paid for inputs. It is an industry of what economists call atomistic competition.

In this setting of atomistic competition, one finds also a series of national policies that have had effects on the business of farming. First, since the close of the Great Depression it has been a national goal to facilitate economic growth and development by applying technology to agriculture in an effort to reduce the resources devoted to agriculture, especially labor. The consequence has been the reduction in farm population and the number of farms shown in Table 1. Capital has been substituted for labor in a dramatic way in farming. Second, it has been a policy and a matter of national pride to reduce the amount of consumers' incomes spent for food, thereby releasing more income

Table 1. Selected Characteristics of U.S. Agriculture 1952 and 1975.

Characteristic	Units	1952	1975
Farm population	10^6 persons	24.2	8.8
Farm population as percent of total population	%	15.5	4.2
Number of farms	10^6 farms	5.4	2.8[2]
Average farm size	acres	216.0	440.0
Cropland harvested	10^6 acres	387.0[1]	303.0[2]
Irrigated land	10^6 acres	29.5	41.2[2]
Cotton acreage	10^6 acres	25.9	12.3[3]
Corn acreage	10^6 acres	81.0	77.9
Soybean acreage	10^6 acres	14.3	53.6
Cotton acreage treated for insects	10^6 acres	13.0	7.5[3]
Small grain acreage sprayed for weeds	10^6 acres	17.0	33.7[3]
Nitrogen use	10^3 tons	1637.0	8607.7
Foreclosure and bankruptcy	No./1000 farms	1.5	1.5

Source: Agricultural Statistics 1954 and 1976 [15, 16]
Census of Agriculture 1974 [20]
Andrilenas [1]

[1] Data for 1950

[2] Data for 1974

[3] Data for 1971

for investment and the purchase of industrial goods. This policy has also been successful. In 1951, consumers spent between 25 and 30% of their disposable incomes for food. In 1960, the estimate was 21% and in 1976 the comparable figure was 19% [17, 18, 19]. The important factor in the achievement of the "cheap food" policy has been the continued expansion of the supply of food.

As a result of these two policies, farming has become dependent on the industrial sector for large amounts of the inputs, placing demands on the farm business to generate cash income to pay for the purchased inputs. In 1952, production expenses were 63% of gross farm income. By comparison, production expenses were 75% of gross farm income in 1975 [15, 16].

The pressure on farmers to compete in this sort of environment has strengthened the demand for technology which, while increasing the relative cash costs of production, holds the expectation that unit costs of production will be reduced relative to the prices received for products. It is argued that this political and economic climate provides, in large part, an explanation for the dramatic increase in the use of commercial fertilizer and chemical pest control products by farmers.

The Decision Making Framework for Pest Control

As data from the U.S. Department of Agriculture indicate, about half or over one million farmers are applying chemical pesticides as a means of pest control on crops [1]. This means that, at a minimum, over one million decisions are made annually

about the application of chemicals. As chemical pest control has developed, this technology is adapted to the small independent decisions. Farmers perceive pest problems and can act on those problems quickly and unilaterally. It is a technology that fits the atomistic nature of the farming industry. The producers of the chemical materials can identify their markets and advertise to promote the sales of their products with the direction of that promotion being the individual farmer-the customer.

This sort of decision making framework does not lend itself necessarily to either (a) the consideration of technical spill-over effects on parties who are not directly involved in pest control decisions or to (b) the consideration of the broader long-term agro-ecosystem effects. It is a decision framework based on short-term private economic benefits and costs. Consideration of the external benefits and costs of particular pest control decisions cannot be given nor is it likely that farmers will consider the effects of a particular decision on pest resistance in the future, or the development of secondary pests.

It is a natural result of the institutional setting that the public has become involved in pest control decisions through the Federal Environmental Pest Control Act of 1972 (FEPCA) and its precursor, the Federal Insecticide, Fungicide and Rodenticide Act of 1947 (FIFRA). In fact, pesticide laws date back in history to 1898 with the passage of a law in New York State to regulate paris green [9]. These laws represent attempts by society to protect not only the users of pesticides, but also

consumers and the natural environment from adverse effects. They represent a recognition of the fact that the market for pesticidal chemicals fails to incorporate the social values that are involved in pesticide decisions. In the jargon of economics, this phenomenon is referred to as imperfections in the market. These imperfections are due to a lack of knowledge-users don't really understand the products they use-and to the fact that there is no way to provide incentives for the user to consider those benefits and costs, which are not measured by the cost of the chemicals applied or by the prices of the farm products produced [4].

Pest Control Problems

Previous sections of this paper have alluded to problems with pest control in modern agriculture. These problems are: (1) the need to develop new methods to deal with pest resistance developed by previous chemical materials, (2) the need to develop controls for secondary pests made necessary by the reductions in beneficial species as the result of previous use of wide spectrum pesticides, (3) the need to reduce hazards to farm workers and other humans due to the use of chemical compounds that are either highly acutely toxic or problems of a more chronic toxicity or both and (4) the need to reduce hazards to non-target species in the natural environment such as fish and wildlife.

Problems of Pest Resistance

As soon as chemicals began to be widely used in U.S.

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agriculture to control pests, especially arthropods, pest populations came under heavy chemical pressure and resistance began to develop. It was first noticed in the U.S. in San Jose Scale control about 1914 [12]. DDT resistance in flies was reported in Italy and Sweden in 1947 [2]. Mosquito resistance showed up at about the same time. Many other cases of resistance have been documented not only among arthropods, but also among the fungi [13, 14].

The economic importance of chemical resistance is that: (a) it increases pest losses because the degree of control declines over time, (b) it increases control costs due to the requirement of extra treatments and (c) it increases control costs because of new investment required to develop replacement compounds [5].

In a system where individual farmers make pest control decisions on a short-run basis there is always the danger that chemicals will be applied enhancing resistance when the long-run benefits do not justify it either to the individual farmer or to society as a whole. What happens in an economic sense is that the life of the capital asset, the susceptible gene pool is shortened due to an accelerated depreciation [7]. The only way to correct this difficulty is to reduce the myopia in pest control strategies. To do this requires both a higher level of knowledge regarding economic thresholds and a method of extending the length of the planning horizon in making pest control decisions. In order to bring this higher

level of management to pest control, one must depart from the past decision system of individual actions and methods adapted to that setting and move more toward a setting where decisions are made in a broader geographical and time framework.

Secondary Pest Problems

There is evidence to indicate that some of the pest problems which now exist in agriculture have been induced by the use of broad spectrum chemicals used on certain key pests such as boll weevil and lygus on cotton in the south and California respectively [13].

The numerous cases of secondary pests which have appeared are evidence that the methods of dealing with pests used have tended to be counterproductive in the long run. Resources are now required to control pests that were previously controlled by natural means. Farmers and society are therefore now bearing the costs of previous pest control strategies. Such a situation is surely the result of the decision framework where unilateral control decisions are made with non-selective methods and without appropriate information or incentives to remove the myopia from those decisions.

Problems of Hazards to Humans

Since chemicals used in pest control exhibit varying degrees of toxicity to warm blooded species, there is always danger of a hazard to farm workers, people in the community where chemicals are used and to consumers of the products on which the chemicals are applied. Early in the history of chemical pest control,

the principal concern was for acute toxicity to humans, farm animals and wildlife. The introduction of DDT was hailed as a remarkable breakthrough because of its extremely low mammalian toxicity. That idea has since been found to be over simplified.

The discovery of chlorinated hydrocarbons in animal fat and its dispersal throughout the food chain led to the eventual banning of DDT and other chlorinated hydrocarbon compounds. Further, the discovery of the oncogenic properties of pesticidal chemicals as well as mutagenic and teratogenic properties led eventually to the full scale review of all registered chemical pesticides by the U.S. Environmental Protection Agency. Again one sees the result of a decision framework based on individual decisions that have the appearance of optimality when in fact there may be significant technical external effects that are not known and therefore cannot be considered as a part of the decision. Governmental regulation has seemed to be the best way to deal with this market imperfection up to this point.

Problems of Hazards to the Environment

Effects of chemicals on the natural environment have also been identified. Fish, birds and other non-target species are affected by chemicals applied to agricultural crops. How important these external effects are is in many cases difficult to determine. Some of these species are perceived as valuable because of their roles in natural control of pests such as birds. Others are seen as important to other species as a source of food. Still others, such as fish, birds and some

mammals are valued purely for their aesthetic value to many members of society. These are effects that the market for chemical pesticides finds difficult, if not impossible, to measure and include in the myriad of pest control decisions made by farmers, homeowners and others. Again regulation has been adopted as the method of controlling these external effects.

Alternative Control Strategies

It is apparent that the pest control strategies that have been followed need to be improved. Evidence available indicates that pest problems are as severe, if not more so, than they were 20 years ago. It is also apparent that at least for the forseeable future, the need for food and fiber by the world will be such that capital and land intensive agriculture will be necessary to prevent hunger. There is a need to change the strategies to minimize, constrained by the full set of social values, the problems with the reliance on chemicals, chosen and applied by individuals, as the main defense against insects, weeds, pathogens and other pests.

Alternatives Available

To deal with the shortcomings of the chemical pest control strategy, two major ideas are being examined. One approach is to substitute biological and cultural controls and the second is to abandon the philosophical concept of pest eradication in either a short or long term planning horizon and to embrace the concept of the management of pest populations at some level determined to be economically justified.

It has been shown that through the use of parasites, predators, attractants growth regulators, pathogens and host plant resistance, that at least certain pest species populations can be controlled. It is also well known that cultural methods such as crop rotations, timing of planting, cultivation and the management of plant residues and alternate hosts can control certain pests.

Biological and cultural controls, however, are faced with two major problems when placed in the commercial agriculture context. First, the research information needs are great. To apply biological and many cultural methods requires an understanding of the basic biology of the pest including its life cycle and its natural enemies. This is a time consuming and expensive capital investment process. Second, there are marketing and distribution problems. Were biological methods commercially saleable, the capital investment needed for their development and distribution would be forthcoming from private enterprise concerns motivated by the profit incentive. However, such is not usually the case. While it is possible to rear and sell natural enemies, and in fact it is being done, much of what is involved in biological and cultural methods is the development of information. The economics of commercial information is complicated by problems of maintaining proprietary control so that the developer can recover the necessary economic return necessary for its generation.

For the reasons just cited, the outlook for the rapid replacement of a pest control strategy based principally on

chemicals is not bright at least for the next 10-15 years. A research study by the author, just concluded [6] surveyed a panel of U.S. agricultural experts in extension and research to obtain estimates of the probable importance of the spectrum of pest control techniques over the next 15 years. These responses are presented in Table 2. Their conclusions were that chemicals will continue to be of major importance with insecticides declining in use and herbicides increasing. Of the biological methods, they believe resistant varieties to be the most promising for grains and soybeans with cultural methods being relatively minor. The experts believed that the use of bacteria will increase although still being a minor technique with little change in parasites and predators and the outlook for the more exotic measures such as viruses, pheromones and pest genetics is not hopeful. Certainly the work on citrus, cotton and selected vegetable and orchard crops makes the outlook there more promising, but there is still a long way to go to get the methods widely applied.

A technology assessment by a large consulting firm supports this general assessment [8]. This study cites unsuitability of certain biological agents to use by individuals, special training or education required which is not possessed by the average producer and the selectivity of many methods, while environmentally desireable, will handicap them due to the restricted size of the market relative to the developmental costs.

Cultural methods can and are being used by farmers. These

amount to management techniques which most farmers are capable of applying if they are demonstrated effective and if benefit-cost ratios show them to be profitable. They do add to costs of production either through the use of more labor and capital or through production lost as in the case of rotations involving crops with lower profit margins. This points directly to the way agriculture has adjusted to the recent economic pressures brought by the policy of industrialization leading to higher labor costs, the force of international demand for crops such as soybeans and the policy of cheap food.

As a compromise between complete dependence on chemicals and dependence on application of natural enemies, the concept of integrated pest management has been developed to combine the use of better technical management skills by farmers with a mix of chemical, biological and cultural methods. In this way it is hoped that the reliance on chemicals can be reduced and the problems associated with chemicals, therefore reduced [10].

Research on integrated pest management is going forward. The Federal Extension Service of the U.S. Department of Agriculture is beginning to develop educational programs for farmers and their advisors to improve their skills. Both the public and the private sectors of the economy have roles to play in the development of integrated control.

Much of the research needed as a foundation is basic biological research. Pest management means the maintenance of

Table 2. Estimated Importance of Pest Control Methods for Grain Crops and Soybeans, U.S. Agriculture 1978-1992.

Pest Control Technique	Probable Use Over Next 15 Years	Trend in Use[1/]
Chemical Poisons		
Insecticides	major	-
Herbicides	major	+
Mechanical Methods	minor	-
Biological Methods		
Parasites and Predators[2/]	minor	0
Bacteria	minor	+
Viruses	not significant	+
Pheromones	not significant	0
Resistant Varieties	major	+
Pest Genetics	minor	-
Cultural Methods		
Crop Rotations	minor	-
Trap Crops	minor	0

Source: A summary of responses from 39 U.S. agricultural extension and research workers, 1977.

[1/] "+", "-", or "0" means a trend that is increasing, decreasing or unchanged respectively.

[2/] Parasites and predators refers to their application of parasites and predators. Naturally occurring parasites and predators have been and will continue to be important in insect control.

pest populations at levels that are greater than zero, but below levels where unacceptable economic damage to production exists. This requires more knowledge than we currently have about the pest-enemy-host relationships. Most of this research will become the responsibility of the public sector.

Chemicals are most effective in quickly reducing pest populations where explosions occur. Individual farmers will continue to need tools such as these to deal with the inability to fine tune an agro-ecosystem everywhere all of the time. The private sector has the responsibility for the development of chemicals that are compatible with the various biological and cultural methods that are a part of the integrated approach.

Implications for the System

The purpose of this paper was to describe the changes in agriculture and agricultural pest control in response to its economic milieu and to provide insights needed to improve pest control to meet social objectives. These social objectives continue to be: (a) an economically viable agriculture consisting of a large number of small units, (b) a minimization of the labor and other resources devoted to food and fiber production, (c) ample nutritious food which can be purchased with the incomes of consumers and (d) an environment that is a safe and aesthetically pleasing place in which to live. These are challenging objectives.

In order to meet them, changes in the institutional framework will be needed. In order to deal with the very real pest problems that exist, new ways will need to be found to

maintain the productivity of agriculture.

It has been argued here that due to the imperfections of markets, atomistic competition in production agriculture will not produce a socially acceptable level or kind of pest control. The implication is that some method must be found to deal with these market imperfections. That is, to adjust for the external effects of the use of chemical pesticides and to adjust for short term planning horizons inherent in the decision framework where pest control decisions are made.

The specific implication is the enlargement of the role that the public at large plays in the development and application of pest control to agriculture. It has been found that governmental regulation of pesticides is inadequate to the task. While useful for the most gross kinds of problems, such as acute and chronic toxicity and short term efficacy, it cannot in an economically efficient manner deal with the other problems that plague pest control.

The need for research and education to cope with the problems of minimizing the resources devoted to pest control, to find ways to make better use of the natural environment, to maintain ecological stability and to determine the essentiality of various technologies calls for a larger public investment in research and development in pest control. Federal and state agencies and the university community need to provide greater leadership to see that this job is done. Agricultural colleges, who are closest to and better able to understand the technical and economic situation of the farmers of their

region, need to be given the specific responsibility to do the research needed to develop and apply integrated pest management for their area. In the development of selective chemicals necessary for use with biological methods, policies are needed to provide for the franchising of private concerns to produce and market chemicals developed with public funds to further the objectives of integrated control.

At the farm level there is a need to design institutions to first broaden the area to which pest control decisions apply and second, as a necessary complement, to provide ways for the pooling of the risks taken by individual farmers under this broad area approach to pest control. The establishment of pest control districts, perhaps conforming to counties, coupled with a scheme of crop insurance could provide a setting where pest control decisions are made that consider both external effects and longer term concerns for ecological stability. At the same time, individual farmers could be protected from any adverse effect that such decisions might have for them.

There is much yet to be done. Courage and imagination on the part of scientists, politicians and the business community is very much needed if the old priorities and policies are not to become those of the future.

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