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CONSERVATION OF THE LAND, AND THE USE OF WASTE MATERIALS FOR MAN'S BENEFITS

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PREPARED FOR THE

COMMITTEE ON AGRICULTURE AND FORESTRY UNITED STATES SENATE

MARCH 25, 1975

Printed for the use of the Committee on Agriculture and Forestry

U.S. GOVERNMENT PRINTING OFFICE
48-738 WASHINGTON : 1975

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FOREWORD

In 1974, I announced that I would begin a systematic study of the nation's renewable resources and what ought to be done to protect them.

Among the most precious of these is the land base upon which we must rely for food and forest production.

It is evident that as a result of asking our farmers to go all out for maximum farm production that we run some risks of eroding that land base. The evidence is that in some circumstances that base has been significantly damaged. The first paper of this report, and the response of the Soil Conservation Service to that report deal with this broad subject area.

Secondly, I am aware that animal and human wastes have become a serious problem to our society, and I wanted to explore what might be done to turn this problem into an asset. Poultry litter, for example is high in protein content. Properly treated it is possible that it might be used as a supplement to cattle feed. Similarly, it would seem possible that animal and human wastes might be used to help renew a deteriorating land base.

The Committee on Agriculture and Forestry is most grateful for the response and hard work of the members of the Council.

We are are also grateful to the Soil Conservation Service for its cooperation for Agricultural Science and Technology on this project. It is expected that the Committee will be doing more work in this area.

The conclusions reached in this report do not necessarily reflect the opinion of all of the members of the Committee on Agriculture and Forestry.

HERMAN E. TALMADGE, *Chairman.*

CONTENTS

	Page
Foreword	III
Land resource use and protection	3
Summary	5
Introduction	8
Land needs for agricultural and nonagricultural uses	9
Agricultural use	9
Nonagricultural use	11
Problems of soil use and its protection	11
Significance of topsoil	11
The erosion and sedimentation hazard	13
Crop rotations	14
Shelterbelts	15
Are we creating conditions for another dust bowl?	16
The weather factor in long-range planning for agricultural production	17
Policy framework for land resource use and protection within the agricultural sector	19
Policy elements	20
Possibilities for expanding cropland	20
High, low and intermediate levels of agricultural production possibilities	21
Agricultural land use policy within national land use policy	22
Private, group and public responsibilities in maintaining and improving agricultural land resource productivity	23
Development and implementation of agricultural land use policy	24
Bibliography	26
Appendix	27
U.S. Department of Agriculture staff evaluation of the report "Land Resource use and Protection"	30
Erosion in 1973–74: The record and the challenge	39
Utilization of animal manures and sewage sludges in food and fiber production	47
Summary	48
Introduction	51
Present usage and trends	52
Fertilizer value	53
Sewage sludge	53
Animal manures	54
Crop response	55
Heavy metals	56
Soluble salts	58
Water quality	59
Ground waters	59
Surface waters	59
Odors	60
Management on the farm	60
Management to enhance utilization	61
Land reclamation	63
Alternative uses	64
Animal manures as feed ingredients	64
Other uses	65
Energy relationships	65
Human and animal health	67
Public concern	68
Need for guidelines	69

LAND RESOURCE USE AND PROTECTION

LAND RESOURCE USE AND PROTECTION

This report on land resource use and protection was prepared for use by the U.S. Senate Committee on Agriculture and Forestry at the request of the Honorable Herman E. Talmadge, Chairman. Participating in the effort were twelve scientists representing states of Illinois, Indiana, Iowa, Kansas, Louisiana, Nebraska, and North Dakota. Subject matter areas represented included agricultural economics, agricultural engineering, agronomy, forestry, horticulture, meteorology, rural sociology, soil science, and soil and water conservation. Although members of the task force were all knowledgeable in the aspects of land resource use and protection as related to their respective scientific disciplines, none of them were employed by the U.S. Government. This selectivity was practiced in an attempt to obtain an appraisal of the subject as seen by scientists not employed by agencies charged with implementation of government programs in land resource use and protection.

Members of the task force met in Des Moines on December 2 to 4, 1974, to discuss the issues and to prepare a draft of the report. The draft was subsequently revised, reviewed, revised again, edited, and reproduced for transmittal.

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SUMMARY

Americans have made a significant effort toward reducing soil erosion since the mid 30's. Nevertheless, the problem is still serious. Efforts by land owners, farm operators and government programs have not kept pace with the pressures of land use. The acreage in cropland in the United States is increasing, and most cropland is being used more intensively, particularly by increased use of row crops. As a result, the exposure of the soils to erosion is increasing.

Although projections of long-term production potential are optimistic, it is recognized that attaining production at reasonable cost will require wise land use, including appropriate conservation practices. The nation's agricultural lands have suffered substantial disinvestment in the past, and this is accelerating as land is farmed more intensively and as less productive land is brought into crop production.

Each year some agricultural land is shifted to other uses. The need for land for special uses will continue to exist in the future, and the demand will enjoy an overriding competitive position in an open market. Land shifted out of agriculture is often of high quality, and the probability that it will be returned to agriculture is negligible. In the future, planning and legislation may be required to ensure that the long-term interest of the public is given due consideration in land-use decisions.

Average crop yields have tended to increase in the United States even though soil losses are often excessive. Use of modern technology, including fertilizers, is largely responsible. But this is a short-term effect. Over the long term, erosion decreases the yield potential and increases production costs.

Soil erosion creates a serious sedimentation problem. Sediment is by far the major pollutant of surface waters. Some of the highest sediment yields come from the most productive and most intensively cultivated soils. Water quality in lakes and streams is also reduced by the nutrients and pesticides carried there by the sediment and runoff water.

In recent years, there has been a shift away from soil conserving crop rotations. Much of the current production is from either a continuous single crop or, as in the Corn Belt, a rotation of two intensive row crops (corn and soybeans). Fertilizers and pesticides have made this system feasible. Although continuous single-cropping is efficient and profitable, it does increase the erosion hazard and the need for soil conservation practices.

Trends that could lead to another "dust bowl" in the Great Plains during a sustained drought include the following: (a) Elimination of strip-cropping for control of wind erosion as a result of change

from a wheat-fallow system to continuous wheat production. (b) Shifting from soil-conserving, stubble-mulch tillage to plowing to help control dowy bromegrass as a weed in wheat. (c) Shifting to wheat production certain rangelands that would be relatively susceptible to wind erosion under conditions of drought because they occur in the drier regions. Such a trend will be fostered by continued high prices of wheat and low prices of cattle.

Many shelter belts planted in the 1930's and 1940's in the Great Plains are being removed because of improper design or inadequate maintenance. New knowledge of the mechanics and design of windbreaks, the values of windbreaks in reducing wind speeds to nonerosive levels and the improvement of microclimate for crops in the protected zone justifies rejuvenating old shelter belts and establishing new ones.

Weather in the United States for 1957 through 1972 was unusually favorable for agricultural production. Decisions concerning food production and conservation practices now and for the future, however, should preferably take into account the possibility of widespread drought in the United States. Climatologists agree that such a condition will occur again. The probability is high that it could occur in the near future.

Policy elements important to achieving adequate agricultural production and maintaining soil productivity are (1) obtaining estimates of the potential for agricultural production and (2) developing ways to absorb and blunt the effects of gyrations in prices and supplies of food and fiber. An additional policy element arising from our concern for the nations with food deficiencies is that of helping them develop their own agricultural potential.

Significant increases in agricultural production in the United States are possible by 1985 with use of good husbandry and additional land not now employed for crop production. This potential underscores the important role that public policies and structures can play in guiding production in light of demand. At the same time, there is continuous loss of good agricultural land to other uses. This essentially irreversible trend underscores the need for a national land policy whereby all uses of lands and protection of the soil resource are considered and guided toward national objectives. In developing and implementing agricultural land-use policy, the nature and diversity of soils, water availability, climatic conditions, and the potential contributions of interested and affected citizens should be given due consideration.

The following policy framework for defining the role of private and public responsibility in management of private land is suggested: (1) The productivity of individual farms and ranches can be carried to the level of private profitability as a private responsibility. Public assistance is limited to that required to help the private entities perform up to their potential. (2) A higher level of productivity and of land resource protection can be achieved by cooperation of farmers and ranchers in watershed, conservancy, drainage and irrigation districts and other group forms of resource management. Here the public role is to help the groups organize and manage their resources within the level of private group responsibility. (3) Still higher levels of pro-

ductivity and of land resource protection that are in the public interest may be achieved, within the maximum physical limits, as a public responsibility. It would appear appropriate to conserve public funds for use in the public-responsibility area.

Additional considerations in developing and carrying out policies for achieving desired goals of land resource use and protection include the following: (1) Price floors for farm products to blunt the effects of external forces on farm income and stability of production. (2) Crop insurance for crop production to aid in stabilizing farm income and production. (3) National reserves of agricultural products as national insurance against shortages, managed in such a way as to avoid passing the costs directly or indirectly to farmers. (4) Agricultural policy that differentiates among income distribution, production measures, and conservation investments. (5) More attention to removing uncertainty by forward programming, program continuity and timely announcements. (6) Guarantees that public investments on private lands are maintained. (7) Appropriate state enabling legislation. (8) Adequate funding for needed research, education and action programs.

Introduction

For the third year in a row, American farmers are being asked to increase agricultural production. More food, feed and fiber are needed by this nation. More agricultural commodities are needed to rebuild reserve supplies, to provide food aid to needy countries and to accommodate an expanded international trade.

Prices of food and feed grains have reached an all-time high. Government crop-restraint programs of the past decades have been relaxed to increase crop acres. Farmers have responded to these incentives by planting more acres to crops, especially corn, sorghum, soybeans and wheat. Most of the cropland increase has come from land that previously had been diverted from production to soil-conserving crops. For example, in 1973, acreage diverted from crop production under Federal programs dropped from 51 million acres to 8 million acres. In 1974, the only remaining diverted cropland was about 2 million acres under long-term contract.

Not only is there a trend toward more land in crops but we are also using most cropland more intensively, particularly by increased use of row crops. Indications are that such trends will persist, since demand for agricultural commodities promises to remain strong.

More acres in cropland and more row crops on the same land year after year increase the exposure of soils to erosion. Although Americans have made a significant effort toward reducing soil erosion since the mid 30's, the problem continues to be serious. Efforts by individual farmers and government programs have not kept pace with the pressures of land use and production. Economic and social incentives are insufficient to encourage the application and maintenance of conservation practices. The need for income each crop-year overrides the long-term disinvestment effects of erosion. The current interest in erosion control to enhance environmental quality has increased awareness of the problem but has done little to encourage conservation practices. As a result, there is growing concern that the land and water base are not being adequately protected to ensure future agricultural production at reasonable prices. Furthermore, it is obvious that the quantity of agricultural land is limited and that both short- and long-run needs must be met from this quantity.

The main objective of this report is to review and evaluate the current problems in the use and protection of land and water resources, especially as related to agriculture in the Corn Belt and Great Plains, and to suggest guideline alternatives for reasonably achieved remedies. The following goals are implicit in the development of this report:

1. Provide adequate food and fiber for U.S. citizens;
2. Meet world demands for trade, emergency aid and reserves;
3. Maintain a productive soil base; and
4. Maintain a quality environment.

We do not propose to discuss in this report all the complexities and interrelationships of land resource use and protection. Rather, we shall attempt to summarize information relevant to the above goals and then identify areas of concern, raise questions and discuss alternatives for action.

The report covers the following four areas:

1. Land needs for agricultural and nonagricultural uses;
2. Problems of soil use and its protection;
3. The weather factor in long-range planning for agricultural production; and
4. Policy framework for land resource use and protection within the agricultural sector.

Land Needs for Agricultural and Nonagricultural Uses

The United States has a land base of slightly less than 2.3 billion acres. Of this amount, 21 percent is in cropland, 27 percent in pasture and range, 32 percent in forests, 8 percent in special uses and 13 percent in other lands (Table 1). Proportions of the national land base in cropland, pasture, and rangeland and forests have remained practically constant for more than two decades, although changes have occurred within regions.

TABLE 1.—USES OF LAND IN THE UNITED STATES[1]

Uses of land	Millions of acres in each use	Percentage of land in each use
Cropland	472	20.9
Grassland pasture and range land	604	26.7
Forest land	723	31.9
Special uses of land[2]	178	7.8
Other land[3]	287	12.7
Total land	2,264	100.0

[1] Based on 1969 U.S. Census data.
[2] Includes urban, highway, park, wildlife, military, and farmstead uses.
[3] Includes land in desert, swamp, rock, and tundra conditions.

Under the special use category of Table 1, urban uses have doubled in area since 1950. Their present total area includes 1.5 percent of the total land base. Highways and airport transportation uses absorb 1 percent; this total includes the Interstate system of highways and the considerable expansion of airports.

AGRICULTURAL USE

The nation's cropland resources total 472 million acres or 21 percent of the land area. In any given year only part of this is used for harvested crops, and the rest is in pasture or soil improvement crops or is idle for some reason. In 1973, the acreage used for crop production totaled 354 million acres.

There have been some changes in the cropland acres used during the past two decades. They decreased from a record high of 387 million acres in 1949 to 335 million acres in 1964. They remained at about this

level until 1973, when they increased sharply to 354 million acres. The decline in cropland acres came about because of great increases in cropland productivity made possible by improved technology. The increase of the past two years is due mainly to greater demand for food and feed, especially by the export market.

The conservation needs inventory (CNI) conducted by the Soil Conservation Service indicates that an additional 264 million acres of the nation's land base has cropland potential. Although this land is now mainly in forest and grassland, it could be developed and converted to cropland within the next decade if needed.

In the future, the demand for agricultural products in the United States will probably rise slowly and steadily in proportion to the increase in total population and will be influenced to some extent by price and income changes.

The future export demand for U.S. farm products will be influenced by numerous factors which are difficult to evaluate. It is likely that the demand will increase, but opinions vary widely on the amount. If export demand rises considerably above present levels, it could significantly increase cropland use and require more nonland inputs such as energy and fertilizer for production and conservation.

There is concern among agricultural scientists that our reserve of unused agricultural technology is growing critically low and that yield increases are leveling off. Furthermore, there is concern that the highly favorable weather of the 1957 to 1972 period is not likely to continue. These two factors are problematical but realistic and must be considered in planning for future needs.

Nevertheless, most of the studies concerned with the size and potential of our cropland base and projected needs indicate that in this century our population will *not* be confronted with a physical incapacity to meet the requirements for agricultural products. On the contrary, there is considerable feeling that there will be a recurrence of excess production such that products cannot be sold at prices high enough to provide reasonable profits for farmers. U.S. farmers have great capability to produce and will likely do so if price relationships are favorable and if inputs such as energy and agricultural chemicals are available.

Although projections of long-term production potential are optimistic, it is recognized that attaining the projected production at reasonable cost will require wise land use and application of appropriate conservation practices. The nation's agricultural lands have suffered substantial disinvestment in the past, and this is accelerating as we farm more intensively and bring less productive lands into crop production.

The diminished productivity of the land resource has been masked by concurrent developments which cannot continue indefinitely. In the 19th century, badly eroded lands went out of production and were replaced by new lands to the west. More recently, and particularly since World War II, declines in soil productivity have been more than offset by improved technology and by large injections of nonland inputs. Today's dramatically higher costs of energy and other production inputs make continued declines in soil productivity of more concern. The price of continued declines will be reduced rates of increases in agricultural output and higher cost per unit of output.

NONAGRICULTURAL USE

Each year some land is shifted out of agriculture to other uses. The Economic Research Service estimates that 2.2 million acres of rural land are shifted annually to other uses. About 1.2 million acres are used for urban development, transportation, reservoirs and flood control. Only about half of this was cropland before it was converted to other uses. About 1 million acres are shifted annually to recreation and wilderness areas, with very little coming from cropland.

Land for these special uses is needed to meet demands of a growing population with higher per capita income. The needs will continue in the future, and the demand for nonagricultural uses will enjoy an overriding competitive position in an open market compared with agricultural uses.

It is projected that by the year 2000, urban and related land uses will increase by 20 million acres, a 40-percent increase over 1969. This diversion of land may cause severe problems in some regions, but on a national basis it will not seriously impair our capacity to produce food, feed and fiber.

We do not mean to imply that shifting rural lands to other uses should be taken lightly. Responsible guidance must be exercised to ensure that the new use is appropriate and in the public interest. The following are a number of relevant considerations:

1. Land shifted out of agriculture is often high-quality land. The probability of shifting it back is negligible.

2. Urban sprawl, skip development and breaking farms into 5- to 50-acre parcels has both direct and indirect effects on agricultural production. There may be speculative idling of cropland, isolation of farming enterprises, increasing land values and production constraints arising from odors, waste disposal and other land-use incompatibilities.

3. Often agricultural land in flood-plain areas is shifted to industrial or commercial development. Pressure is then created for public investments to provide flood protection.

4. Modern double-land highways are sometimes located where high-quality land must be taken out of production. Development of such highways may cause farms to be divided into irregular shapes and access to be restricted.

5. Surface mining is on the increase, and its effect on productive agricultural land should be considered. The location of power-generating facilities and transmission lines may be an additional concern.

6. Historically, most land-use decisions have been made by open pricing in the market place. On this basis, land for agriculture can seldom compete when the land is in demand for nonagricultural use. In the future, planning and legislation may have to be initiated to ensure that the long-term interest of the public is given due consideration in land-use decisions.

Problems of Soil Use and Its Protection

SIGNIFICANCE OF TOPSOIL

Topsoil is valuable to crop production because it contains most of the soil organic matter and a major share of the nutrients required by

plants. It has a physical environment favorable to seedbed preparation and plant establishment. Since topsoil is on the surface, it absorbs the energy of falling rail and controls the rate at which water enters the soil and the amount that percolates to deeper layers. The organic matter in the topsoil acts as a binding agent that helps hold the mineral particles together into crumb-like structural units. This results in good "soil tilth." It is this condition that helps soil resist erosion, reduces surface crusting, encourages water intake and storage, and provides ease of tillage with resulting seedbeds favorable to planting and crop establishment.

Topsoil thickness may vary from a few inches to two feet or more. Productive Corn Belt soils have a topsoil thickness of 6 to 16 inches.

Once it is lost by erosion, topsoil can be redeveloped only over long periods of time. Loss of the topsoil will generally have a disastrous effect on the productivity where the topsoil is underlain by a thick layer of sand, clay or rock. Rejuvenation of topsoil may then be impracticable. At the other extreme, loss of the topsoil will produce little impairment of the productivity if suitable additions of fertilizers are made in instances in which materials with favorable physical and chemical properties extend to depths of several feet or more. Rejuvenation of topsoil in practical agriculture can then occur as plant nutrients are replaced by fertilizers and as organic matter is added by roots and crop residues.

Average crop yields have tended to increase in the United States even though soil losses are often excessive. The use of fertilizers and other good soil- and crop-management practices tend to mask the effects of soil loss. Even with the best of soils that are underlain by considerable depths of favorable materials, however, erosion decreases the yield potential in the absence of considerable input of fertilizers, and this effect becomes increasingly evident as more and more of the soil is lost. The amount of soil that soil scientists believe can be lost and still maintain production over a long period varies from one ton per acre per year on shallow soils to five tons on deep soils.

The depth of favorable soil material over unfavorable subsoil is a major criterion for predicting the effect of excessive erosion on soil productivity. Information from the central Corn Belt indicates that, with current management, including moderate use of fertilizer, soils on a 4 to 12 percent slope from which most of the topsoil has been lost have incurred a 30 percent reduction in productive capacity if subsoils are unfavorable and a 15 percent reduction if subsoils are favorable. Under high levels of management, including large amounts of fertilizer, for the same slopes, erosion accounts for a 20 percent reduction over unfavorable subsoil and a 10 percent reduction over favorable subsoil.

Where sand, rock, pebble bands or clay are near the surface, continued erosion may force abandonment of land for production of tilled crops. Long-term accelerated erosion of steeper lands results in deep rills and gullies and leaves the surface too irregular to farm efficiently with large machinery.

Because the consequences of excessive erosion differ so much among soils, there is reason to relate erosion control measures to the potential losses in future productivity, with some possible additional limitations

where agricultural practices may affect a critical water resource. The inventory and description of soil areas, properties and capabilities provided by detailed soil surveys and invaluable in the evaluation and planning aspects of erosion control. Modern soil surveys have been completed on about two-thirds of the land area in the 48 states.

THE EROSION AND SEDIMENTATION HAZARDS

Soil erosion and sedimentation remain a serious problem in the United States today. In terms of mass, sediment is by far the major pollutant of surface waters. Since soils vary in properties, susceptibility to erosion and use intensity, it is to be expected that erosion and sedimentation rates vary greatly among and within regions. For example, the average annual sediment concentration for all U.S. rivers ranges from around 200 to 50,000 parts per million. Much higher concentrations may be found in ephemeral or small upland streams after storms. Sediment yields in the Mississippi basin average about 390 tons per square mile annually, but production varies among tributary streams from 9 to 10,000 tons per square mile per year. The highest sediment yields in the United States occur in the sand hills of the state of Mississippi (about 15 tons per acre per year) ; the next highest yields occur in zones along the Mississippi River in Missouri and Illinois and along the Missouri River in western Iowa and eastern Nebraska. Some of the highest sediment yields come from America's most productive and intensively cultivated soils.

The U.S. government has sponsored programs to reduce the erosion problem since the mid 30's. The progress that has been made varies with location and the severity of earlier erosion problems. Generally where past erosion has been extremely serious, as in the southeastern states, the Great Plains and the more rolling areas of central United States, much progress in control has been made by use of permanent cover, sod-based rotations, strip cropping, terracing, and conservation tillage, which leaves crop residues on the surface. Many land owners have learned by experience that it is essential to protect the soil if they are to maintain a productive agriculture.

In the Corn Belt, however, estimates indicate we are less effective in controlling erosion today on lands with severe erosion problems than we were 15 years ago. Conservation Needs Inventory (CNI) data from 12 north central states show that 7 to 12 states were doing a better job on these kinds of lands in 1958 than in 1967. In 1958, the percentages of highly erodible cropland with adequate treatment in Indiana, Illinois and Iowa were 36%, 31% and 29%, respectively. In 1967, correspondingly the percentages were 14%, 14% and 20%. Adequate treatment was considered to include the presence of crop residues on the surface of the soil, an annual cover, strip cropping, terracing and diversions. The 1967 CNI data showed that only 36% of the total U.S. cropland was adequately treated.

Recent events such as altered government programs promoting intensive cropping, strong prices for major crop commodities, and unfavorable livestock prices have encouraged farmers to expose more cropland to intensive tillage. A recent Soil Conservation Service survey showed that 8.9 million acres present as grassland and idle land in

1973 were converted to cropland in 1974. Four million of these acres have inadequate soil erosion control. A much greater switch occurred at the beginning of 1973 when acreage restrictions were first lifted. At that time, 43 million acres were converted. Increasing production of row crops on sloping marginal land has a major influence on soil erosion. Soil losses as great as 50 tons per acre were estimated to have occurred in south central Iowa watersheds in the spring of 1974. Losses as great as 200 tons per acre from sloping cultivated fields in Illinois were reported. Unusual losses occurred in 1974 because intense rains fell in the spring and early summer when fields were most vulnerable.

Another aspect of erosion is that of environmental degradation. Water quality in streams and lakes is reduced by additions of sediment, pesticides and nutrients. Based on the 1972 market value of fertilizers, an estimated $800 million is lost in available nutrients alone. The 1974 value of the nutrient losses is at least 50 percent greater. Besides damage to the soil itself and the impact on recreation and aesthetic values, erosion results in measurable costs to society. Estimates of these societal costs include $83 million for dredging channels and harbors, $50 million for reservoir sedimentation and flood plain overwash and $25 million for added maintenance and turbidity removal by industry and cities.

Existing technology is physically capable of greatly reducing erosion and sedimentation. Watershed studies have demonstrated that good conservation practices and structures, properly installed and maintained, will reduce sediment yield by 50 to 90 percent. Conservation practices often are not used because of the economic, social and institutional aspects of conservation. The pressure of financial obligations encourages farming practices that result in excessive erosion. Farmers usually do not experience noticeable yield decreases because they have increased the use of technology which more than offsets the loss of production from excessive erosion. Land owners and farm operators thus tend to ignore long-term disinvestment damage to their land as well as offsite damages which may not affect them directly but which result in costs to the public.

CROP ROTATIONS

There has been a gradual shift away from crop rotation for the past 30 years in the Corn Belt and Great Plains. Much of the current crop production is either from a continuous single crop or, as in the Corn Belt, a rotation of two intensive row crops (corn and soybeans). The old sod-based rotation has largely disappeared. This system included planting legumes and grasses, which helped control erosion. In addition, the legume provided nitrogen for a following grain crop.

The production of hay and pasture crops, usually considered as soil-conserving crops, has declined and in fact has been totally eliminated on many farms. The trend is illustrated by the change in crop acreage in Illinois from 1945 to 1973. The acreage of corn and soybeans increased from 13 million acres in 1945 to 19 million acres in 1973. During the same period, the acreage of oats, wheat and hay dropped from approximately 7.5 million acres to 3 million acres, these crops being largely replaced by soybeans. The same trend has occurred in other Corn Belt states.

Wheat production in the Great Plains has become more intensive by the growing of wheat every year rather than using summer fallow every other year. Irrigation has increased in the Great Plains, and some grass and wheat lands have been shifted to corn and grain sorghum.

Farmers have found that continuous single cropping is relatively efficient and profitable. It allows for greater specialization in management and equipment and permits growing more acres of high-profit crops. Chemical fertilizers, particularly nitrogen, have enabled grain farmers to eliminate less profitable legume and grass crops from the cropping system. Improved crop varieties and the availability of insecticides and herbicides have enabled farmers to control pests that once were controlled primarily by crop rotations.

The elimination of sod crops and small grains from the cropping system causes increased erosion on sloping lands. In some instances, efforts are being made to control erosion on such lands by conservation tillage and the use of mechanical practices such as contouring, strip cropping and terracing. But such practices require additional management. They are costly, and often they do not bring extra profits in the short run. As a result, the application of these soil-conserving measures has not kept pace with the need. More than one-third of the U.S. cropland is suffering annual soil losses in excess of the limit at which soil productivity can be sustained over time.

Crop rotations will continue to have some use, primarily on sloping land and where livestock are a part of the farm program and can utilize grass-legume crops. Quality farm land, however, will continue to be farmed intensively to maintain farm income and to provide the needed food, feed and fiber crops. Ways are needed to reduce intense row-crop production on highly erodible land and to increase the use of soil-conserving tillage and mechanical erosion-control practices on lands suited to intensive cropping.

SHELTERBELTS

Many shelterbelts which were planted in the 1930's and 1940's in the Great Plains are being removed because they have become too dense and wide. This configuration produces wind currents which cause snow to pile up adjacent to the trees. When the snow melts, runoff is high, and soil erosion and leaching of soil nutrients result. Some farmers are removing multiple-row belts because they take significant amounts of high-value land out of production.

The multiple-row windbreaks planted during the 1930's and 1940's were patterned after farmstead windbreaks and are now considered unsuited for field protection. Research has now provided a better understanding of windbreak mechanics than was available to the Shelterbelt Project leaders. To be effective, windbreaks must be porous at the base so that turbulence near the belt is minimized and leeward windspeed is reduced over a considerable distance. Single- and double-row windbreaks planted in recent years provide the desired wind shelter, require less space and are suited to current cultural systems involving large fields. Old multiple-row windbreaks can also be renovated by the selective removal of rows or judicious thinning of trees in the row.

Properly designed windbreaks in the northern and western Great Plains have proven effective in reducing wind speeds from erosive levels to nonerosive levels. They can be used effectively in conjunction with other agronomic conservation methods such as strip cropping and stubble-mulch tillage.

A study in North Dakota indicated that the shelter effect on wheat yields is not great enough, in itself, to warrant the use of windbreaks. However, world literature indicates considerable increase in yields of most field and horticultural crops—particularly during years when rainfall is deficient. This positive effect on yield is attributable primarily to the conservation of soil moisture which follows when windbreaks are properly designed. Yield increases are reported when windbreaks are used in conjunction with irrigation as well as in dry-land agriculture.

Windbreaks alter microclimate in the protected zone. They provide more favorable daytime temperature and absolute humidity. Coupled with the decrease in wind speed, this change results in a significant moderation of the evaporative demand and, hence, in the evaporative stress imposed on the crop. Normally, vegetative and reproductive growth of crops benefits from this more moderate microclimate.

Modern windbreaks hold and spread out much of the drifting snow. Large drifts are avoided. The resulting snow-melt water enters the soil where it can be used by plants.

It is well known that windbreaks are useful for livestock protection, especially during the winter months. Windbreaks can also provide shelter and food for wildlife. For wildlife shelter, the windbreak should be constructed of closely spaced trees and shrubs.

Windbreaks usually consist of trees and shrubs, but rows of tall crops can be an effective windbreak to shelter shorter adjacent crops. Rows of tall grasses or corn or sorghum, properly spaced, have been used to shelter small grains, sugar beets, soybean, dry beans and other low-growing crops in a varety of experiments carried out in the Great Plains. Systems of wind protection can be arranged for large fields through the use of trees and tall-growing crops in combination. For the future, it is appropriate that windbreak improvement and establishment be given greater attention, especially in open dry-land areas where protection from wind is needed.

ARE WE CREATING CONDITIONS FOR ANOTHER DUST BOWL?

The farm community may be creating another dust bowl. Five problem conditions are evident which could trigger a dust bowl if a sustained drought were to reoccur in the Great Plains and perhaps extend into the Corn Belt:

1. Farmers in the Great Plains are changing from wheat-fallow or wheat-sorghum-fallow rotations to continuous wheat as a result of high wheat prices. Continuous wheat eliminates the use of strip-cropping for wind erosion control.

2. Many farmers in the Great Plains are plowing with moldboard plows to bury the seed of downy bromegrass, a growing weed problem with continuous wheat. This leaves the soil surface bare of residue and subject to serious wind erosion.

3. Fields in the sandhills placed under center-pivot irrigation have been smothered or leveled for more efficient irrigation and farming. Barren sand is exposed in the smoothed areas and is subject to wind erosion when planted to row crops. Some areas remain unwatered and barren, thus creating a serious wind erosion hazard for a number of years.

4. Although little rangeland in the Great Plains has been shifted to grain production to date, such conversion will be promoted by high grain prices and low cattle prices. Cropland is more susceptible than rangeland to wind erosion.

5. Fall-plowed cropland in the Corn Belt creates a serious wind erosion hazard in the winter and spring. Moldboard plowing and crops such as soybeans with only small amounts of surface residue leave the soil exposed and subject to blowing, often filling roadside ditches with wind-blown sediment.

Research and farm experience have demonstrated that erosion can be effectively controlled through soil management and conservation practices. In the Great Plains, the use of "stubble mulch tillage" has been very effective. This practice involves seedbed preparation using tillage tools such as sweeps or chisel plows which leave crop residues on the soil surface. Such methods are sometimes referred to as conservation tillage. They are effective against wind and water erosion and also help conserve needed soil moisture. One ton of crop residues per acre on the surface of most soils will stop soil from blowing. On sandy soils, strip cropping combined with a cover of crop residues may be necessary.

In the Corn Belt, winter and spring wind erosion can be stopped when fall plowing is eliminated and conservation tillage methods are used which leave corn or soybean residues on the soil surface. Fall-sown cover crops can also be used occasionally.

Progress is being made in the Corn Belt in shifting from moldboard plowing to conservation tillage for controlling both wind and water erosion. For example, conservation tillage in Iowa increased from 237,000 acres in 1972 to about 5 million acres in 1974. Faster field work and benefits from increased plant-available water have been important factors in casing this shift.

The Great Plains Conservation Program initiated in 1957 has done much to enhance the control of wind and water erosion. It provides the opportunity to develop a complete conservation plan for a farm with continuity of funding. This allows farmers to make long-range plans, and it permits contractors and service agencies to arrange their time and commitments. These features have been important to its success.

The Weather Factor in Long-Range Planning for Agriculture Production

The weather, year by year, is an important factor in determining the most appropriate management practices and the yields that result. If unfavorable weather conditions that reduce crop yields persist for several years, the total socio-economic structure of an afflicted region is affected.

It is generally accepted among climatologists that the weather in the United States as a whole during the period from 1957 to 1972 was unusually favorable for agricultural production. To assume that such favorable weather is a permanent feature in projecting future production and in designing future cultural practices, however, would be unrealistic.

Although a method for predicting variations in weather from one year to the next would be of immense practical value, present techniques of examining the recurrent features of weather variability do not support the view that there are weather cycles which can be predicted with precision. Some consider that the relationship between sunspot activity and weather on earth is suggestive of cyclic cause and effect. The lack of wide support for this theory is in part a consequence of a lack of understanding of a physical mechanism connecting sunspot activity with variations in weather in different parts of the world. The numerous exceptions lead to further skepticism. At best, this relationship can be used for predicting a period of years but not a particular year.

Although agreement is lacking on when and why, there is little disagreement that conditions of drought will occur again. The probability is high that such conditions could occur in the near future. Certainly decisions concerning food production and conservation practices should consider this possibility.

Modern technology has not made agriculture weather-proof. On the contrary, many aspects of this technology have developed an agriculture with a high degree of weather sensitivity, a factor that should be considered when plans for world food supplies and agricultural reserves are developed.

The recent period of favorable weather may have led to the expansion of crop production into regions of marginal climate in semi-arid areas. The stress of less favorable weather may prove this to be unwise. The relaxation of good conservation practices in these areas may bring adverse results that will require many years to overcome.

Recent predictions of major climatic changes related to an increased particulate load in the atmosphere are of interest, but not widely accepted. There is speculation that the global cooling trend since the 1940's is a result of increased turbidity of the atmosphere. This increase is postulated to be a result of man's activity and an increase in the activity of world volcanoes. Some suggest that the current cooling trend is not just a climatic fluctuation but the beginning of another ice age. Such forecasts of climatic doom do not have wide support from climatologists.

The possibility that an impending drought can be deterred by weather modification activities is appealing. The rewards of positive results would be so great that there is merit in continuing investigations despite the fact that the results of cloud-seeding projects in non-mountainous areas are not encouraging, even with very favorable conditions for precipitation. Producing a significant increase in precipitation in times of drought does not appear at present to be a likely possibility.

Policy Framework for Land Resource Use and Protection Within the Agricultural sector

Since 1972, U.S. farmers, U.S. consumers of food and fiber, and the nation's land resources have been whiplashed by forces of inflation, energy shortages, foreign trade and unfavorable weather conditions. Consequences of these forces have: (1) depleted the U.S. food and feed reserves, (2) brought higher costs to farmers, (3) brought higher prices to consumers of farm products and (4) exposed our land resources to wind and water erosion plus related environmental deteriorations.

Interrelated forces affecting present and future land use, both man made and nature made, are intertwined in demanding responsive and deliberate policy actions. For example, droughts in Russia, South Africa and Australia contributed to the depletion of U.S. wheat and feed-grain stocks and sent prices skoyrocketing. Currency devaluations and efforts to ease balance of payment deficits through export of agricultural products have led to pressure for more intensive land use. Anchovy shortages off the coasts of Peru and Chile, coupled with an increase in price of petroleum, have brought shortages and sharp price increases in soybeans and cotton as protein, oil and fiber replacements. Thus, price and shortage of one product affect production and price of other products.

Futhermore, land uses become altered through principles of substitution and competition. For example, high wheat prices, particularly when accompanied by low feeder cattle prices, induce increased wheat production on marginal and fragile lands. The same reasoning applies to corn, soybeans, cotton and feed-grain lands. Most land uses are interlinked and shift back and forth in response to changes in product prices and factor costs emanating from foreign and domestic demands and supplies.

Serious questions arise concerning the impact of these external forces upon land and related natural resources. Our policies and management of land resources should take due recognition of the consequences of these impacts. A more active role must be generated through land-use policy and planning to cope with questions such as the following: (1) Will extension of wheat production into fragile lands set the stage for a new dust bowl? (2) How will uses of land emanating from balance of payments transactions involving agricultural products interfere with urban and recreational uses of land and the quality of water, air and other aspects of the natural environment? (3) How may these deleterious impacts be mitigated? (4) What are the trade-offs among numerous and often conflicting land uses?

These questions and possible consequences with adverse effects on farmers, consumers, and the land resource will continue in the years ahead unless measures are taken to limit and mitigate them. Agricultural policies born from the Great Depression to curtail agricultural production and to distribute income are ill adapted to the nation's present and prospective agricultural problems. New policies, geared and targeted to the new problem-set, must be innovated and applied now and in future years.

48-738—75 ——4

POLICY ELEMENTS

Three major policy elements may be identified in connection with the four goals in the introduction of this report that involve use and protection of our land base in the best interest of the nation and its people. Two major and complemenary policy elements are identified for domestic agriculture and one major policy element for our assistance to the hungry nations.

The *first major domestic policy element* is to estimate the limits of agricultural production in terms of high, low and intermediate levels. The high and low levels constitute possible parameters of production with the intermediate level being an in-between possibility. U.S. agriculture can neither feed the world nor bale out our balance of payments problems. However, it can meet the needs of U.S. citizens and, in addition, can make important contributions to world food and fiber needs and to the U.S. balance of payments. The crucial point is that the limits of agricultural production must be ascertained as a basis for policies which influence land use and its protection.

The *second major domestic policy element* involves actions to absorb and blunt the shocks occasioned by gyrations in prices and supplies of food and fiber that send shock waves through both producers and consumers of food and fiber.

The *third major policy element concerns* the hungry nations, and is to help them to help themselves. The old Chinese proverb remains applicable: "Give a man a fish, and he can eat a meal; teach a man to fish, and he can eat many meals." Obviously, the United States cannot feed the world from our resources. But the United States can, in tandem with other advanced agricultural and industrial nations, teach and help hungry nations to feed themselves through developing both their agricultural potential and their raw resources and manufactured products for export in exchange for food from the United States and other agricultural exporting nations.

These three highly interrelated policy elements constitute the foundations for U.S. agricultural policy geared to future national and world conditions.

POSSIBILITIES FOR EXPANDING CROPLAND

The possibilities for expanding the acreage of U.S. cropland are analyzed in Appendix Table 2. According to the Conservation Needs Inventory, it appears that an additional 264 million acres, representing a 56 percent expansion of current cropland, could be converted to cropland. This expansion consists of Classes I, II, and III land [1] not now in cropland but suitable for cultivation if improved and if managed properly to prevent erosion and deterioration. This potential cropland, as shown in Appendix Table 2, includes 124 million acres of forest land, 117 million acres of pasture and range land and 23 million acres of other land. These lands could be developed and converted to cropland within the next decade if needed.

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[1] The land capability classes referred to here are defined by the Soil Conservation Service as follows: Class I soils have few limitations that restrict their use. Class II soils have some limitations that reduce the choice of plant or require moderate conservation practices. Class III soils have severe limitations that reduce the choice of plants, require special conservation practices or both.

Adding this potential cropland to the present cropland base could substantially increase production according to estimates by the U.S. Department of Agriculture. The expected increase would depend on the realization of assumptions such as (1) favorable product prices, (2) adequate available supplies of inputs such as agricultural chemicals and energy at favorable prices, (3) normal weather conditions, (4) unrestricted use of lands and (5) increased use of technologies. These assumptions are important constraints in realizing potential increases in production for major food, fiber and feed crops.

Appendix Table 3 summarizes potential increases in production for five major crop categories by 1985. These increases are not predictions, but they do appear possible under the stated assumptions.

As shown in Appendix Table 3, average production in 1985 as compared with the 1969–71 average could increase 53 percent for corn, 52 percent for soybeans, 58 percent for feed grains, 65 percent for wheat and 62 percent for cotton. These estimates provide some idea of the magnitude of the production potential of U.S. agriculture in the near future. These estimates also provide a preview of the potential problems for U.S. agriculture if foreign and domestic demands do not materialize to absorb the large increases which could be produced. These estimates underscore the importance of guiding production potentials in light of demand through public policies and structures.

U.S. farmers and consumers may expect recurring export demands and prices that bounce briskly upward in years of world crop shortfalls, just as they did in 1972 and 1973. Then, once weather has become normal or favorable and other countries have replenished their stocks, our supply capacity will still be large enough to cause a sharp fall in prices of U.S. farm commodities. Hence, American consumers (in food prices) and farmers (in income) are faced with whiplash effects related to (a) weather, (b) inelastic food demands, (c) insufficient U.S. and world grain storage capacity and (d) outdated and transitory agricultural policies.

Future instability of food prices and farm income is likely to be extreme for the United States due to these conditions plus our own large supply capacity. However, as mentioned previously, excess supply capacity of our agriculture may well tend to decrease because of such factors as increases in export demand due to currency devaluation and growth in both world population and per capita incomes. But demand increases of the size we have witnesssed during the past two years are random or chance occurrences in the above setting and under normal world weather and supply conditions, and our producing capacity will be too large to maintain prices at or near recent levels. We are likely to go along with production at a reduced level under normal world weather—then suddenly be whiplashed again under conditions of drought coupled with greater demand inelasticity in other countries.

HIGH, LOW AND INTERMEDIATE LEVELS OF AGRICULTURAL PRODUCTION POSSIBILITIES

In an effort to suggest bounds on aricultural production as a basis for applying the policy elements described previously, Appendix Table 4 has been developed from the cropland acres shown in Appendix Table 2 and the yield levels shown in Appendix Table 3.

The low level in terms of acres required and production output, is shown as representing the average yields, acres and production of the 1969–1971 period. It would appear reasonable that domestic and foreign demand would not likely drop below the production shown for this level for the five crops considered in the example.

High level production involves substantial increases in acres and in yields under assumptions stated in connection with Appendix Tables 2 and 3. It represents an estimated upper bound on U.S. output for the crops considered. This upper bound would present the limit on which the base food aid to hungry nations and exports to help balance our trade payments with other nations.

The low and high levels of agricultural production possibilities involve the use of 258.5 and 333.9 million acres of land, respectively. This increase in acres devoted to the five crops by 1985 amounts to an additional 75.4 million acres which must be drawn from the other uses shown in Table 1 and Appendix Table 2. Such an increase would involve conversion to cropland of some marginal and fragile land that would require careful and expensive management to prevent deterioration of the soil and water resources and the natural environment.

Moreover, the increases in yields for these five crops to 1985 assume continued technological progress, availability of inputs, and prices and costs favorable to using the additional land and inputs to achieve the increased production. These estimates suggest the upper bound of productivity for the five crops which might be achieved within the next decade.

An intermediate level of production, between the low level and the high level, is also shown in Appendix Table 4. The intermediate level is represented by two sublevels. Sublevel A is estimated from acres included in the high level and yields included in the low level. Sublevel B is estimated from acres included in the low level and yields included in the high level. The variables of acres and yields responsive to conditions affecting each would appear to represent the production possibilities affecting the intermediate level of production under various conditions of prices, costs, weather, etc.

The values shown in Appendix Table 4 are not to be regarded as refined figures arrived at through exhaustive analysis. Rather they should be considered as illustrations of the kinds of information required to form and test policy designed to serve the aforementioned objectives within various mixes of conditions affecting agricultural production.

AGRICULTURAL LAND USE POLICY WITHIN NATIONAL LAND USE POLICY

Agricultural land uses must necessarily be reconciled with demands of industrial, transportation, housing, trade, recreational and other uses. Many of these uses are complementary to agricultural land uses. Other uses are conflicting between agriculture and uses by other sectors.

Initially, the nation needs a national land policy whereby all uses for lands are considered and guided toward national objectives. Until national land policy is enacted, urban residential and industrial uses, for example, will continue to sprawl into open areas in chaotic fashion.

For several years, national land policy legislation has languished in the Federal Congress. Important elements of national land use policy as embraced in Senate Bills 632 and 992, introduced in the first session of the 92nd Congress, have remained alive but have not been developed through congressional and executive action.

Within the orientation provided by national land use policy, agricultural land use policy can be developed within the agricultural sector as an inherent part of total land use policy. Agriculture has much to gain as well as much to contribute to the development of such national policy.

PRIVATE, GROUP AND PUBLIC RESPONSIBILITIES IN MAINTAINING AND IMPROVING AGRICULTURE LAND RESOURCE PRODUCTIVITY

Since most of the agricultural lands are in private ownership, problems arise concerning public intervention on private land. Conversely, private exploitation and deterioration of natural resources affect the public interest.

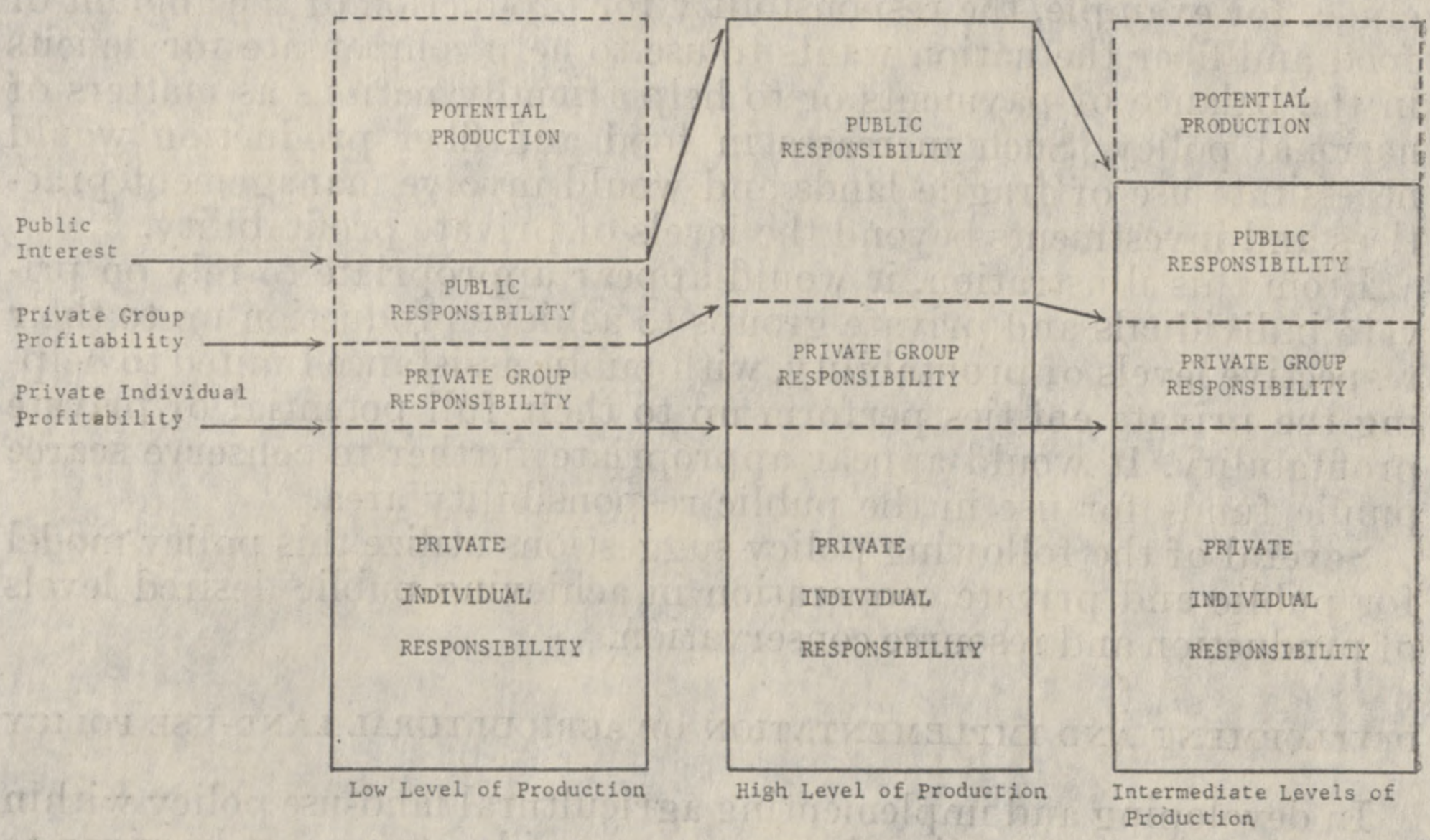

FIGURE 1.—Schematic diagram of policy framework for public and private cooperation in programming and implementing agricultural land-use policy.

Figure 1 diagrams a policy framework for defining and carrying out private and public responsibilities on private land using the three levels of production suggested in Appendix Table 4 as an example. In the Figure 1 policy example, a combination of private, group and public responsibilities and participation would be involved in achieving the three levels of production. Assumptions in this reasoning, supported by research, are that the productivity of individual farms, ranches and plantations can be carried to the level of private profitability as a private responsibility. Certain individual farmers, of course, may not move to this level because of imperfections such as lack of credit, uncertainty, rental arrangements, uneconomic farm size, lack of information and the like. But the public role within the

private responsibility zone is one of helping ameliorate these specific obstacles preventing individual farmers from moving to the level of private profitability.

Beyond the level of private profitability, farmers may work together as groups in watershed, conservancy, drainage and irrigation districts and other group forms of resource management. Additional production and safeguards to the soil resource may thus be achieved up to the level of private group profitability, which is designated as private group responsibility. Here the public role is to help the group of farmers organize and manage their resources within the level of private group responsibility.

Beyond the levels of private individual and private group responsibilities, additional production and protection to the land resource involve public responsibilities up to the level of the public interest to be achieved. Since the levels of production desired by the public go beyond what the private individual or private group can achieve at profitable returns to them, the public must help bear the cost.

Public responsibility under the high level of production would include, for example, the responsibility for production of the amount of food and fiber the nation wants to use to help compensate for deficits in the balance of payments or to help friendly nations as matters of national policy. Such increases in food and fiber production would necessitate use of fragile lands and would involve management practices and investments beyond the levels of private profitability.

From this illustration, it would appear appropriate to rely on private individuals and private groups to achieve production up to their respective levels of profitability, with public assistance limited to helping the private entities perform up to their full potential of private profitability. It would appear appropriate further to conserve scarce public funds for use in the public responsibility area.

Several of the following policy suggestions utilize this policy model for public and private cooperation in achieving public desired levels of production and resource conservation.

DEVELOPMENT AND IMPLEMENTATION OF AGRICULTURAL LAND-USE POLICY

In developing and implementing agricultural land-use policy within a national land-use policy framework, consideration must be given to the nature and diversity of soils, water availability and climatic conditions throughout the nation. Soil and water use standards must necessarily be varied to conform with varying conditions.

Aside from the physical conditions, development and implementation of agricultural land-use policy must enlist the participation of all interested and affected citizens in planning and carrying out policies and programs.

Additional considerations in developing and carrying out agricultural policies generated around the three major policy elements discussed on preceding pages include the following:

1. *Price floors for farm products* would have the desirable effects of blunting the impact of external forces on farm income and of stabilizing production.

2. *Crop insurance for crop production* would have the same desirable effects. Price floors and crop insurance are two sides of the same coin of income to the farmer and flow of food and fiber to consumers. High prices of products without production are meaningless. Production stranded by prices below production costs will not encourage stability of production to meet the nation's needs.

3. *National reserves of agricultural products, adequately managed, are desirable* because of the unpredictability of natural phenomena. It seems prudent to maintain a minimum supply of food and feed grains to tide the nation over domestic shortfalls. However, such reserves should preferably be considered as national insurance against shortages, with their management being arranged in a manner that will not pass costs directly or indirectly to farmers.

4. *Agricultural policy should preferably differentiate between income distribution and production measures* and not permit one to interfere with the other. Past agricultural policy has tended to confuse these two concepts and to bring about consequences inconsistent with either concept.

5. Also, *agricultural policy should preferably differentiate between production and conservation investments* in land resources. Production investments, defined as inputs that will increase production in a given framework (e.g., adding nitrogen fertilizers), are reversible and are largely the responsibility of individual farm owners and operators. Conservation investments, defined as inputs that will change the production framework to a higher level or prevent it from falling to a lower level (e.g., terracing) are irreversible and largely the responsibility of society. In past policy, the two concepts have been confused and confounded.

6. More attention to removing uncertainty from agricultural policy and programs through *forward programming, program continuity and timely announcements* of changes would be desirable.

7. Agriculture possesses considerable *capacity to absorb the unemployed* in improving and developing the natural resources through conservation investments of labor (item 5).

8. Although federal investments in natural resources are appropriate to maintain and improve productivity in terms of conservation investments (item 5), it is also appropriate that guarantees be provided that such public investments are maintained, particularly when made on private lands.

9. State enabling legislation, where needed to validate and protect the public interest, may well become a prerequisite for federal investments and other types of public activity.

10. Finally, the research and educational foundations necessary for development of these concepts and the mechanisms necessary to apply them and to carry them out will require adequate funding.

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[From Headquarters Office : Department of Agronomy, Iowa State University, Ames, Iowa]

APPENDIX TABLES

TABLE 2.—CURRENT AND POTENTIAL CROPLAND IN THE UNITED STATES

Current cropland [1]		Potential cropland sources [2]		Current and potential cropland (millions of acres)
Uses	Millions of acres	Uses	Millions of acres	
Cropland used for crops	333	Forest land	124	
Soil improvement and idle	51	Pasture and rangeland	117	
Cropland pasture	88	Other land	23	
Total	472	Total	264	736

[1] Based upon 1969 U.S. Census.
[2] Based upon conservation needs inventory, Soil Conservation Service, U.S. Department of Agriculture, 1967. Includes class I, II, and III land not now in cropland but suitable under certain management limitations for regular cultivation if improved. Excludes Alaska and Hawaii.

48-738—75——5

TABLE 3.—ACTUAL AND POTENTIAL PRODUCTION OF 5 MAJOR CROPS[1]

Year	Corn			Soybeans			Feed grains (including corn)			Wheat			Cotton		
	Acres (millions)	Yields (bushels per acre)	Production (billions of bushels)	Acres (millions)	Yields (bushels per acre)	Production (billions of bushels)	Acres (millions)	Yields tons per per acre)	Production (millions of tons)	Acres (millions)	Yields (bushels per acre)	Production (billions of bushels)	Acres (millions)	Yields (pounds per acre)	Production (millions of bales)
1969–71 average	58.7	82.2	4.8	42.1	27.4	1.2	100.4	1.18	118	46.1	31.9	1.5	11.2	437	10.2
1972	53.3	96 9	5.2	45.8	28.0	1.3	94.1	2.13	200	47.3	32.7	1.5	13.2	507	13.7
1973	61.5	93.8	5.8	56.2	28.5	1.6	102.4	2.05	210	53.7	32.2	1.7	12.4	502	12.9
1980	73.7	109.5	8.1	64.1	32.0	2.1	114.7	2.47	283	62.3	34.5	2.2	14.1	510	15.0
1985	75.5	120.0	9.1	65.7	34.5	2.3	115.7	2.72	315	62.3	36.6	2.3	14.7	535	16.4
Percent increase in potential production in 1985 over 1969–71 average			53.0			52.0			58			65.0			62.0

[1] Adapted from "The Farm Index," Economic Research Service, U.S. Department of Agriculture, vol. XII, No. 12, December 1973.

TABLE 4.—HIGH, LOW, AND INTERMEDIATE LEVELS OF PRODUCTION FROM 5 MAJOR CROPS IN THE UNITED STATES BY 1985 UNDER DIFFERENT ASSUMPTIONS

Crop	Low level of production [1]	High level of production [2]	Intermediate levels of production [3]	
			A	B
Corn:				
bushels (in billions)	4.8	9.1	6.2	7.0
acres (in millions)	58.7	75.5	75.5	58.7
Soybeans:				
bushels (in billions)	1.2	2.3	1.8	1.4
acres (in millions)	42.1	65.7	65.7	42.1
Feed grains (including corn):				
tons (in millions)	118.0	315.0	136.0	273.0
acres (in millions)	100.4	115.7	115.7	100.4
Wheat:				
bushels (in billions)	1.5	2.3	2.0	1.7
acres (in millions)	46.1	62.3	62.3	46.1
Cotton:				
bales (in millions)	10.2	16.4	12.8	12.0
acres (in millions)	11.2	14.7	14.7	11.2
Acres harvested (in millions)	199.8	258.4	258.4	199.8

[1] Derived from 1969–71 averages of acres, yields and production.
[2] Derived from increases in acres and in yields per acre.
[3] A is derived from the high level acres and the 1969–71 average yields, and B is derived from the 1969–71 average acres and the high level yields.

U.S.D.A. STAFF EVALUATION OF THE REPORT "LAND RESOURCE USE AND PROTECTION"

FEBRUARY 20, 1975

HON. HERMAN E. TALMADGE,
Committee on Agriculture and Forestry,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: We appreciate the opportunity to make a staff evaluation of the report, "Land Resource Use and Protection," prepared for your Committee by the Council for Agricultural Science and Technology. Our evaluation is enclosed.

You will understand that our comments are those of the Soil Conservation Service only, and we have purposely limited our responses to those portions of the report that are related to our agency's areas of expertise and responsibility.

Sincerely,

NORMAN A. BERG,
Acting Administrator.

[Enclosure:]

COMMENTS OF THE SOIL CONSERVATION SERVICE ON "LAND RESOURCE USE AND PROTECTION" *

The Soil Conservation Service commends the scientists who comprised the task force of the Council for Agricultural Science and Technology for their scholarly and thoughtful paper entitled "Land Resource Use and Protection."

The Service agrees wholeheartedly with the need for careful study and examination of the impact of expanding crop production on the Nation's soil and water resources. We also agree that it is just as essential to protect these basic resources adequately as it is to increase our production of food and fiber to meet increasing domestic and foreign demand. Finally, we agree that adequate resource protection will not be attained without clear public policies and action programs.

The concern of the Soil Conservation Service, and of the U.S. Department of Agriculture as a whole, for encouraging farmers and ranchers to apply conservation measures as they increased farm output was expressed in a nationwide campaign begun in the fall of 1973 under the slogan, "Produce More, Protect More." It was carried on in close cooperation with the National Association of Conservation Districts and with many state conservation district associations.

The campaign was launched on September 10, 1973, with an address by Assistant Secretary of Agriculture Robert W. Long, to the Iowa Association of Soil Conservation District Commissioners, in Des

*Prepared by the Council for Agricultural Science and Technology.

Moines. In his talk, Mr. Long called for higher farm production, but cautioned that "it is equally important" for farmers to do careful conservation planning.

"This is no time to have a Great Plow-up followed by a Great Washaway," he declared. "If our soils become pollutants instead of a resource, the long investment that we and you have made will go down the drain and a good many futures with it."

Subsequently, in a USDA press release issued October 5, 1973, Secretary of Agriculture Earl A. Butz called on farmers "to use sound conservation practices on cropland that is being brought back into production in 1974."

Since that time, thousands of SCS employees and conservation district supervisors have employed personal contacts, public meetings, news stories and articles, and radio and television broadcasts to encourage farmers and ranchers to improve and expand soil and water conservation programs on their land.

But intensive as those efforts were, they evidently were insufficient, as demonstrated by a USDA survey of conservation on acres brought back into production in the 1973–74 growing season. As the CAST report points out correctly, some four million acres of this newly converted land lacked measures adequate to protect them from soil erosion.

Details of the results of this study have just been published in the January-February issue of the Journal of Soil and Water Conservation, in an article, "Erosion in 1973–74: The Record and the Challenge," by SCS Administrator Kenneth E. Grant. A copy of this article is enclosed for information.

The Soil Conservation Service staff examined the statistics used in the CAST report and found them to be generally accurate, with valid conclusions drawn from them, in most cases. To be specific, SCS agrees with the following general findings of the report:

1. Despite a significant effort by Americans to reduce soil erosion since the 1930's, the problem is still a serious one.
2. Attaining higher farm production at reasonable cost will require wise land use, including application of appropriate conservation management systems.
3. Land shifted out of agriculture is often of high quality, and there is little probability that it will ever be returned to agriculture.
4. While average crop yields may increase over the short run where there are excessive soil losses, erosion will decrease the yield and increase production costs over the long run.
5. Soil erosion creates a serious sedimentation problem. In terms of volume, sediment is by far the major pollutant of surface waters.
6. In recent years, there has been a shift away from crop rotation in some areas toward a continuous single crop or rotation of two intensive row crops, like corn and soybeans.
7. Several disturbing trends have been observed in the Great Plains which could create serious dust storms in years of drought and high wind.

8. Decisions concerning food production and conservation practices should take into account the probability of adverse weather conditions, including drought, heavy rains, and flood. Conservation practices should be planned to withstand these times of adverse weather.

In several specific instances, the SCS staff is not in complete agreement with the findings and emphasis of the CAST report. In other instances, our staff found it necessary to amplify the report's conclusions. Admittedly, it is difficult to generalize about conservation in a multistate region, much less in the nation as a whole.

We are not all certain that anti-erosion "efforts by land owners, farm operators, and government programs have not kept pace with the pressures of land use," as the report states. SCS would say instead that while gains have not been spectacular, the soil conservation districts, SCS technicians, and conservation researchers have proved themselves flexible and innovative in meeting changing conservation challenges and in keeping pace with altered farm technology and changing land use patterns in the United States. This is not to say that the pace could not or should not be accelerated. But most observers at the district level do not believe that we are slipping behind in conservation work.

It is true that this is a period of intense change in agriculture, but conservation practices are also changing. The CAST report notes that more soil is exposed to the threat of erosion as farmers move toward more intensive cropping systems. It should be added, however, that various minimum tillage practices, including no-till farming, tend to reduce exposure of soil to wind and water. Minimum tillage practices are among the fastest growing conservation practices in the country, and are being used and accepted by more farmers every year. During fiscal year 1974, SCS helped farmers to adopt minimum tillage techniques on an additional 2.5 million acres, bringing the cumulative total of cropland acres under such practices to more than 32.6 million.

SCS has found that a farmer going from no conservation treatment at all on cropland to minimum tillage generally reduces soil losses by one-half. And soil losses under no-till, which presently comprises about 12 percent of minimum tillage practices in the United States, are almost negligible—far below what SCS has traditionally defined as "allowable soil loss limits." Further research and experience with various types of minimum tillage hold forth more promise for reducing erosion on cropland than any other conservation development in recent years.

Another fast-growing conservation practice is the installation of parallel terraces with tile outlet drainage. In many instances these are replacing conventional terraces to accommodate larger equipment, while providing improved soil protection. Four thousand miles of parallel terraces were installed with SCS technical help in fiscal year 1974, raising the total miles of parallel terraces to more than 86,000.

And while SCS is aware that a number of obsolete or aging field windbreaks, or shelterbelts, have been torn out in recent years, it also finds that many are being replaced by new and more effective windbreaks. During fiscal year 1974, SCS field people assisted farmers and ranchers with planting of nearly 2,600 miles of new field windbreaks,

as well as some 46,000 acres of windbreaks to protect farmsteads and feedlots. What we are witnessing is a change from one type of conservation practice to another, and not the abandonment of a practice.

In the section on "Crop Rotations," the CAST report observes that "wheat production in the Great Plains has become more intensive by the growing of wheat every year rather than using summer fallow every other year." In the opinion of SCS staff people, even if the substitution of annual wheat production for summer fallowing is occurring, some summer fallowing remains a serious erosion hazard. Wind stripcropping, stubble mulching, and wind barriers properly applied are presently the best remedies against wind erosion. Contribution to the problems of establishing and maintaining these practices have been larger machinery, labor shortages, and absentee ownership of wheatland.

In the same section, the CAST report states that "ways are needed to reduce intense row crop production on highly erodible land." In the opinion of the SCS staff, the problem is not one of lack of knowledge, but rather one of obtaining compliance and providing sufficient economic incentives to landusers. Many farmers presently feel that they have no choice but to use such soils for row crop production.

SCS also questions the emphasis of the report in its discussion of "another dust bowl." There are indeed many farm and ranch practices in the Great Plains which could help create severe dust storms, particularly in time of drought. Many of these practices are enumerated by SCS in its fall and winter reports on wind erosion conditions in the Great Plains states.

Helping to counterbalance these threats, however, are the steady gains for conservation being made under the Great Plains Conservation Program. The CAST report notes this, and points out that the program "has done much to enhance the control of wind and water erosion."

We would add that it holds forth the promise of greatly diminishing the threat of another "dust bowl" in the Great Plains. While nothing can be done about periodic drought in the plains states, we can help bring about those conservation programs that can help assure a virtual end to the kind of disastrous soil erosion which took place in the 1930's.

SCS field experience with this program since 1957 leads our staff to this optimistic conclusion. An exhaustive evaluation of the Great Plains Conservation Program, published in May 1974, showed that the use of cost-shares in the program has resulted in a reduction of erosion by about 221 million tons per year in the region. The Federal cost-share per tons of erosion reduction achieved was found to be about five cents.

This would appear to be a very low cost for preventing the loss of such a valuable resource.

The success of the Great Plains program illustrates a point which SCS believes received insufficient recognition in the CAST report. While the scientists who prepared the report are correct in calling for additional inputs for research and education, we would like to point out in addition the necessity for transferring the information about conservation techniques and soils technology to the actual situation

on each farm or ranch. Experience in the Great Plains program has demonstrated beyond question the effectiveness of on-the-ground technical assistance and long-term conservation agreements with landowners. The procedure developed by SCS and the conservation districts of applying a whole system of conservation management practices, tailored to the specific soils and other features of each operating unit, is a unique one. Without long-term agreements and this type of technical assistance, research findings, no matter how well publicized, frequently fail to be transferred to the land.

While SCS was able to verify most statistics used throughout the report, we were unable to substantiate the figures used in a statement on page 10, paragraph 3,[1] which compared "adequately treated" land in three states in 1958 and 1967.

According to our Conservation Needs Inventory, the sentence should read: "In 1958, the percentages of highly erodible cropland with adequate treatment in Indiana, Illinois, and Iowa were *36%*, *42%*, and *30%*, respectively. In 1967, corresponding percentages were *28%*, *34%*, and *34%*." These changes alter the comparisons significantly.

It should be understood, of course, that much of the land classed as "inadequately treated" in the Conservation Needs Inventory had some conservation measures installed. While some of these lands may have had very little protection, others had up to 80 or 90 percent of the needed treatment applied.

On page 9,[2] the last sentence on the page should read: "Modern soil surveys have been completed on about *55%* of the land area in the *50* States."

On page 5 [3] and at several other points, the report refers to an additional "264 million acres" of potential cropland on privately owned lands in the 48 contiguous states, over and above what is being used today. This figure, in the opinion of SCS, should be used with caution, since it includes land in farmsteads, farm lanes, hedgerows, and many small parcels not suitable for modern machine cultivation. A realistic figure for potential cropland would be somewhat smaller.

SCS and the Economic Research Service have calculated that only about 100 million acres of Class I, II and III land could be converted to cropland in a relatively short time—such as a year. This is mostly grassland in the Plains, Corn Belt, Atlantic Central Plain, and the Piedmont.

Another 55 million acres with drainage problems could be brought into crops, but it would take more than one year. These acres, in the main, are in the Atlantic Coast Lowlands and Coastal Plain, Mississippi Delta, Corn Belt, Great Lakes States, and Florida. Probably an outside estimate, considering the most favorable price-cost relationship, would be an additional 200 million acres of cropland.

Substantial increases in cultivated lands, of course, would come only with expectations on the part of farmers and prospective farmers of substantial profit for a number of years. Conversion of pasture and rangeland would necessitate a reduction in beef operations in many areas. A substantial investment also would be required in draining wetlands.

These more conservative estimates, of course, underscore the necessity for taking good care of the cropland resources now in use.

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[1] See p. 13, paragraph 4 of this report.
[2] See p. 13, paragraph 1 of this report.
[3] See p. 10, paragraph 1, of this report.

Beginning on page 22,[4] the report cites a series of considerations for development and implementation of agricultural land-use policy. While the content of several of these falls outside the purview of the Soil Conservation Service, a number of the considerations are related to our work or that of conservation districts.

We agree in principle with the objective set forth in Item 5 and we believe that the Great Plains Conservation Program is an example of an act which differentiates very well between short-term production investments and longer-term conservation investments. But even in this 18-year-old program, such distinctions occasionally become clouded.

For example, the success of many of the long-term conservation systems and structural measures depend on the year-to-year maintenance by the landowner. What is long-term and what is short-term become intermixed. Unless policies are specific as to which investments are to be considered as "production" or "short-term" and which are "conservation" or "long-term," confusion will continue to ensue.

SCS also concurs with the intent of Item 6, but we point out that conservation programming and planning should be based on up-to-date inventories of actual conditions on America's farms and ranchlands. The Conservation Needs Inventory, last updated in 1967 and quoted several times in the CAST report, is already more than 7 years old. Much of the material needs to be updated. Soil surveys, urgently needed to identify the best farmland for crops and other purposes, also need to be accelerated. There is a need for more up-to-date facts on which to base our land use decisions and future programming.

Item 7 notes that agriculture possesses considerable capacity to absorb the unemployed in improving and developing the natural resources through conservation investments of labor. This is undoubtedly true, although SCS would add the ranks of the "underemployed" to those of the unemployed, and point out that the conservation districts, as well as SCS, have a potential for providing useful and necessary work in practically all of the conservation and community improvement programs with which we are associated.

SCS also agrees with Items 8 and 9. In connection with Item 9, soil conservation district enabling legislation presently on the books in each state provides a vehicle for protecting the public investment in soil and water conservation.

Finally, SCS concurs with Item 10, but would expand the term "research and educational foundations" to "research, educational, and technical assistance institutions. . .", for reasons explained earlier in this commentary.

In conclusion, it should be pointed out that a growing number of groups, both within and without the government, are giving attention to many of the same questions about soil and water conservation demands on our land base that are considered in the CAST report.

One is the 1975 National Water Assessment, an undertaking of the U.S. Water Resources Council which includes the development of an agricultural resources assessment model. This model is a cooperative project of the Center for Agricultural and Rural Development at Iowa State University and a number of governmental units, including the Soil Conservation Service. This assessment should provide sound information about the Nation's land and water resources.

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[4] See p. 24, paragraph 7, of this report.

A significant study already published is *Agricultural Production Efficiency*, published this year by the National Academy of Sciences. The scientists who prepared that study considered the question of whether the United States is reaching the end of its period of phenominal growth in farm output. They concluded that "we see no way to avoid the problem of basic uncertainty about the future." Among the limits on production they considered were environmental constraints on opening additional land to cultivation.

Also concerned with policies and regulations affecting soil erosion is the Environmental Protection Agency, which is currently exploring standards for non-point source pollution with USDA and the National Association of Conservation Districts. EPA hopes to involve districts in the development and application of these standards.

EROSION IN 1973–74
THE RECORD
AND
THE CHALLENGE

EROSION IN 1973–74: THE RECORD AND THE CHALLENGE

[By Kenneth E. Grant, Administrator, Soil Conservation Service,
U.S. Department of Agriculture]

The 1973–74 growing season in many ways was not a good one for the nation's soil and water resources.

Excessive soil erosion from both wind and water accompanied the efforts of many farmers to increase crop production.

Contributing to the year's poor record was some of the worst weather in years. But severe erosion could also be traced to the unwise selection of certain soils for cultivated crops, as well as the existence of too few conservation measures on the land.

The vagaries of the weather ranged from a fall and winter drought in the southern high plains to spring floods in the northern Great Plains. In parts of the Corn Belt, torrential rains deluged fields in the spring—at the worst possible time—only to be succeeded by prolonged drought.

In all parts of the country, there were farmers who ignored the lessons of history—not to mention the data contained in soil surveys—and who planted crops where it was practically impossible to protect soil from washing or blowing. Some farmers lacked the time, money, or incentive to protect their fields with appropriate soil and water conservation. It was a year in which too many farmers gambled with their basic resources and lost. The debt will be a long time being repaid.

One fact that emerges clearly from the year's experience is that the need is more urgent than ever to increase permanent conservation practices on America's farms and ranches before even *more* damage is done to our agricultural resource base.

Another fact is that last year's difficulties already have prompted thousands of farmers and ranchers to step up conservation work. Report from State Conservationists of the Soil Conservation Service reveal a new surge of interest in stubble mulching, minimum tillage, and no-till farming. They also report widespread construction of such conservation measures as terraces and field windbreaks. Evidently many farmers were sufficiently disturbed by the 1973–74 erosion warning signs to respond to the threat with greater soil conservation efforts.

The year's erosion record did not come as a total surprise to conservationists. On February 14, 1974, the Soil Conservation Service delivered an ominous forecast of the erosion outlook for cropland newly converted from pasture, woodland, and set-aside acreage. Based on USDA surveys in the field SCS predicted that some 9.5 million acres were going to convert to cropland in the spring of 1974 and that some 4 million acres of this total were going to be subject to erosion losses of more than 4 tons per acre.[1]

[1] Up to "5 tons per acre per year" for most soils is considered an "allowable loss limit" by the Service.

The same forecast pinpointed several areas where severe erosion on newly plowed acres seemed likely. Among these regions were the drought-stricken high plains of Oklahoma, Texas, New Mexico, and the Corn Belt, where thousands of additional acres of land—some of it rolling land—were expected to be planted to crops. Other probable trouble spots, SCS predicted, could be the Palouse in the northwestern United States and the Piedmont and Coastal Plains of the Carolinas. Unfortunately for America's resources, these forecasts proved all too correct.

One purpose behind publication of the erosion outlook last February was to stimulate farmers, USDA employees, and local conservation district officials to intensify efforts to get new cropland acres under conservation plans. In the short time remaining before planting, the Service wanted to see as many measures applied as possible to stop excessive soil erosion. The agency also wanted farmers and ranchers to give careful consideration to the characteristics of their soils before they took acres out of grass and put them into corn, wheat, or soybeans.

A major campaign aimed at accomplishing this end had been set in motion by the Department of Agriculture several months prior to the February 14 warning. Shortly after the Department's announcement that farmers would be free to plant as many acres of wheat, corn, and feed grains as they wished during the 1973–74 season, SCS began work on a "Produce More, Protect More" campaign to be pursued at national, state, and local levels.

From the outset, planning and execution was carried on in close cooperation with the Extension Service and the National Association of Conservation Districts. The primary aim of the campaign was to encourage farmers to apply sound conservation practices on land newly planted to crops.

The drive was launched on September 10, 1973, with an address by Assistant Secretary of Agriculture Robert W. Long. He spoke on "A Challenge to Produce and Protect," before the Iowa Association of Soil Conservation District Commissioners, in Des Moines.

In his talk, Mr. Long called for higher farm production, but he cautioned that "it is equally important" for farmers to do careful conservation planning.

"This is no time to have a Great Plow-up followed by a Great Wash-Away," he declared. "If our soils become pollutants instead of a resource, the long investment that we and you have made will go down the drain and a good many futures with it."

Subsequently, in a USDA press release issued October 5, 1973, Secretary of Agriculture Earl A. Butz called on farmers "to use sound conservation practices on cropland that is being brought back into production in 1974."

Secretary Butz said that while there is enough potential cropland available that can be erosion-proofed, "there are also millions of acres of farm and ranch land with soils so prone to blowing or to water erosion that they should never be used for crops. Such land should remain in grass or under other vegetative cover. We do not want to risk starting another Dust Bowl."

The Secretary's message to farmers was re-emphasized in an editorial published in the November–December 1973 issue of the Journal of Soil and Water Conservation in which he stated: "Soil that cannot adequately be protected from soil erosion by wind or water should be nailed down with grass or trees and kept that way."

Information materials in support of the Department's "Produce More, Protect More," campaign poured into the field during the next few months. They include tens of thousands of color posters, exhorting producers to "get your land under conservation plan"; public service radio and TV announcements; newspaper and magazine articles; and a picture story for editors, used by many of the country's most influential publications for farmers. Suggestions to farmers and ranchers also were included in packets to producers from USDA's Extension Service.

The impact of these national campaign efforts was multiplied many times over by publicity and face-to-face meetings with farmers by district level employees of SCS, county agents, and district officials. And many of these efforts seemed to bear fruit.

To cite but one example, the SCS area conservationist serving Northeast Nebraska reported that USDA field employees in his area had discussed the merit of reduced tillage with 938 farmers during February and March. Of those contacted, 399 said that they planned to reduce the number of tillage operations this year on a total of 76,000 acres.

During those two winter months, area newspapers published 307 stories on reduced tillage; 22 newspapers carried full-page advertisements on the subject; 157 radio and TV spots and programs were broadcast; 15 ASCS newsletters carried campaign material. One natural resource district in the area—the Lower Elkhorn NRD—alone spent more than $1,600 for radio and TV time to promote minimum tillage.

But laudable as these local efforts were—and there were hundreds comparable to the Lower Elkhorn campaign—they evidently weren't good enough, particularly on acres of "new" cropland.

In July of this year, thousands of SCS and other USDA field employees carried out a second survey to determine the conservation treatment and soil losses on acres converted to crops in the 1973–74 season.

Their findings show that 3.6 million acres were switched from grassland to crops, 0.4 million from woodland, and 4.9 million from idle cropland and land withheld from crop production under Federal programs. The total acreage converted to crops, according to the survey, was 8.9 million.

Of this total, about 5.1 million converted acres—more than half—had inadequate conservation treatment and water management. Of these, 4 million acres had inadequate erosion control.

Total tons of soil lost on the 8.9 million acres amounted to about 60 million tons for the 1973–74 season, over and above the estimated soil loss that would have occurred had the land not been converted. Some 13 million tons of soil were eroded by wind; 47 million tons were eroded by water. Most of this loss occurred on land that had received

inadequate conservation treatment; these lands experienced an average soil loss of over 12 tons/acre/year.

Areas with new cropland in trouble were widely scattered over the country. In the Corn Belt, SCS estimates that 390,000 acres of converted land experienced soil erosion ranging from 15 to 100 tons/acre/year. These losses were over and above those that would have occurred had the land not been converted to crops.

The western Great Plains of the Dakotas, Montana, Wyoming, and eastern Colorado suffered severe wind and water erosion on about 325,000 converted acres, where soil losses ranged from 5 to 40 tons/acre/year.

The eastern Great Plains, including much of Nebraska, Kansas, and South Dakota, experienced severe erosion ranging from 5 to 55 tons/acre/year on about 260,000 converted acres. Areas around the Great Lakes had soil losses of from 5 to 55 tons/acre/year on about 195,000 converted acres.

The southern Coastal Plains of Florida, Georgia, Louisiana, Alabama, and Mississippi had severe water erosion on about 210,000 acres of new cropland, with losses ranging from 5 to 70 tons/acre/year.

Other trouble spots for converted acres included the Palouse of the Northwest, with losses ranging from 5 to 75 tons/acre/year on 35,000 acres; the eastern Piedmont and coastal plains from Pennsylvania south to the Georgia line, with losses of from 5 to 30 tons/acre/year on 70,000 acres; the Mississippi Valley silty uplands of west Kentucky, Tennessee, and Mississippi, with water erosion of from 5 to 60 tons/acre/year on 56,000 acres; and the central farming area of Kentucky and Tennessee, where severe water erosion on 35,000 acres resulted in losses ranging from 5 to 40 tons/acre/year.

Compared to *total* erosion in the southern high plains, the acreage of new cropland damaged was slight, but that was only because very little acreage was converted to crops in 1973–74; on that acreage, soil losses were very heavy. Fifty thousand acres of new cropland experienced losses from wind erosion of from 15 to 140 tons/acre/year.

Of particular concern on acres newly converted to crops from grassland is the fact that erosion is normally lighter the first year after cultivation than in succeeding years. The fibrous root structure of native grasses helps bind soil particles for a year or two or more. As this fiber slowly breaks down with time and tillage, we can expect the erosion hazard on these acres to increase unless measures are taken to protect them.

Soil erosion in excess of "allowable loss limits" during the past year was not limited, of course, to newly converted cropland, but no nationwide survey was conducted last year with respect to losses on older cropland. The last exhaustive survey of the condition of America's farmlands was the 1967 USDA Conservation Needs Inventory (CNI). That survey, it may be recalled, reported that "judged against current standards, 64 percent of cropland needs additional conservation treatment."

The CNI report further stated: "Although we have abundant soil resources for foreseeable future needs, three-fifths of locally controlled land is not being cared for in a way that protects the soil resource for sustained production."

It is almost axiomatic that when substantial changes in agriculture take place—as they have in the United States in recent years—there is a time lag between the production changes and the conservation response to those changes. That was certainly apparent in the findings of the Conservation Needs Inventory, which demonstrated once again that putting conservation measures on the land is not a "one-shot" affair. It is a continuing task and one in which the techniques are constantly undergoing change as the methods of farm production change. It is no more possible to "complete" the job of soil and water conservation and management than it is to "complete" the education of the young or the conquest of illness.

The inadequacy of conservation on the land—both old and new cropland—showed up all too clearly in two areas during 1973–74 that were hit hard by adverse weather. One was the southern high plain, involving parts of Oklahoma, Texas, and New Mexico; the other was Iowa.

The southern plains were hit hard by drought, with a total of 2.7 million acres damaged by wind. Texas alone reported more than 2 million acres damaged by erosion. This was more than half the damage reported for all ten Great Plains states during the 1973–74 blowing season.

Even more land in the southern high plains was reported as "in condition to blow"—nearly 6.2 million acres—but, fortunately, many of the prolonged 40–60 mph windstorms that strike the Plains so often in February and March failed to materialize in 1974.

According to SCS field reports, the major contributing factors to wind erosion in Oklahoma, Texas, and New Mexico this past year included besides lack of moisture, lack of residues, land clean tilled for seedbed preparation, unsatisfactory tillage operations, poor soil structure, and excessive grazing. The report demonstrate what conservationists learned so often during the last 40 years; Man can do practically nothing to control the weather, but he can do a great deal to mitigate its impact on the land . . . or to worsen it.

Water erosion also took a heavy toll of old and new cropland in several parts of the United States, but no state suffered more severe damage during the past year than Iowa. According to personal observations of SCS State Conservationist Wilson Moon, "Erosion in Iowa was the worst in about a quarter of a century."

More than one third of the state declared a disaster area following torrential thunderstorms, floods, and tornadoes during May and June. SCS inspections revealed that about 4.5 million acres of Iowa's 20.7 million acres of corn and soybean land suffered severe erosion of more than 10 tons per acre. Soil losses of 40 to 50 tons per acre were not uncommon, and some farms experienced the staggering loss of 200 tons of soil per acre.

Besides the loss of topsoil, seed was washed out, fertilizer lost, crops covered with mud, and ditches and waterways plugged or eliminated. Why did it happen? Can we blame all our troubles on the weather? Don Muhm, farm editor of the Des Moines Register and an experienced observer of Iowa agriculture, is one man who doesn't think so.

"There is no way of measuring the damage to this year's crops or to future crops," he wrote in the May 26, 1974, Sunday Register, "be-

cause landowners failed to construct enough terraces or utilize sufficient strip-cropping or other means to protect the soil resource."

We agree. It is true that really severe soil erosion generally occurs during extreme weather conditions, and in a very short period of time. But erosion control measures, if they are going to provide producers with adequate protection, simply cannot be predicated on average rainfall or typical windstorm velocities and durations. Soil conservation measures must be planned and installed to protect resources, not against the adverse weather of an average sort of year, but against the drought or wind or storms of an unusually bad year. And without question, someplace in the United States every year, that "worst weather in years" is going to come.

The important thing, therefore, is to be prepared for the exceptional. Even in Iowa, where one storm last spring delivered 3 inches of rain in 40 minutes, the farms with modern soil conservation practices on the land survived the deluge. Well-built terraces did the job for which they were intended, even during the hardest downpours within many farmers' memories. And conservation tillage and no-till practices, that have been gaining favor rapidly in Iowa in recent years, saved countless tons of soil from washing downstream. Farmers report that a good cover of cornstalks and other crop residues on the surface of the soil kept erosion to a minimum, even on gently sloping land. Already the past year's experience has led to a big increase in terrace building and minimum tillage methods in Iowa, as well as many other farming areas.

So while the task ahead for all those engaged in the work of soil and water conservation is a challenging one, it is far from impossible. Events of the past year should not be cause for pessimism, but rather should renew the conservationist's determination to move faster with his important work. Commenting on the year's erosion record in my annual message to Service employees last fall, I said:

> These setbacks underscore the act that farmers and ranchers simply cannot afford to let up on conservation, and we need to redouble efforts to assist them. We need to help them use soils information to select the right kinds of acres for crops and we need to show them how to protect those acres from erosion. We want to help farmers make their acres as productive as possible, but we want to make sure that the cropping systems leave the land resilient enough to bounce back after flood, drought, or what have you.

I am confident that we have the wherewithal to bring conservation on the American land up to standard by reducing soil erosion to "allowable loss limits." Soil conservationists have the knowledge and the expertise. Our program's assets include more than 2 million voluntary district cooperators, more than 15,000 district officials serving nearly 3,000 conservation districts, a growing number of state and county conservationists, and more than 13,000 SCS employees, as well as other USDA people in the field, who are dedicated to the principles of soil and water conservation. I invite all who share our concern for improved conservation of our basic resources to join us now in an all-out effort to protect and manage America's soil and water. The need was never greater than it is today, nor the stakes so high.

UTILIZATION OF
ANIMAL MANURES AND SEWAGE SLUDGES
IN
FOOD AND FIBER PRODUCTION

UTILIZATION OF ANIMAL MANURES AND SEWAGE SLUDGES IN FOOD AND FIBER PRODUCTION

This report on utilization of animal manures and sewage sludges in food and fiber production was prepared for use by the U.S. Senate Committee on Agriculture and Forestry at the request of the Honorable Herman E. Talmadge, Chairman. Participating in the preparation of the report were sixteen scientists representing the states of Alabama, Arizona, California, Illinois, Kansas, Missouri, Oregon, New York, Texas, and Wisconsin. Subject matter areas represented included agricultural economics, agricultural engineering, agronomy, animal science, dairy science, poultry science, sanitary engineering, soil science, veterinary pathology, veterinary toxicology, and water resources. Members of the task force met in Kansas City from December 10 to 12, 1974, to discuss the assignment and to prepare a draft of the report. The draft was subsequently revised by the chairman, reviewed by members of the task force, edited, and reproduced for transmittal.

SUMMARY

The utilization of animal manures and sewage sludges as fertilizers and soil amendments and the use of properly processed animal wastes as ingredients for animal feeds offer a number of advantages to society. Proper utilization in agriculture, forestry and land reclamation will improve water quality as a result of decreased disposal of wastes into rivers, lakes and oceans and will improve air quality as a result of decreased incineration. Savings in use of natural resources, including fossil fuels, and in livestock production are potentially important advantages.

Application of animal manures and sewage sludges to agricultural and forest land is influenced by physical, chemical, microbiological, sociological, economic and political or legal factors. The limitations or obstacles to the present use or increased efficiency of use of these materials include the following:

1. Animal manures and sewage sludges, as sources of plant nutrients, are bulky, low-grade fertilizers of variable composition. The total plant nutrient content is only 10 to 20% of that of most commercial chemical fertilizers. Concentrations of nutrients, soluble salts, trace elements and water vary tremendously and are seldom known. Optimum rates of application are thus difficult to predict.

2. As low-grade fertilizers, these materials cannot be transported more than a few tens of miles before the costs of transportation exceed their fertilizer value. Many animal confinement facilities and many large cities lack agricultural land within economic transportation distances of the point of production.

3. Difficult on-farm management problems are created by the physical properties of these materials. Application techniques are inefficient and time consuming. When liquid sludges are applied to the surface of the soil, a drying interval is required, and this loss of time can result in costly delays in seeding. The production of animal manures and sewage sludges is continuous, whereas the needs for fertilizers are seasonal. Thus, storage is required by either a distributor or the farmer. The products, particularly sewage sludges, are difficult to store on the farm.

4. Animal manures and sewage sludges both contain soluble salts that can create problems in their use as fertilizers, particularly in the irrigated lands of arid regions where soluble salts are already present from irrigation waters. In arid, irrigated regions, applications of manures and sludges must be limited because of the detrimental effect of the salt on crops when large quantities are applied.

5. The undesirability of leaching of soluble salts, particularly nitrate, to ground waters may limit the rates of use of animal manures and sewage sludges on lands.

6. Sewage sludges contain heavy metals that are retained in soils and can accumulate to the point where they are toxic to some plants and thus restrict the types of crops that can be grown. As a result of uptake by crops, they may also be toxic to animals and humans, and this may limit the use of the harvested crop. So little is known about this hazard at present that it cannot be properly evaluated. Of primary concern as potential toxicants are zinc, copper, nickel and especially cadmium.

7. Sewage sludges contain pathogenic bacteria, viruses and parasites that represent a public-health risk to farm workers and the public via the food chain. The degree of risk depends on the processing of the sludge and on its management on the farm, but experiences with application of sludge to land in a number of locations suggest that the risk is low.

8. Odors and associated nuisances, both real and imagined, create conflicts between urban residents and the farmers of adjacent croplands who could advantageously use the wastes. These conflicts add transportation or application costs for land application of sewage sludge or of animal manures from dairy or animal-feeding operations located near cities.

9. One of the serious obstacles to the use of sewage sludges on cropland is sociological resistance that stems from fear of pathogens, odors and nuisances and possible environmental deterioration. Once resistance and fear have been generated in a community, the people have great difficulty in accepting the fact that the risk of creating any of these problems is extremely low in a properly managed system of applying sludges or manures to land.

10. Another obstacle to the use of sewage sludges for crop production is the requirement by environmental protection agencies that both crop and water quality be monitored. Farmers who would otherwise receive and use this material cannot or will not pay the additional costs of monitoring for possible environmental side effects. Monitoring is not required if chemical fertilizers are used.

11. One obstacle to the use of processed animal manure as a feed ingredient has been the concern for possible transmission of pathogens and undesirable organic residues into food products. Because of this concern, Federal and state government agencies have been slow to approve the practice.

12. The lack of meaningful guidelines that can be interpreted on a regional basis or in terms of local situations and needs has been an obstacle to the use of sewage sludges on cropland and also to the use of animal manures as feed ingredients. Investments in systems to apply sewage sludges to land or in processing plants to produce feed ingredients from animal manures cannot be expedited until such guidelines are established.

Actions are needed that will promote the beneficial use or increased efficiency of use of sewage sludges and animal manures. As a society

with limited resources, we need to stop thinking in the negative terms of waste disposal and instead should think in the positive terms of appropriate use. Research and development activities are needed that will concentrate on the beneficial-use concept to overcome some of the disadvantages and obstacles discussed in this report. It would be helpful if government agencies at all levels would take actions to favor rather than to restrict the reasonable use of these resources. The following alternatives might be considered as ways to promote beneficial uses.

1. An increases in quality of the products and adequate quality control would make sewage sludges and animal manures more competitive with chemical fertilizers. Conservation, in an immediately available form, of the nitrogen that usually volatilizes as ammonia would greatly increase the value of many of the products. Decreases in salts and trace elements that might result from changes in animal rations (decreased salt in rations of beef cattle for example), improvement in systems of collecting and treating waste water or control of trace elements at the source before industrial waste waters are put into sewage systems would also be helpful. Improvement in the physical condition of many products would allow better control of placement and rates of application.

2. Development of new management systems that would not delay other farm operations would create a better image for these materials in the minds of farmers. Development of a system of storage would be helpful. Perhaps the best system would provide custom application from central storage facilities.

3. Appropriate guidelines for applying sewage sludges and animal manures to croplands and for inclusion of processed animal manures as feed ingredients would promote or enhance beneficial uses. Guidelines are needed that will (a) be easily interpretable in terms of local and regional conditions and (b) protect the public health and the quality of the environment. At the same time, the guidelines should also be based on facts and acceptable risks rather than on fears or on unknown or unsubstantiated claims of environmental damage.

4. An effective educational program stressing the advantages to society of the beneficial use of sewage sludges and animal manures would help remove sociological resistance. An appropriate theme for the program would seem to be the concept that the total environment can be improved by using sewage sludges and animal manures to improve soils and increase crop production as compared with alternative methods of disposal.

5. Research and demonstration projects of high visibility could serve not only to develop improved management of sewage sludges and animal manures but also to convince local populations that use in crop production is a desirable and feasible alternative.

Introduction

Application of animal manures to land has been practiced for centuries. This practice developed partly because there was no other place to put the manure but also because crops grew better as a result. Manure supplies nutrient elements needed by crop plants, and it also improves the physical condition of the soil.

In some societies, the use of human wastes as a fertilizer and soil conditioner has also been practiced for centuries. Human wastes contain the same nutrient elements and have the same beneficial effects on soil physical conditions as animal manures.

Until the last few decades, animal production consisted of many small units on small farms where the feed for the livestock was grown on or near the farm where the animals were raised. Also, confined housing of animals has been practiced for centuries in cold climates. In the spring, the manure was taken to the fields in wagons. This system worked well as long as the number of animals owned by each farmer was small. The manure accumulated in the confined housing or in corrals used for temporary confinement was used on the fields of the same farm.

During the past few decades, the trend has been to divorce animal production from crop production and, for economic reasons, to concentrate the animals into large units. For example, tens of thousands of beef animals or hundreds of thousands of laying hens are now raised in single production units. A consequence of these large animal cities is the accumulation of manure in amounts which often exceed the capacity of the surrounding cropland to use effectively as a fertilizer. The lack of sufficient land near large animal confinements, the cost of transporting manure long distances and the competition from relatively low-cost chemical fertilizers have created strong economic incentives to use animal manures on lands near animal confinements at rates far exceeding crop needs for nutrients. Experimental plots have amply demonstrated that these high rates produce environmental disadvantages to surface and ground waters.

An analogous situation exists with human wastes. When most people lived on farms or in small towns and only a few large cities existed, human wastes were mostly widely dispersed. However, since 1900 the U.S. farm population has decreased to about 4% of the total population. During this same period, the total population has increased. As a result, we have experienced a tremendous increase in the number of people who live in large cities where human waste is discharged into sewerages. There it becomes mixed with other products of human activities, including effluents from many types of industries. About 75% of the U.S. population now lives in sewered communities. The resultant point discharges of wastes contain some substances at concentrations

much greater than in human wastes. Among these are heavy metals that come not only from industries but also from the pipes and fixtures used in construction of houses and water-distribution systems.

Water, air and land are the only available resources for disposition of waste products in the environment. Governmental regulations prohibit the use of water resources for such disposition, and economics, energy requirements and air pollution regulations discourage use of air resources through combustion processes. The land remains the most viable alternative for disposition of the waste products through landfill or application to croplands.

Landfill is currently under stress in many areas of the nation due to the large and complex problem of management of solid municipal wastes. Therefore, increased application of sewage sludge to land is expected in the near future for purposes of fertilization of cropland; improvement of such areas as golf courses, parks and landscaping; enrichment of forest land; and reclamation of marginal or seriously disturbed land.

Animal manures and sewage sludges have a number of properties in common. Both are bulky, low-grade fertilizers that do not compete well with chemical fertilizers. Transportation costs per unit of available plant nutrients are high for both materials. Contents of plant nutrients and also of undesirable components such as salts and heavy metals are extremely variable. The heavy-metal content of animal manures does not usually create a problem with land use, whereas the heavy metals in sewage sludges represent a potential hazard for long-term use. Both materials can create odors and nuisances if improperly managed.

This report deals primarily with beneficial use of animal manures and sewage sludges in the production of food and fiber. Use in reclamation of land and use on recreational land are given brief treatment. Manures and sludges are considered as resources that should be used. Animal manures considered are those from farm animals, and sewage sludges include dried, composted or liquid sludge from secondary treatment of waste waters from city sewage systems.

The main beneficial uses considered are application to cropland to supply plant nutrients and to improve soil tilth and for manures as feed ingredients in the rations of farm animals. Obstacles to use or hazards of use and opportunities for increased use or improvement in use efficiency are discussed. Application to land implies use at rates consistent with enhancement of crop yields or land reclamation and does not include the concept of disposal.

The use of animal manures and sewage sludges on crop lands and the use of animal manures as feed ingredients raises certain questions concerning (1) production and management of these materials to increase their value, (2) public and animal health and (3) contamination of the environment. The inherent disadvantages and advantages of these materials that must be considered in their use are discussed.

Present Usage and Trends

Of the 7 million tons of dry sewage sludge equivalent now produced annually in the United States, it is estimated that 40% goes into landfills, 20% is applied on land, 25% is incinerated and 15% is discharged

into the ocean. Because land use is the only direct beneficial use of this material, we have opportunities for a fivefold increase in such use.

Implementation of the Water Quality Act of 1972 (Public Law 92–500) is expected to result in a three- to fivefold increase in the production of sewage sludge in the next 5 years. We can thus anticipate a large increase in the pressure to use sludges on agricultural land.

The present production of animal manures in the United States is equivalent to about 1.7 billion tons per year on the wet basis or (assuming 20% solids) about 340 million tons per year on the dry basis. About 50% of this manure is deposited on croplands, pastures and rangelands in a diffuse manner. The other 50% is deposited in various types of confinement facilities where it can be recovered and used on cropland. Perhaps over 90% of the animal manure recovered is used on cropland. Some of it goes into specialty uses such as landscaping, nurseries and home gardens. Some is probably accumulating in storage, and a small amount is being used as feed ingredients.

The amount of animal manures available will probably not increase during the next few years. As a result of economic conditions, the number of beef animals present at a given time in large confinement facilities has decreased in recent months, and it is not known how long this situation will persist.

The potential for supplying more of the nation's fertilizer needs by increased use of sewage sludges and animal manures is not great, but it is sufficient to be worthy of consideration. A 15% increase in the efficiency with which animal manures are used would be equivalent to freeing about 25 million tons of dry animal manures for use on croplands that had previously used chemical fertilizers. If all the sewage sludge that is projected to become available were used on cropland, the total could be the equivalent of 21 to 35 million tons of dry sludge per year. Thus, the potential for increased use in the future might be about equally divided between animal manures and sewage sludges.

Fertilizer Value

Both sewage sludges and animal manures, as commercial products, have the disadvantage of a lack of uniformity. Concentrations of nutrients, salts, heavy metals and water vary within wide limits. These variations, particularly in plant nutrients, make sound management practices difficult.

SEWAGE SLUDGE

The concentrations of nitrogen, phosphorus and potassium (the three principal fertilizer elements) depend on the inputs into the waste-water system, the type of treatment and the management of the sludge between production and incorporation into the soil. Because of the instability of inorganic, combined forms of nitrogen, there is an unusually large variability in the amount of this element in sludges. Ammonia volatilizes into the atmosphere during drying and also during aerobic digestion. During anaerobic digestion, the nitrate form is denitrified, and the nitrogen returns to the atmosphere as nitrogen gas.

The availability to plants of the nitrogen in sludges decreases as the content of inorganic forms of nitrogen (ammonium and nitrate) decreases and as the organic nitrogen becomes more stable as a result

of digestion processes in the sewage treatment plant. The proportion of the nitrogen that is available for uptake by plants in the first year after application could be as high as 70% if one-half of the total nitrogen is present as mineral nitrogen and if there are no losses during and following application. At the other extreme, if all the mineral nitrogen has been lost and if the sludge is highly stabilized, the proportion of the nitrogen that becomes available for uptake by plants may be as low as 5 to 10% during the first year.

The phosphorus and potassium in sludges are considered to be as available as the usual sources of these elements in chemical fertilizers. Thus, except for the low concentrations of the fertilizer elements, sludges are considered good sources of these elements.

The current production of sewage sludge in a form that could be used in crop production is estimated as the equivalent of 7 million tons of dry sludge annually. As produced in a liquid form with about 2 to 4% solids, the nitrogen content might be about 3% on a dry-weight basis. If all this sludge were applied to cropland after loss of one-third of the nitrogen as ammonia, and if 15% of the remaining nitrogen were to become available for uptake by plants during the first year after application, the amount of available nitrogen supplied would be about 21,000 tons, which is equivalent to 0.2% of the nitrogen used annually in chemical fertilizers in the United States.

If the phosphorus content of the sludge is 2.0% on a dry-weight basis, 140,000 tons of phosphorus could be supplied to croplands annually by applying the 7 million tons of sewage sludge produced each year. This amount of phosphorus is equivalent to about 6.3% of the phosphorus used annually in chemical fertilizers in the United States. Similarly, if the potassium content is 0.4%, the amount of potassium that would be supplied would be 28,000 tons or about 0.7% of the potassium used annually in chemical fertilizers in the United States. The data on use of chemical fertilizers were for 1954 and were provided by the Tennessee Valley Authority.

The nutrient content of dry sewage sludge, in the usual fertilizer terminology (percent N [nitrogen]—P_2O_5 [phosphorus pentoxide]—K_2O [potassium oxide or potash]), approximately 2–4–0.5, totaling 6.5%. This total may be compared with an average total analysis of 43.2% for chemical fertilizers used in the United States in 1972. Obviously, sludges are low-grade fertilizers.

Using values of 20, 25, and 8 cents per pound of nitrogen, P_20_5 equivalent and K_20 equivalent (these are reasonable prices for chemical fertilizers for late 1974), the fertilizer value of sewage sludge may be estimated as $22 per ton on the dry basis. This calculation involves the assumption that 15% of the nitrogen in the sludge is available for uptake by plants in the first year after application.

ANIMAL MANURES

About one-half of the animal manure produced in the United States each year is estimated to be recoverable in a form that could be applied to cropland. This amount is estimated as the equivalent of about 170 million tons of dry manure per year. The manure added to cropland is extremely variable in chemical composition. The nutrient content depends on the type of animal, the ration fed, the amount

and type of bedding material, the collection system and the management between production and use. The nitrogen content and the availability of the remaining nitrogen decrease with losses of ammonia and nitrate, but the phosphorus and potassium in manures are as readily absorbed by plants as are most sources of these elements. These variabilities may be overlooked for purposes of calculations to indicate the approximate fertilizer value of animal manures. If, on the average, manure contains 2% nitrogen, 0.5% phosphorus and 1.5% potassium on the dry-weight basis, and if 50% of the nitrogen is available for uptake in the first year, 170 million tons of manure would supply 1.7 million tons of available nitrogen, 850,000 tons of phosphorus and 2.6 million tons of potassium. These quantities are equivalent to about 19, 38 and 61% of the quantities of nitrogen, phosphorus and potassium used annually in chemical fertilizers in the United States.

The nutrient content of this average animal manure, in the usual fertilizer terminology (percent N [nitrogen]—P_2O_5 [phosphorus pentoxide]—K_2O [potassium oxide or potash]) can be expressed as about 2–1–2 for a total analysis of about 5.0%. The plant nutrients in a ton of manure with a 2–1–2 fertilizer analysis could be purchased in the form of chemical fertilizer from about $16 at late 1974 prices. The cost of the nutrients would be about $12 per ton if the nitrogen is entered at half value on the basis that half of it may be available for uptake by plants in the year of application.

The fertilizer value of manures varies widely. Chicken manures containing very little bedding have relatively high nutrient contents and a form of nitrogen that is almost all available during the year of application. At the other extreme, bovine manures which have been aged by cycles of wetting and drying and have been leached with rainwater may have lost so much nitrogen by volatilization and other nutrients by leaching that the fertilizer value is much lower than assumed for purposes of calculation in the preceding paragraphs.

Crop Response

Increases in crop yield as a result of the use of sewage sludges and animal manures have been demonstrated many times. These yield increases result mainly from the nitrogen, phosphorus or potassium or a combination of these supplied by the sludge or manure. Wherever the soil is deficient, sewage sludges or animal manures can be used to supply all or part of the needed elements.

Sewage sludges and animal manures have some disadvantages as sources of nitrogen. Much of the nitrogen content is organic and must be mineralized or changed to inorganic form before it is available to plants. Because mineralization is a slow process, the organic material acts as a slow-release fertilizer. The main disadvantage is that insufficient nitrogen may be available to meet the needs of rapidly growing, short-season crops. If sufficient sludge or manure is added to compensate for the slow rate of release, secondary problems develop. After the crop is harvested the nitrogen mineralization continues, leaving potentially leachable nitrate in the soil. In arid, irrigated regions, the salt present in the manure from feedlots (due to addition of salt to the feed) can reduce germination and yields.

From a resource conservation point of view, sludges should be used to supply the phosphorus needs of crops, using chemical fertilizers to supply needed nitrogen and potassium. From the same point of view, animal manures should be used as sources of phosphorus and potassium, with supplemental nitrogen added as needed.

On the other hand, the slow-release feature of the nitrogen contained in organic sources can be advantageous in many situations. Also, sewage sludges and animal manures properly worked into soils can increase water infiltration and in other ways improve the physical conditions of soils and thus increase the ease with which the soils are managed.

Heavy Metals

The major factor limiting the long-range use of sewage sludge on agricultural land has proved to be the potential hazard associated with the presence of certain heavy metals in the sludges. These metals remain bound in the soil, and thus any problems they may create could be difficult to correct. The inadequate understanding of the potential long-range effects of these metals on animals and human consuming plants grown on sludge-treated soils has led to a very conservative position on the part of regulatory groups.

The elements of most concern are zinc, copper, nickel and cadmium. These elements, particularly cadmium, are toxic to animals and man, when ingested in sufficient amounts, and their entry into the food chain should accordingly be kept to acceptable levels. The concern about the presence of these elements in sludge is that, after years of repeated application of sludge to soils in quantities sufficient to supply the plant nutrients needed, the heavy metals added in the sludge could build up to levels that would be toxic to crops and in turn to animals and man. The heavy metals are strongly bound to the organic matter in the sludges (the strong binding capacity of the organic matter in the sludges for heavy metals is the reason the sludges have picked up the metals from the very low concentrations in the waste water), and the concentrations of the metals usually are too low to result in immediate detrimental effects on crops if the sludges are added in amounts sufficient to meet the nutrient requirements. The fear is that, as the organic matter added in the sludges decomposes over a period of years, the metals will be released in the soil, and then they will become toxic unless the properties of the soil are such that the soil will bind the metals.

The content of heavy metals in sewage sludges varies widely from city to city, depending on the amounts and types of industries, the plumbing, etc. Table 1 gives some ranges in observed values and values that might be considered typical of a sludge coming from a city with little or no industry. Animal manures also can contain considerable copper and zinc if large quantities of these elements are used as feed additives. Sludges also contain chromium, lead and mercury. Chromium and lead are present in forms of relatively low solubility and low toxicity after anaerobic digestion. Mercury does not injure plants at the low level found in sludges, and it is not accumulated by plants.

TABLE 1.—CONCENTRATION OF HEAVY METALS IN SEWAGE SLUDGES

Element	Concentration in milligrams per kilogram of dry material	
	Range in sludges from industrial and nonindustrial cities	Range in sludges from nonindustrial cities
Zinc	500–50,000	500–2,000
Copper	250–17,000	250–1,000
Nickel	25–8,000	25–200
Cadmium	5–2,000	5–10

Injury to plants can arise from high concentrations of zinc, copper and nickel. A number of factors, many of which are only poorly understood, are involved in this toxicity. These include the total amounts of each metal added, the degree of soil acidity or pH, interactions among these metals, the ability of the soil to bind these elements in an unavailable form and the plant species grown. Since the availability of these metals when present in excess is much lower in approximately neutral soils (pH 6.5 to 7) than in acid soils, the extent of accumulation of the metals in plants can be limited to some degree by liming. Organic matter and clay are the soil constituents that are most important in binding the heavy metals. Accordingly, soils well supplied with organic matter and clay can receive the greatest amounts of sludge high in heavy metals without eventually developing toxicities, and sandy soils, which contain little clay and usually are low in organic matter, can receive the smallest amounts.

The vegetable crops are the most sensitive to excesses of heavy metals. Most field crops are more tolerant. The grasses are the most tolerant. It seems possible, therefore that long-continued use of heavy-metal-bearing sewage sludges on a given land area might limit the types of crops that could be grown.

Because the principal concern about the effects of the heavy metals is based on conditions that might develop over a period of years and not on conditions that have developed, long-term experiments will be needed to permit an evaluation of the delayed effects. Such experiments are underway. In the meantime, progress is being made in developing soil tests to provide an index of the availability of the heavy metals to plants, and considerable information on toxicity of heavy metals to plants is being gathered in experiments throughout the country. In general, the results of these experiments indicate that the toxicity problem is not as severe as was once thought, especially if care is taken in site selection and if sound management programs are followed.

Even less is known of the significance to animals and man of the heavy metals in sewage sludges used as fertilizer. Zinc, cadmium, copper and nickel are all toxic to animals, in sufficient concentrations, although experiments with swine have shown that concentrations of copper far higher than those normally found in plants are beneficial to the swine. Evidence now available indicates that crop plants, especially the grains, are injured before they accumulate dangerous

amounts of these metals. Experiments with citrus indicate that, although excess copper in the soil is toxic to the trees, the copper is mostly confined to the absorbing roots, and it is there that the primary damage is done.

The principal concern is about cadmium. Cadmium is a cumulative poison, and its toxicity to animals and humans has been documented, although not as a consequence of application of sewage sludge to soil. Permissible levels of daily intake for humans, however, have not been established. It is known that cadmium content of most foods is less than 0.05 ppm and that plants will accumulate cadmium from soil treated with sewage sludge even when the soil has been limed to neutrality. More cadmium goes into plant leaves than into the grain, and some leafy vegetables such as spinach can accumulate considerable cadmium. Because of the relatively small acreage devoted to application of sewage sludge, it would seem that the amount of cadmium in the U.S. diet would not be affected significantly by sewage sludge applications, particularly if plants that accumulate cadmium were excluded from the cropping system.

It seems evident that concern over possible toxicities from application of sewage sludge to agricultural land in certain instances is entirely legitimate and proper. If sewage sludge is proposed for application to agricultural land, it is important that the content of heavy metals be known. If the metal concentrations are medium to high and the sludge is applied again and again to the same land, there is reason to monitor the composition of the crop, and perhaps of the soil, say, every 3 years. Alternatively, sludges high in heavy metals might be applied to nonagricultural land. Sludges exceptionally high in cadmium should probably always be used on nonagricultural land to provide an ample safety factor.

As the waste-discharge provisions of PL 92–500 are implemented, the heavy-metal content of sludges can be expected to decline. This decline, however, will take considerable time. Because of the many nonregulated sources and because sludges concentrate the metals from waste waters, some accumulation of heavy metals in sludges will always exist. Perhaps then, however, the concentrations will be low enough that the possibility of toxicities can be safely avoided by the simple expedient of avoiding heavy loadings and applying the sludges as fertilizers only in quantities sufficient to meet the phosphorus needs of the crop.

Soluble Salts

Sewage sludges and animal wastes contain inorganic salts of potassium, sodium, magnesium and calcium. When a large quantity of waste is applied to supply plant nutrients, more salts may be added to the soil than are leached out by water from irrigation and natural precipitation. Except for isolated locations, this salt buildup is most likely in drier regions of the United States (roughly west of a line from central North Dakota, south through central Texas). In areas where soils are naturally high in inorganic salts, even relatively small applications of waste can increase salt concentrations enough to reduce yields.

The salt content of organic wastes is extremely variable and is dependent on the salt put into the process as well as the management of the waste after it is produced. The salinity hazard of using organic wastes as fertilizers can be reduced by (1) analyses of each waste for salt as well as nutrients so that proper rates of application can be determined, (2) conjunctive use of wastes and inorganic fertilizers where the salt effect limits the amount of waste that can safely be applied, (3) management of wastes to preserve the nitrogen content so that the weight of waste and of salt per unit of nutrients added can be kept to a minimum, (4) continuing education of farm managers concerning salt management, and (5) reduction of the salt in the rations for farm animals to reduce the salt content of manures.

Water Quality

GROUND WATER

Degradation of ground water with soluble salts and nitrate from sludges and animal wastes is one of the factors limiting their use on land. The soil effectively filters out the heavy metals, organic materials and pathogens, but the soluble salts, including nitrates, may leach into tile drainage lines or into the ground water.

The soluble salts contained in all sludges and manures must be considered part of the salt-balance problems in many ground water basins If the rate of recharge of the basin with rainwater is high, dilution may render the salts and nitrate relatively harmless. In other basins the salt from wastes used as fertilizers or spread on the land as a means of disposal should be considered a potential water contaminant.

Most of the nitrogen in sludges and manures is in the ammonium or organic form. However, these forms of nitrogen in the soil are converted to nitrate, which is free to move with leaching waters. Whether from inorganic or organic fertilizers, a hazard exists where the amounts of nitrate greatly exceed the needs of the crop. This hazard is greater with sandy soils than with clayey soils, where slower leaching occurs and where conditions usually develop that convert nitrate to nitrous oxide and nitrogen gases which escape to the atmosphere above the soil.

In modern agriculture, there is no way to avoid some ground water contamination by either nitrate or soluble salts. Degradation can be limited by judicious use of fertilizers and organic wastes. In irrigated areas, increasing the efficiency of water use can reduce the total mass of salts leached and can increase the efficiency with which plants use the available nitrate.

SURFACE WATER

Animal wastes and sludges applied to the surface of the land can be a hazard to surface waters if runoff occurs. Runoff from fields and feedlots or farmyards will accumulate organic materials, salts and nutrients which, if not captured in retaining facilities, will enter streams or lakes. When manures or sludges are incorporated as soon as feasible after application, the hazard of loss by erosion is greatly

reduced. Injection of liquids incorporates the material in the soil where it cannot degrade surface waters, and this practice also reduces ammonia volatilization.

Odors

Current livestock production techniques result in the generation of odors which are a source of conflict between the livestock producer and other members of society. The odors which constitute the nuisance are principally from gases generated during decomposition of the manure. Manure is biologically active when excreted and continues to undergo microbial degradation of various descriptions dependent upon the nature of the environmental conditions maintained in the process. The volatile compounds produced, especially the gases of low molecular weight generated under anaerobic conditions, are unquestionably offensive.

The processes involved are complex, with at least 45 compounds having been identified in air contaminated by these gases. Once the gases are produced, counteractive measures to eliminate or mask their presence are expensive and relatively ineffective.

The greatest potential for control lies in management techniques to prevent or minimize the production of the gases considered unpleasant. On open feedlots, this can be accomplished to a degree by keeping the manure reasonably dry and aerated by maintaining an orderly operation free of large accumulations of manure and trapped surface water. The aerobic degradation provides some reduction in manure volume, but more importantly, it produces a product which can be distributed on land areas with relatively little odor emission.

Manure from closed confinement, especially where high-moisture manure must be collected and stored for even short periods, constitutes a much more difficult odor problem. Recommendations for odor control during storage have included containers sufficiently tight to prevent the escape of gases during storage. If these stored manures are to be distributed on the land, however, the release of the accumulation of anaerobically generated gases will contaminate the air for an appreciable distance around the disposal area.

There is no known method for odor-free distribution of previously stored manure. Techniques to minimize it include (1) application on cropland during periods of rapid evaporation to reduce the duration of the odor nuisance, (2) oxidation during storage to inhibit the generation of odorous gases, (3) injection of the manure beneath the soil surface to limit the escape of gases and (4) the use of odor-control chemicals.

The first method is often incompatible with management schedules, and the others involve additional expense. However, in many cases, management practices which incorporate a combination of these methods will appreciably reduce the odor nuisance during application of manure to land.

Management on the Farm

Animal manures and sewage sludges as substitutes for inorganic fertilizers pose management problems in application that increase the farm work load and management requirements. Storage of manures and sludges on farms presents environmental problems not encountered

with chemical fertilizers. The bulky nature of manures and sludges does not lend itself well to the tight schedule of farm work during seedbed preparation, especially if adverse weather develops. If liquid sludges are applied, time must be allowed for the soil to dry before the next farm operation can be undertaken. Thus, manures and sludges do not mesh well with the precision of operation of modern agriculture in the United States.

Because urban and animal wastes and sewage sludges are less stable, less uniform in composition and lower in concentration of available nutrients than are chemical fertilizers, the manures and sludges are under a certain disadvantage. Their effective and efficient use an land is more difficult to achieve and requires more careful management and planning on the part of the grower. Moreover, regulatory agencies frequently require permits and monitoring practices that the small farmer cannot meet, and this discourages the use of urban sanitary wastes and liquid sludges on much agricultural land.

As a prerequisite to developing interest on the part of farmers in using urban and animal wastes and liquid sludges in agricultural production, several conditions must be met. First, these materials must be economically competitive with chemical fertilizers. Second, regulatory agencies and the public must accept the practice of applying these materials to agricultural land. Third, the farmer must have greater freedom to use the materials as his particular operation requires.

As an aid to developing circumstances conducive to effective use of urban and animal wastes and liquid sludges in agricultural production, the following activites should prove useful: (1) Educational work to acquaint both the public and the farmer with the value of the materials and their proper handling in agricultural production. The public needs greater understanding of the limited hazards in using the materials on land in quantities that meet the nutrient requirement of crops. (2) Research and development of more effective ways to store wastes and to apply them effectively to land. (3) Development of local commercial services that could custom-apply urban and animal wastes and liquid sludges on specification to the land. (4) Research and development of techniques that will stabilize urban and animal wastes and liquid sludges into products that maximize their fertilizer values and that can be handled and stored on farms for rapid application to the land.

Management To Enhance Utilization

In view of the large quantities of manimal manures and sewage sludges available and the wide variety of conditions under which they are produced, it is understandable that a great variety of handling and utilization techniques have evolved. Successful systems include features which accommodate waste collection, transport, treatment or storage, and utilization. Since all these functions are interrelated, a system must evolve which is compatible with the climatic characteristics of the area, the economic constraints of the day. and existing social-legal structures. Public health and environmental quality considerations are additional restraints.

Wastes are collected in a variety of forms. The most important variable contributed by the collection system is moisture content. Both

animal manures and sewage sludges are available in a wide range of moisture contents. Runoff from out-door animal feeding areas and liquid manures generated by the hydraulic flushing of confinement feeding buildings may contain less than 2% solids and must be processed as liquids. Manure from feedlots may contain 50% solids or more and therefore requires the use of equipment for handling solids. Sewage sludges range in characteristics from liquids (about 5% solids) as produced by digesters, to semi-solids (about 20% solids) if they are filtered, to solids if they are air-dried.

Depending upon the form in which the materials are generated, the amounts of materials available and the distances involved, transport may be by pipeline, barge, rail, truck, wagon or manure spreader. Transport may occur prior to treatment and storage or immediately preceding utilization.

Processing (treatment and storage) of waste may be advisable to make it more suitable for the eventual utilization, to have it available at a time or location in which it has greater value, to enhance its value or minimize its negative attributes, or to control odor emissions between production and utilization.

In the recent past, when low-cost alternative sources of plant nutrients were available, many of the treatment schemes were devised to reduce the nitrogen and organic matter content of manures and sludges, thereby reducing the land required for disposal and the potential for water pollution. Current efforts are to accomplish the other goals of waste treatment (reduced cost of application and enhancement of other reclaimable values) but with the preservation of plant nutrients.

Biological treatment is most common in the management of animal manures. Aerobic treatment of liquid manure controls odors and reduces transport difficulties. Composting of drier manures and sewage sludges is a specialized process to stabilize the organic matter and reduce nuisance factors normally associated with handling fresh wastes. Anaerobic treatment of manures and sludges, which reduces handling difficulties, may be incorporated with storage. With proper design, an operation can produce a limited quantity of a low-grade, burnable gas.

Animal manures and sewage sludges may be applied to cropland using a variety of techniques. Where the quantity is relatively small and the transport distances are short, manure spreaders and tank wagons serve adequately. For larger quantities, these forms of transport are being replaced by specially designed irrigation systems. Whatever the method of application, consideration must be given to uniform distribution as well as the application of an appropriate quantity of waste material.

Consideration must be given also to the application of waste so as to control runoff to surface waters. Runoff from cropland which has received a recent application of manure or sludge is a potential source of water pollution. This potential is particularly severe if wastes are applied to frozen or snowcovered land or if the soil is saturated with water from previous precipitation and poor soil drainage. Where the potential exists for odor complaints due to manure application, equipment is available for injecting liquid manure and sludge beneath the

soil surface. Injection requires additional time and equipment and is therefore currently restricted in its application to relatively small areas in which odor control is most critical. Injection also minimizes runoff problems and conserves nitrogen.

The potential exists for the management of waste materials, especially livestock manures, to minimize plant nutrient losses. These techniques involve changes in practices of manure handling which in some cases will result in more costly or time-consuming procedures. The application of manure to cropland promptly after production decreases nitrogen loss but may not be compatible with existing cropping practices or the unavailability of land during winter conditions. Storage of manure in covered storage containers further decreases nitrogen loss but contributes to the cost. Immediate incorporation of manures and sludges into the soil is a technique that reduces volatilization and runoff losses but again may add to the overall cost of waste disposal.

Land Reclamation

Many thousands of acres of land have been physically disturbed by mining operations to remove coal and mineral resources. Because of the physical and sometimes both the physical and chemical nature of the refill material, some of these lands are left in such condition that reforestation or revegetation for other land uses is difficult without the addition of soil amendments to improve the physical and chemical characteristics of the refill material. According to present concepts, reclamation begins with regrading, usually includes the addition of nutrients and is complete only when the desired vegetation is producing well. The use of sewage sludges in large amounts as an amendment to aid in establishing vegetation is under development and is accepted by some as a desirable practice.

The use of large amounts of sewage sludge or animal wastes (100 to 200 tons per acre per year) adds relatively large amounts of soluble salts. Also, the conversion of organic nitrogen to nitrate will greatly exceed the capacity of the vegetation to use it. Thus, leaching of soluble salts and nitrate may degrade the local ground water. If one single large application is used and repeated applications are at rates that meet the nutrient needs of the vegetation being grown, the impact on ground water quality will be largely from the first large application. In humid regions, the salt and nitrate may not be a hazard because of high dilution, but in arid regions dilution is less likely.

The reclamation of these drastically disturbed lands is environmentally highly desirable, whereas the degradation of ground waters is environmentally undesirable. The decision to use wastes to reclaim such lands should be made on a case-by-case basis so that consideration can be given to (1) costs of alternative methods of reclamation, (2) the dangers to and importance of ground water supplies and (3) the value of the reclaimed land for agricultural production, recreation or forestry or a combination of these.

Because the area of disturbed lands will continue to increase, it is important that the technology for the use of sludges and animal wastes in their reclamation be carefully considered and developed.

Alternative Uses

ANIMAL MANURES AS FEED INGREDIENTS

Although application to cropland is the historically proven technique for the utilization of animal manures and sewage sludges, other options exist. The feeding of animal manures to ruminants and, to a limited extent, nonruminants has been shown to be of value.

During the past 10 to 15 years, a wealth of research data has demonstrated that properly treated or processed animal manures can be effectively used to feed animals. The manure is used to substitute for part of the usual ingredients in the feed, and its use extends the value of feed, especially the portion that is usually supplied from roughage. This research has also shown that no harmful effects are imposed on people or livestock through the use of animal manures as feed for cattle. Published data define effective management plans for use of waste from cattle, swine and poultry in animal feeding programs. These data have been critically reviewed by a U.S.D.A. task force and are currently on public display in the Office of the Hearing Clerk of the U.S. Congress.

Full and effective utilization of animal manures as feed ingredients could be promoted by (1) the official publication by regulatory agencies of uniform and realistic rules and regulations regarding the use of animal manures in various forms for animal feeds, (2) publication of adequate and clearly defined quality-control measures for processing plants designed to produce feed ingredients from animal manures and (3) adequate funding for research to ensure a technology adequate to serve the changing needs of the animal industry.

Poultry production systems provide the greatest opportunities for feeding animal manures, and the industry has taken a leadership role in this practice. Poultry operations are now highly specialized and often consist of large complexes containing thousands of birds on relatively small land areas and often near large cities. Many of these operations have little land on which the manure can be properly used as a fertilizer.

Of the 30 million tons of poultry manure produced each year, a large part no doubt will continue to be used for crop production. Probably no more than 25 to 30% would be used as a feed ingredient, but this is the part that is of most concern because there is no economic way to use it in crop production for lack of adjacent or nearby cropland.

If properly processed, poultry manure could be of economic value as a protein supplement. If fed to ruminants, which can use the nonprotein nitrogen, poultry manure has a protein equivalency of 25 to 30%. Its use could aid in reducing costs of animal food products but would not reduce the waste problems proportionately because of lowered digestibility.

Various treatment processes, including fractionating, drying and ensiling, improve the handling characteristics of manure and the availability of the nutrients it contains. More sophisticated schemes are also being examined for their potential. Bioconversion, the controlled growth of bacteria or algae, provides a means of capturing the soluble

nutrients from a liquid manure system in a secondary biomass which may be fed. To be viable in the future, techniques to accomplish these transformations with lower energy consumption are being sought.

OTHER USES

The use of washed dairy waste fiber as a bedding material is being practiced in areas which can provide natural drying conditions. Removing the large suspended solids from a liquid manure stream simplifies the application of the liquid fraction to cropland by use of conventional irrigation equipment, and it subtracts little from the plant nutrient content. It further enhances use as a soil amendment by eliminating the accumulation of a thatch on the soil surface.

The application of anaerobic digestion technology (as used in sewage sludge processing) to animal manures for the production of a low-quality fuel gas has drawn recent public attention. The high cost of facilities and the limited quantity of gas produced make the process appear of doubtful practicability for livestock operations of average size. As a point of reference, if the total manure from 100 swine weighing 150 pounds each is anaerobically digested in a 570 cubic foot digester, the daily gas production is estimated to be 430 cubic feet. This much gas has a heating value equivalent to 2 gallons of gasoline. At least half of that gas would be required to heat the digester and warm the incoming manure to the operating temperature of 98° F. Thus, the energy returned from the investment is relatively small unless the operation could be developed on a very large scale. Also, this process does not dispose of the animal manures. The residue from the gas generator is a waste product similar to a sewage sludge that must be put somewhere.

Laboratory investigations are underway on the use of pyrolysis as a means of using manure and other carbonaceous wastes as an alternative to petroleum. Thus far, the technology has not proven sufficiently attractive to prompt commercial development. However, pyrolysis of sewage sludges with municipal solid waste for production of syngas, methanol or ammonia is technologically and economically feasible.

The direct use of animal manures and sewage sludges as a fuel has been proposed. This practice would require that a large and reliable supply of the materials be available in a dry condition at an appropriate location. This condition has not been realized to date in a form sufficiently attractive to draw the necessary investment. If this alternative were to be pursued, additional handling and air-pollution-control technologies would be required.

These alternative uses for animal manures and sludges continue to warrant development, yet it is evident that, even if adopted, they would not have a major impact on the total quantities of manure and sludge available for application to cropland.

Energy Relationships

Manures and sludges can be either net consumers or net suppliers of energy, depending on their management and use, even apart from any energy-offset benefits resulting from their direct substitution for chemical fertilizers.

Any handling of manure or sludge expends energy. Unless the ultimate disposal precludes some further energy consumption or unless the inherent residual energy is utilized, handling beyond what is legally mandated or socially essential is not technically justifiable. "Do nothing" management may best serve the economic interest of the producer as well as the public benefit if there is no means at hand to salvage the residual energy content. However, to have no apparent practical use for manure or sludge today is an outdated attitude carried over from the era of unlimited resources. It fails to acknowledge adequate environmental and social concerns.

The dehydration of wet manures and sludges with fossil fuel, a common practice used to process these wastes for specialty markets such as the plant nursery trade, or the use of manures for feed ingredients, is usually energy-negative. It takes more energy to dewater and dry the waste than can be recaptured through any final consumptive use or conversion of the energy in the waste per se. For example, mixed cow manure excreted at 88% water has an energy break-even moisture level of about 41%. However, using energy from the sun to dry manures or sludges is not energy-negative in terms of fossil fuels. Dry regions thus have an advantage over wet regions in waste processing.

The residual energy in sludges and manure is represented primarily by their carbon content and secondarily by their hydrogen content. Biological or chemical oxidation of the carbon usually produces about 60 to 70% of the released energy. Fats, carbohydrates and proteins constitute the feed energy in organic wastes and can be consumed by microbes, intermediate animal forms or high order species, all of which metabolize the digestible matter to varying degrees. (Microorganisms raised on waste may be separated and dewatered or dried and then blended into feed for livestock.)

Substitution of manure for chemical fertilizer for use on cropland near the site of manure production could save substantial quantities of energy that are now expended in fertilizer manufacture and distribution. The energy required to manufacture fertilizers varies with the composition but in all cases substantially overshadows the amount required for distribution from manufacturing to retail outlets and ultimately to the field.

For purposes of comparison, a ton of fertilizer with a 12–12–12 analysis requires 9 million BTU to manufacture, an average 4 million BTU to transport to retail outlets and 0.1 million BTU to distribute to the field. If manure has a plant nutrient content of 30 lb. of nitrogen, 25 lb. of P_2O_5 equivalent and 35 lb. of K_2O equivalent per ton, a ton of the commercial fertilizer could be replaced by 10 tons of manure, which would provide an equivalent amount of phosphorus and additional quantities of nitrogen and potassium. Most of the energy requirement for manure as a nutrient is in the collection, stockpiling and distribution, totaling about 120,000 BTU per ton for a ten-mile haul. Thus, in terms of energy required, the ton of commercial fertilizer which requires 13.1 million BTU can be replaced by 10 tons of manure, requiring only 1.2 million BTU, less than one-tenth as much. This comparison attributes no energy cost to the manure as such.

What is the total potential energy saving from using manure as a fertilizer? U.S. livestock manure production in 1971 was estimated at the equivalent of 340 million tons of dry manure, about 50% of which was produced in feedlots and confined rearing situations. Utilization of all this manure as a replacement for fertilizer would involve an energy saving of over 2×10^{14} BTU annually. A 15% increase in efficiency of use could save about 3×10^{13} BTU annually, an amount equivalent to the energy in about 0.12% of the natural gas used in the United States in 1974.

Human and Animal Health

Obstacles to the utilization of sewage sludges and animal manures must include the possible effects on human and animal health. The health effects must be considered from the microbiological, epidemiological and toxicological viewpoints. Utilization of urban and animal wastes is probably impeded to a greater extent by the fear of disease than by the actual disease hazard involved.

Information from field tests suggests that the hazards from pathogens are more imaginary than real. Irrigation of soil with liquid digested sludge is accepted in Great Britain, Germany and France, where more than 100 years of practice in sewage-farm irrigation has produced no epidemics of cattle or animal disease.

A farm in Melbourne, Australia, has received applications of raw waste since it was first seeded to pasture grasses in 1893. Pasture grasses and about 10,000 grazing animals have done well. Records show that the rate of rejection of the cattle when they were inspected for export meat standard was one-half that for cattle that were raised under conventional management. There was no evidence of unusual health problems among the people who worked on the farm.

Pathogenic organisms may be found in raw urban and agricultural wastes. In the normal handling of urban wastes by treatments including anaerobic digestion and chlorination processes, most of the pathogens are destroyed. Remaining pathogens are then destroyed by environmental conditions after application to soil.

For a discussion of health problems, animal waste utilization must be separated into recycling as animal feed and application to land. Although animal manure is applied to the land as a raw product environmental conditions can effectively control the possible pathogens. Although some spore-forming bacteria (anthrax) are capable of remaining viable in soil for years, this is not the usual case.

The feeding of raw animal waste products to livestock gives rise to the possible development of disease from organisms in the wastes as well as from development of mutant strains of bacteria which might be of consequence to human and animal health. Consequently, it seems desirable to treat the animal wastes by processes such as ensiling or thermal dehydration prior to feeding. Other possible consequences of the feeding of animal wastes are the development of allergic reactions of people to residues in the meat of antibiotics fed to certain animals and the development of bacteria resistant to the antibiotics. Federal agencies have investigated these possibilities. The likelihood of occurrence of the problems is not great.

The possible occurrence of adulterants or foreign chemicals in meats as a consequence of feeding animal wastes has also been questioned. Regulatory agencies have some concern about this matter. Although traces of some such substances may get into the food chain with the feeding of some animal wastes, this is not a problem with the application of animal and urban wastes to the land.

Of primary concern to animal health is the possible occurrence of nutrient imbalances and toxicants in animal feeds. Some of the more common problems are nitrate-nitrite intoxication, copper-molybdenum imbalance and magnesium deficiency. Management systems can easily control these problems. Trace elements such as nickel, cadmium and zinc are of concern, but little is known of the possible long-term effects of the incidental addition of small quantities of these substances to the land and/or animal feeds. The usual trace-element contents of animal manures are about the same as those of animal rations and organic residues that are returned to the soil in normal crop practices. Thus, the potential hazard from animal manures is low. The concern is the possible long-term effects of the trace elements that are put onto lands with sewage sludges.

There is no risk of disease transmission from wastes used on grain crops when only the grain is harvested. Also, the transmission of disease in wastes has occurred in very few cases where cattle were grazed on pastures which received the waste. The risk of disease transmission is very low because most pathogens are host-specific and cannot endure a hostile open environment. Because of microbiological competition in soils and in wastes and because of other adverse conditions enteric pathogens seldom survive when the wastes are applied to land.

One must bear in mind that, throughout most of its length, the digestive tract of animals is normally in contact with substances in various degrees of conversion from food to animal waste. The occurrence of animal waste in the digestive system, therefore, is not, as might be supposed at first thought, an entirely new phenomenon that is likely to introduce an entirely new set of unknown problems with profound implications.

Public Concern

Perhaps the greatest obstacle to the use of sludges in crop production is the lack of knowledge on the part of the general public and public agencies about the possible impacts of such use on soils and plants, on ground and surface waters, on energy conservation, and on human and animal health and the overall balance of the positive and negative aspects. Scientists in these fields, represented on this task force, generally agree that waste utilization is practical and should be encouraged so long as proper procedures are followed.

Education is the best approach to gaining the confidence of the public. An effective educational program could begin by establishment of demonstration projects to be observed by the public and monitored by researchers. Educational forums could be held in conjunction with the demonstration projects so that scientists from the many disciplines involved could respond to the legitimate inquiries from a concerned public.

Need for Guidelines

Raw and processed sewage have been used in agricultural production in Europe and Australia for nearly 100 years with no known adverse effects on animal or human health. One of the major obstacles to large-scale utilization of sewage sludge for agricultural purposes in the United States, however, is fear and sociological resistance related to possible adverse effects of such use on human health.

Recent experience with proposed U.S. Environmental Protection Agency guidelines indicates an over-reaction to exisiting fear and sociological resistance. Guidelines thus affected tend to ignore scientific facts and economics and, ultimately, to reinforce sociological resistance. As shortages and energy costs become more critical, it becomes increasingly important to abandon the doctrine of zero risk and to adopt the objective of eliciting as much of the positive value from available resources as is realistically feasible without unduly jeopardizing the health and safety of the human population.

To be meaningful, guidelines for agricultural use of sewage sludges and animal manures (1) should consider these materials as a resource, (2) should be adaptable to regional and local needs and situations, (3) should be compatible with established farming practices or at least not disrupt them unnecessarily and (4) should provide for interpretations at the point of implementation which would permit full consideration of resource use and economics.

To emphasize the need for judicious guidelines, the following brief comments on resource conservation and economics are relevant. Data from the Environmental Protection Agency show that in 1972 the nation was consuming the energy equivalent of about 135,000 gallons of oil per day or 50,000,000 gallions annually for incineration of municipal sludge. If unrealistic, overly restrictive guidelines force this nation to adopt incineration as the most attractive sludge management alternative, the energy requirements would increase to 350,000,000 gallons of oil per year in the immediate future. The Environmental Protection Agency estimates further that, when PL 92–500 is fully implemented, the volume of municipal sludge will increase by 3 to 5 fold. If incineration is used for disposal, this increase in sludge production translates to 1.05 to 1.75 billion gallons of oil annually. These estimates do not include the energy requirements for compliance with current or anticipated air-pollution regulations. Compliance with these regulations could double the fuel requirements and, in critical air sheds such as Los Angeles and San Francisco, this increase could be much higher due to afterburner requirements.

Guidelines that would force them municipal wastewater treatment industry to incinerate sewage sludges would be clearly inconsistent with the long-term, energy-conservation goals of the nation. Incineration also would fail to address the more substantive problem of dealing with the heavy metals present in the ash. The ash could not be disposed of in water, it could not be stored indefinitely, and, if spread on land for disposal, it would produce whatever effects on the crops might be associated with the heavy metals it contained.

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