Chapter 1

Summary

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Chapter I

Summary

LAND PRODUCTivity

Every year, the Nation's cropland erodes at an average rate of 7 tons per acre. Yet soil is thought to form at a rate of only 0,5 ton per acre a year or less, Thus, even though knowledge of soil formation is grossly inadequate, it appears that America's agricultural soil is being eroded more than 10 times faster than it is being formed,

Erosion is not the only process that can damage the productivity of the Nation's croplands and rangelands, though it is the most pervasive. Compaction and inadequate drainage can reduce crop yields. Salinization (salt build-up in soils) can force lands out of production. Mismanagement and overgrazing can degrade rangeland productivity, Withdrawing too much ground water can deplete underground supplies and limit future agriculture. Land subsidence, whether related to ground water withdrawal or other factors, can remove lands from production with little hope for restoration.

Inherent land productivity, as used in this report, means the ability of land resources to sustain long-term production of crops, forage, and a broad range of other benefits such as water quality, genetic resources, and wildlife habitat. Land is broadly defined to include not only soil but water and all the physical, chemical, and biological components of cropland and rangeland ecosystems.

Land productivity varies from site to site and changes over time. It interacts with the other components of agricultural productivity, which are the productivity of capital, the productivity of labor, and the state of the art of technology. Because of these interactions, land productivity is exceedingly difficult to measure, Nevertheless, it is a distinct concept that farmers and ranchers understand to profoundly influence the productivity of their capital and labor resources.

This study assesses how agricultural technologies affect the inherent productivity of U.S. croplands and rangelands, It examines processes that affect the quality of croplands and rangelands and addresses the question of whether land productivity is sustainable under various modern agricultural technologies,

The report finds that certain productivity-degrading processes, especially erosion, are widespread and serious. Yet for most agricultural land, technologies exist that could achieve high production while maintaining land quality, There are, however, some particularly fragile lands where no currently available ways exist to sustain high levels of production. These lands are used because it is profitable, under the present system of agricultural technologies, markets, and policies, to "mine" the inherent productivity of the fragile cropland and rangeland sites as if they were nonrenewable resources. In doing so, long-term productivity is sacrificed for shorter term profits.

This assessment was requested by the Senate Committee on Environment and Public Works and endorsed by the House Committee on Agriculture, the Senate Committee on Appropriations, and the Subcommittee on Parks, Recreation, and Renewable Resources of the Senate Committee on Energy and Natural Resources. The assessment was designed to exclude detailed study of: 1) problems that tangentially affect agricultural lands but are not caused by agricultural technologies (e. g., air pollution); 2) impacts of agricultural technologies on lands other than croplands and rangelands (e. g., the effects of chemical runoff on estuaries); 3) technologies and impacts covered by other OTA assessments [e. g., Integrated Pest Management, 1979; Biomass Fuels, 1980; and Applied Genetics, 1980).

NTRODUCTION: TECHNOLOGY AND AMERICAN AGRICULTURE

This Nation's agricultural successes are the product of many factors: abundant resources of land and water, favorable climate, and also a history of hard work, skill, and innovation. Recent generations in particular have benefited from technological developments, U.S. agriculturalists and scientists have created a production system that not only meets our own needs but also provides a growing portion (about one-tenth in 1979) of the agricultural products used by the rest of the world.

The technologies that made this extraordinary production possible were developed primarily during the 1950's and 1960's, when fuel and capital costs were low and labor was comparatively expensive, These technologies made farmers extremely successful at replacing labor with cheap energy inputs. The principal problem policy makers faced was keeping abundant supplies of food and fiber from driving prices (and profits) so low that farmers would be forced out of business. As a result, price supports and a variety of land retirement programs were adopted.

Agricultural policy makers now face problems quite different from those of the past. The 1970's brought profound changes in the economic and resource environments, Foreign demand for U.S. agricultural products grew rapidly. Energy and fertilizer prices skyrocketed. Stockpiles of surplus commodities dwindled. Development of the interstate highway system and related changing settlement patterns took large areas of prime farmland out of production. At the same time, areas of marginal cropland began coming back into production because stronger commodity markets made price supports and the concomitant land set-aside programs less attractive.

By the end of the 1970's, the United States was exporting 30 percent of its agricultural production and expecting even higher exports in the future. With virtually all the land previously idled by Government programs already returned to crops, exports are projected to be met in part by cultivating more land, including much which is fragile and basically unsuited to long-term production under conventional technologies,

Conservation and Production

Neither empirical evidence nor compelling logic show that agricultural production must be harmful to the quality of the land resource. On the contrary, production and conservation can be mutually reinforcing, even on marginal lands, if appropriate production technologies are developed and used.

But present agricultural practices in the United States are degrading the inherent productivity of large amounts of cropland and rangeland. Much agricultural land suffers from accelerated erosion, soil compaction, water quality and quantity problems, or other adverse physical, chemical, and biological changes in soil ecology,

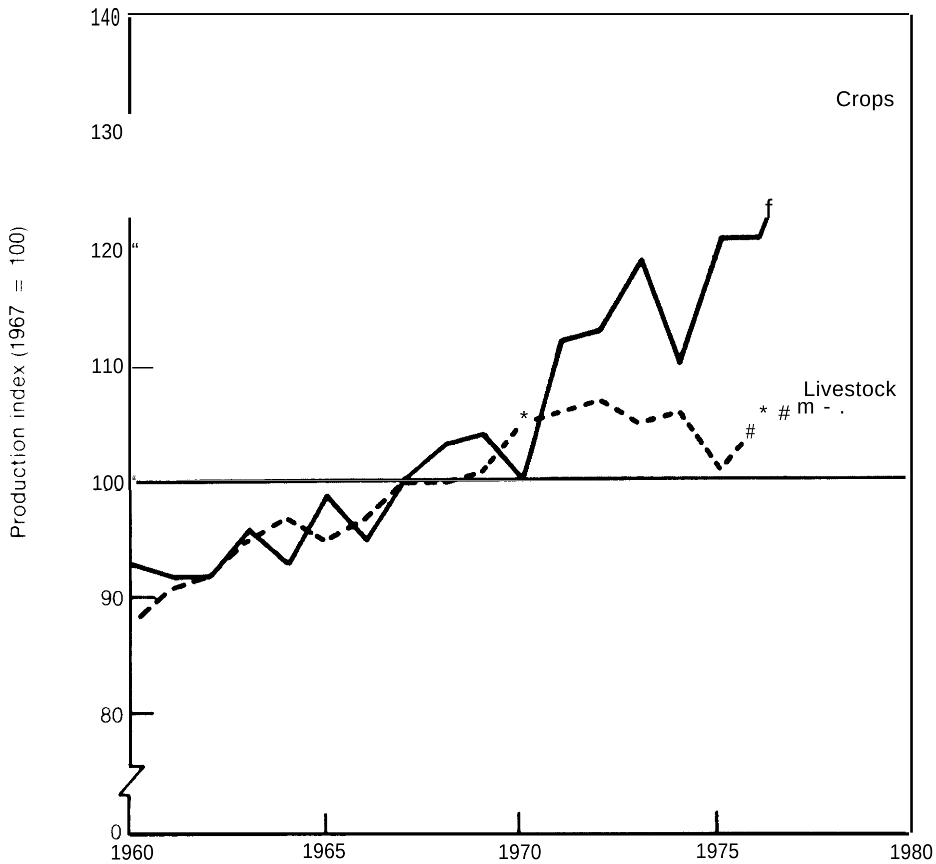
To date, losses in inherent productivity have been masked by gradual increases in capital inputs such as fertilizers, pesticides, and improved crop varieties. But productivity degradation is an accelerating and self-reinforcing process; this year's losses contribute to increasing losses in the years to follow, As capital costs rise, and losses in inherent productivity become increasingly severe, it will become more difficult to sustain production on depleted agricultural land.

Nationally, soil erosion is the most important process degrading inherent productivity. It is an acute problem on a relatively small part of the Nation's cropland, and a chronic problem on a much larger acreage.

No one can estimate the precise amounts of fuel, fertilizer, and other nonsoil resources that are required to compensate for the erosion-caused losses in soil fertility, tilth, * and water-holding capacity. The future availability and affordability of these nonsoil resources are also

*Tilth refers to the physical condition, texture, and aggregation of soil.

Agricultural Production, 1960-78



SOURCES 1960.1963 *Agrlculfural* **Stat(st/cs** *1975,* U S Department of Agriculture (Washington, D C U S Government Prl nt !ng Office, 1975), table 618, p 440
1964-1978 *Agrfcu/tura/ Statistics 1979,* U S Department of Agriculture (Washington, D C , U S Government Prl nt ing Office, 1979), table 633, p 440
Data for 1978 are preliminary
CEO *Errv/rorr* Trands, 1981

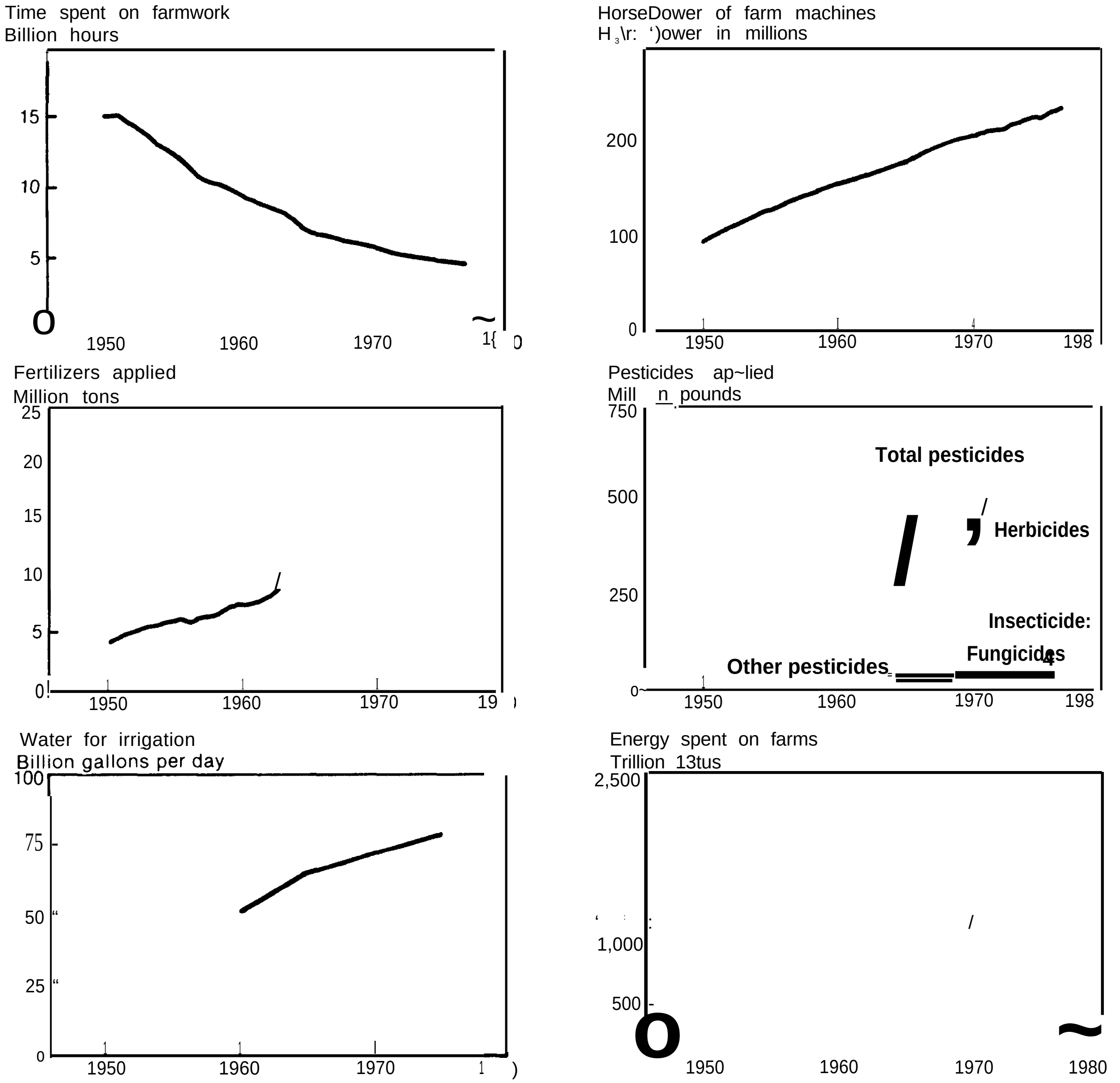
uncertain. Many of them, however, are nonrenewable and increasingly expensive.

Many practices used to maintain or improve inherent soil productivity can reduce current farm profits. For example, planting erosive fields into hay or pasture slows soil erosion, but is less profitable than planting corn or soybeans. Terraces break long slopes and retain eroding soil, but in many cases farmers cannot recoup high construction costs, even when they are shared by the Government. Contour farming reduces soil erosion and can increase yields, but it also increases labor and machinery costs. Because erosion may not noticeably affect crop yields for many years, economic considerations discourage farmers from adopting even these proven erosion control technologies.

Some new, innovative technologies can save soil and improve profitability for many farm operations. The use of some of these technologies—for example, conservation tillage*—is increasing, and they will play an important role in maintaining inherent land productivity in the future. However, there are substantial impediments to their widespread adoption. Many

*Conservation tillage refers to various wajrs of reducing the frequency and degree of tilling the soil, Conservation tillage methods generally share three characteristics: I) they use implements other than the moldhoard plow, z) t}]ey leave crop residues on the soil to mitigate erosion and help retain moisture, and 3] they depend on chemical rather than mechanical weed control, [See ch. IV for a complete discussion,)

Agricultural Inputs, 1950”78



SOURCES. Time spent on farmwork: Ctrarrges In *Farm Production and EMcierrcy, 1977,* USDA Economics, Statistics, and Cooperatives Service (Washington, D C U.S. Government Prlntlng Office, 1978), statistical bulletin 612, p. 32.

Horsepower of farm machines: **Changes kr Farm** *Production and Effic/errcy, 1977,* p. 31.

Fertilizers applied: Changes *in Farm Production and Efflc/ency, 1977,* p. *27*

Pesticides applied, 1964: *Quantities of* Pesticides *Used by Farmers in 1%54,* USDA Economics, Statistics, and Cooperatives Servce (Washington, D.C. US. Government Printing Office, 1968), agr. econ rep. 131, pp. 9, 13, 19,26 1966: Farmers Use *of Pest/cldes in 1971—Quant/ties,* USDA Economics, Statistics, and Cooperatives Service (Washington, D. C.: US Government Printing Office, 1974), agr, econ. rep. 252, pp. 8, 11, 15, 18. 1971 and 1976: *Farmers Use of Pesticides in 1976,* USDA Economics, Statistics, and Cooperatives Service (Washington, DC U S. Government Printing Office, 1978), agr. econ rep 418, pp. 6, 9, 15, 20,

Water for irrigation: *Estimated We of Water in the United States in 1975,* U.S. **Geological** Survey (Washington, D C : U S. Government Printing Office, 1977), circ, 765, p, 38 and previous quinquennial surveys.

Energy spent on farms: The U.S. *Food and F/bar Sector: Energy Use and Outlook,* USDA Economic Research Service (Washington, D C : U S Government Printing Off Ice, 1974), p, 2.

Btu converted from kilocalories (kcal), as published in “Energy Use in the Food System, ” J S. and C. E. Steinhart, *Science* 184309 (1974) (1 kcal = 3:968 Btu, 1 Btu = 0.252 kcal.)

Time spent on farmwork includes crops, lwestock, and overhead. After 1964, time used for horses, mules, and farm gardens was excluded.

Horsepower Includes tractors only (excluswe of steam and garden)

Fertlllzers Include nitrogen, phosphate, and potash nutrients used.

Pesticides include amounts used on corps only, excludes pesticide use for livestock and other purposes

Water used for irrigation refers to water consumed, not water withdrawn

Energy spent on farms Includes fuel, electrlclty, fertlllzer, agricultural steel, farm machinery, tractors, and Irrigation

Ctted In CEQ, 1981 *Env/ron Trends.*

farmers and ranchers resist abandoning conventional practices because the innovative technologies often require more management expertise. Furthermore, farmers often are unconvinced that the new practices can be profitable for their particular farming conditions. Capital requirements for specialized mechanical equipment also impede the adoption of new technologies.

Innovative farming and grazing methods are being adopted, but not necessarily in the places where they are most needed. Farmers adopt innovative technologies first on lands where the new methods will be most profitable—often these are the highly resilient lands with low potential for productivity degradation. At the same time, large parts of the Nation's most erosive and otherwise fragile cropland, pastureland, and rangeland are not being treated with conservation practices.

The scientific community is showing renewed interest in the determinants of inherent land productivity, A new U.S. Department of Agriculture (USDA) research program* is expected to study the relationships among soil erosion, substitution of other resources, and crop yields. But much work is needed to discover how inherent land productivity is affected by management of such factors as organic matter, soil biology, irrigation water, soil compaction, and soil chemistry. Furthermore, while Federal research efforts do develop needed improvements in existing technologies, improved mechanisms are needed for developing and implementing innovative technologies.

Federal programs designed to affect crop production and support farm incomes have had mixed effects on resource conservation. While most such programs do affect the natural resource base, they generally have not been designed to provide collateral conservation benefits. Little work, in fact, has ever been done to analyze the interrelationships between agricultural policy and conservation. Mathematical models that would permit policy makers to analyze relationships among conservation, production, and income objectives have not been adequately developed. In many cases, the basic physical and biological data necessary to build such models are lacking.

Agricultural technologies have significant effects on a number of public goods other than food and fiber production—e. g., water quality, wildlife habitat, and recreational opportunities. Sustaining production of these benefits does not have to conflict with sustaining crop and forage production and could be an explicit objective in developing site-specific agricultural technologies.

On the whole, inherent land prouctivity is deteriorating gradually. But neither the problems nor the potential solutions can be broadly generalized. Throughout this assessment, scientists, farmers, and other agricultural experts have stressed the regional diversity and site-specific nature of both degradation problems and technologies appropriate for dealing with them, * If Federal policy is to be effective in preserving inherent land productivity, it must recognize the regional and local nature of this issue. Dealing with acute localized problems may require politically difficult decisions to reallocate Federal technical and financial assistance, research, and extension work.

*The Soil Erosion-Soil Productivity Research Prolect.

*This report has highlighted Alaska as an example of a region with special agricultural potent ials and problems. Most of this information is in app, B.

LAND PRODUCTIVITY PROBLEMS

Erosion

Loss of soil by wind and water erosion* is the major productivity degradation process occurring on U.S. croplands and rangelands. The national average sheet and rill (water-caused)

* Erosion rates do not represent net losses of soil because eroded soil does not Simply vanish. Much of the soil moved by erpsopm remains in the same field, but farther downs lope. Soil is eventually lost, however, as it moves downslope off fields, into waterways, or onto noncroplands. Soil quality is affected by soil movement because organics and lighter materials are moved first, leaving behind poorer soils.

erosion rate from row crop and small grain cropland is 5.4 tons per acre. * When wind erosion is included, the average erosion rate for the Nation's croplands is at least 7 tons per acre. Meanwhile, soil is thought to form at an average rate of only 0.5 ton per acre. Thus, even though knowledge of soil formation rates is grossly inadequate, it appears that soil is eroded more than 10 times faster than it is formed.

Nationally, erosion exceeded 5 tons per acre* * on more than 112 million acres of cropland, including 33 percent of the corn land, 44 percent of the soybean land, 34 percent of the cotton land, and 39 percent of the sorghum land.

About 45 percent of the Nation's total sheet and rill erosion occurs on the most rapidly eroding 6.5 percent of the cropland. Since it is often unprofitable to protect highly erosive sites, much of that land is farmed without the benefit of any major erosion control technology. Aiming conservation efforts at the most rapidly eroding sites could increase the cost effectiveness of programs designed to prevent soil loss.

Soil loss rates are not the same as productivity loss rates, however. Many studies have demonstrated that soil erosion reduces yields for specific crops. But most of these studies were conducted decades ago. In the interim, crop production technologies have changed substantially and the old data on yield reductions have little relevance to modern farming. Consequently, it is impossible to accurately compare the costs of erosion control technologies with their benefits. When the cost of substituting capital inputs for eroded soil is considered, some farms with low erosion and thin soils may suffer more productivity loss than farms with high erosion but deeper soil. Also, from a national perspective, the seemingly low rate of erosion on the majority of the land may be more significant than the high loss rates occurring on a relatively small acreage, since the latter lands account for a small proportion of total national farm production,

Less is known about the rates and effects of rangeland erosion. Wind and water erosion on non-Federal rangeland averages 4.6 tons per acre. As is the case with cropland erosion, a large portion of the total tonnage eroded on rangeland comes from a relatively small area—on 91 percent of the non-Federal rangeland, wind erosion is less than 2 tons per acre. The most susceptible 3 percent of the land, however, erodes in excess of 14 tons per acre and accounts for 31 percent of the total wind erosion. Because rangeland soils form so slowly, and because they are so difficult and expensive to reclaim, even low rates of soil erosion are cause for concern. Anecdotal evidence and some data indicate that rangeland soils over wide areas, particularly in the Southwest, are so eroded that they can no longer provide adequate moisture storage to sustain a good cover of forage plants.

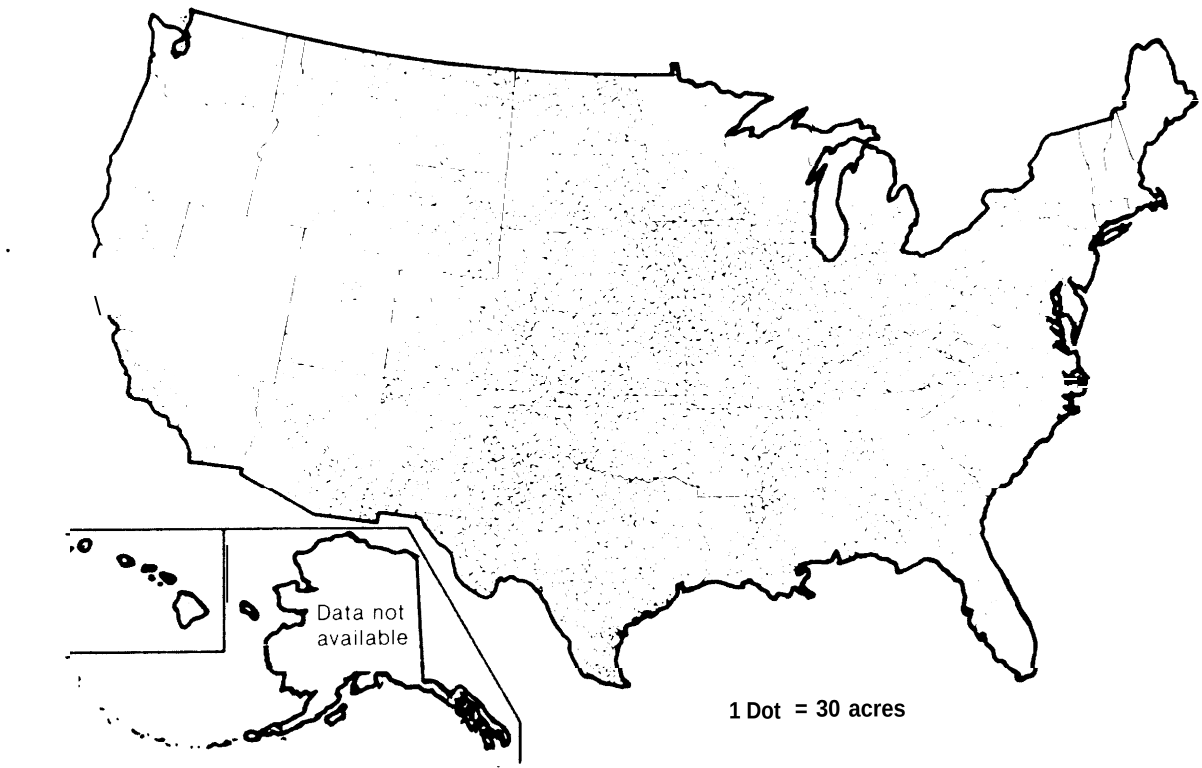
Maintenance of soil cover (by plants and crop residues) and other farm management practices (e.g., the type, frequency, and timing of tillage) are important ways to change cropland erosion rates. The most important new technologies to control erosion in the near future will be methods to minimize tillage on row crop and small grain croplands. However, none of the available erosion control technologies is likely to make row crop or small grain farming sustainable on the most fragile cropland. The most effective means of controlling erosion on such land is to cease using it for annual crops, planting it instead to permanent pasture, orchard, or wildlife habitat. For the long term, it may be possible to develop other profitable crop systems using perennial plants.

On rangelands, erosion control methods include establishing adequate plant cover, reducing or eliminating compaction on overgrazed sites and on overused animal and vehicle trails, and manipulating the soil surface to increase water infiltration,

*In this report, "tons per acre" refers to "tons per acre per year. " Erosion rates are from the 1977 National Resource Inventories, USDA, as revised in 1980.

**A rate of soil loss widely used as an objective for cropland erosion control programs is 5 tons per acre. This number, called the "T value, " was selected by the founder of the Soil Conservation Service, Hugh H. Bennett, and has since been reaffirmed by committees of Soil Conservation Service experts. However, there is essentially no research to scientifically establish the 5 tons per acre T value.

Acreage Where Wind and Water Erosion Are Greater Than Five Tons per Acre per Year, 1977



SOURCE USDA, 1978

Drainage

About 105 million acres of U.S. cropland have wet soils. Although only some wet soils are classified as "wetlands, " many of the 3.8 million acres of wet soils converted to cropland between 1967 and 1975 were indeed wetlands. Their conversion meant the loss of valuable habitats, reduced flood prevention, and the loss of natural cleansing mechanisms for watersheds.

On the other hand, drainage of wet cropland can enhance crop production significantly. Wet soils often have high potential productivity because they contain more organic matter than soils that are not so wet. In the late 1960's, concern mounted over the loss of true wetlands, investment in drainage systems dropped, and Federal cost sharing for drainage systems was terminated, As a result, investment in subsurface drainage systems for the wet soils already used as croplands has declined over the past 20 years,

Many existing drainage systems were built in the early 1900's and are outdated and need repair. While repairing or replacing tile and ditch systems appears to be cost effective for individual farmers, outlet systems commonly demand collective management. Cleaning and maintenance need local funding. Cost sharing, guaranteed loans, or developing farmers' cooperatives could aid in the rejuvenation of outlet systems.

Soil Compaction

Routine operation of tractors and other farm equipment and trampling by livestock can harm land productivity by damaging soil structure. On susceptible cropland soils, a persistent layer of densely compacted soil, a "traffic pan, " may form just below the depth of tillage operations. On rangelands, which are not normally tilled, animal trampling compresses surface soil so water cannot infiltrate and plants cannot reproduce.

Concern over compaction has increased in recent years, partly because the heavy machinery characteristic of modern farming is thought to cause more compaction than lighter machines. Soil compaction can cause crop yield reductions as great as 50 percent. Some soil types are more susceptible to compaction than others, and susceptibility generally increases with increased soil moisture.

Timing field operations to avoid periods when the soil is especially susceptible, and plowing deeper than normal ("subsoiling"), are effective ways to alleviate compaction. However, both can reduce short-term profits and information is often inadequate for farmers to make the best possible decisions.

On rangelands, the compaction problem is not well understood and practical technologies to correct it are not well developed. Both vehicle traffic and the hooves of grazing animals can compact range soils. This constrains plant growth, retards seed germination and seedling emergence, and accelerates erosion.

Techniques to control rangeland compaction include restricting vehicle traffic and intensively managing livestock to reduce their impact on wet and other susceptible soils. However, practical technologies to correct compaction are not available and, as with croplands, data are inadequate to optimize site management and policy decisions.

Expert opinion on the national significance of the compaction problem differs. Some scientists allege widespread damage to productive lands in general, while others see damage occurring only on certain susceptible land. Data have not been and are not being gathered to indicate the location or extent of soil compaction constraints on productivity, although experts indicate that national data collection is feasible.

SalinizatiOn

Irrigation can cause salinization of the land. Cropland salinization is primarily a drainage problem aggravated by incorrect application of irrigation water. On irrigated fields, the Sun and crops extract almost pure water, leaving behind salts that had been dissolved in the water. If the salt is not flushed deeper into the ground by rainfall or additional irrigation, it can concentrate in and on the surface soil, ultimately destroying the land's productivity.

But flushing salt into the ground does not necessarily solve the salinization problem. If subsurface conditions are relatively porous, the saltwater may contaminate the ground water supply. If subsurface conditions are relatively impermeable, the salty water may drain into the nearest river and flow to irrigators downriver. Saltwater may also accumulate beneath the surface so that a salty, "perched" water table accumulates. This can eventually rise and damage crop roots.

Most crops cannot survive in saline environments. High salt concentrations harm plants directly by causing physiological stress and indirectly by destroying soil biota. Salinity has already constrained production on 25 to 35 percent of the irrigated land in the Western United States, or about 5 percent of the total national cropland. This 5 percent is especially important because yields here are higher, the growing season longer, and high-value crops predominate on irrigated lands.

Salinization can have costly consequences. For example, in the San Joaquin Valley, high, salt-contaminated watertables under 400,000 acres are costing $32 million annually in reduced yields. Some 1 million to 2 million acres of prime land in that region are expected to go out of crop production during the next 100 years if salinization continues unchecked.

Salinization can be controlled with elaborate drainage and disposal systems. Smaller scale, less expensive approaches include using improved irrigation techniques and converting to crops that use less water or tolerate more salt. Although less costly, these management technologies have proven more difficult to implement than large-scale, publicly funded engineering projects because they require attitude changes and capital investments from many individual farmers. And whiIe small-scaIe technologies can reduce the accumulation of saline water beneath irrigated fields, they will not eliminate the need for drainage where subsurface conditions inhibit downward percolation—e.g., most irrigated areas in the Colorado and San Joaquin has bains.

Ground Water Depletion'

The next several decades will bring a marked decrease in the availability and quality of the Nation ground water resources. This will significantly reduce the productivity of much irrigated agricultural land, especially in the Southwestern States. The most severe problems will probably be confined to the West, but some Eastern States will suffer local water shortages and water quality problems that will affect agricultural productivity.

Various technologies can alter irrigation and farming systems and prolong the productivity y of ground water resources, These vary from modest changes in the way water is applied to major changes in farm management such as converting to perennial crops. Although changing the technologies used can reduce water demands, the actual reduction in ground water withdrawals that will result probably will be small and will only postpone the exhaustion of some major U.S. ground water reservoirs,

The technological change most likely to occur in Western regions during the coming decades will be the return of irrigated lands to dryland farming or grazing, Such conversion will cause sharp decreases in production, Also, as wind erosion and other problems associated with dryland farming develop, a continuing, gradual decrease in land productivity can be expected,

Although some schemes for recharging overdrawn aquifers* * have been proposed, the lack of local water to replenish supplies and the high energy costs involved in transporting water from distant sources may preclude such remedies. On a national scale, schemes for long-distance water transport will have to be compared with the alternatives of bringing marginal agricultural lands into production in the more water-abundant East or intensifying production on prime agricultural lands.

The current lack of effective State and Federal policies to discourage wasteful water use works against widespread adoption of water-conserving technologies. Ground water is a common property resource, so individuals have few economic incentives to practice conservation as long as others continue rapidly depleting the resource.

Land Subsidence

Subsidence—the sinking or collapse of land surfaces—is likely to become more common in the United States as the use of ground water and subsurface mineral resources intensifies. Subsidence can occur in various circumstances: when cities, industries, and irrigated agriculture withdraw large amounts of ground water; when coal and other mineral resources are mined; when there is solution mining of salt or other subsurface mineral deposits; or when large amounts of petroleum are extracted, All of these activities can result in slow subsidence or the unexpected collapse of the land surface. If agriculture overlies these areas, it can suffer slow or immediate consequences.

The effect of subsidence on agriculture has been most extensive in areas where ground water mining for irrigation is common. For example, on 5,400 square miles of San Jacinta Valley cropland in California, where irrigation wells pump as much as 1,500 acre-ft of water annually, land has subsided nearly 28 ft since 1935. Subsidence damages irrigation systems, wells, buildings, drainage and flood control structures, and other improvements. Data on this problem seem to be adequate for agricultural planning purposes. Subsidence effects are permanent and there are no attractive technological solutions.

*OTA is conducting a more detailed study of this topic in a separate assessment, *Water-Related Technologies for Sustaining Agriculture in U.S. Arid and Semiarid Lands.*

**An aquifer is a water-hearing underground layer of permeable rock, sand, or gravel.

Soil Organic Matter

Soil *organic matter* is important to soil productivity because it:

- contributes to the development of soil aggregates, which enhance root development and reduce the energy needed to work the soil;
- increases the air- and water-holding capacity of the soil, which is necessary for plant growth, and helps to reduce erosion;
- releases essential plant nutrients as it decays;
- holds nutrients from fertilizer in storage until the plants need them; and
- enhances the abundance and distribution of vital soil biota.

The importance of these functions varies greatly from one soil type to another.

Soil scientists generally emphasize the positive influence organic matter has on land productivity, but it can affect productivity adversely in some cases. For example, because organic matter holds soil moisture, it sometimes acts indirectly to shorten the growing season by delaying planting where moist soils warm slowly in the spring.

Although modern farming practices can affect organic matter content, this study found no data to indicate whether organic matter levels have increased or decreased in the years since widespread use of fertilizers replaced the use of crop rotations. Recent research has focused on the production-enhancing effects of off-farm inputs, and as a result soil scientists have not studied the management of organic matter to optimize land productivity under various modern farming systems.

Soil Organisms

Soil micro-organisms and larger soil invertebrates, such as earthworms and insects, perform functions essential for plant growth. Before the widespread availability of commercial fertilizers, nutrients recycled by the biota were recognized as a major component of land productivity and thus soil ecology ranked high among the agricultural sciences. In recent decades, however, this aspect of soil science has been largely neglected.

Agricultural scientists generally are not alarmed about pesticides harming soil ecology in the near term. Current insecticides and herbicides are tested for their impact on soil biota. They inhibit some biological processes and suppress particular types of biota, but generally the gross effect of each pesticide application seems neither great nor long-lived.

Frequent applications of toxic chemicals probably change the composition of soil biota communities, favoring species that can adapt to the new chemical environment. The impact of these changes on long-term land productivity is not known. Because methods are not well-enough developed to make practical differentiation among microbe species in the field, and soil invertebrates are seldom studied, the cumulative effect of agricultural technologies on productivity cannot be fully measured.

Soil chemistry

The *chemical composition* of the soil also affects land productivity. The nutrients that cropland and rangeland plants extract from the soil come naturally from decomposing organic matter, from the weathering of soil minerals, and in the case of nitrogen and sulfur, from the atmosphere, Nutrients are removed from the land by harvesting crops, livestock, and dairy products, and by erosion, leaching, and (in the case of nitrogen) loss to the atmosphere. In addition, nutrients can be changed chemically or be bound to soil particles, thus becoming unavailable to plants.

To replace depleted nutrients, farmers used to apply manure and grow “soil-building” crops such as clover in rotation with “soil-depleting” crops such as corn. While manure is still returned to the land where it is available, it is almost always supplemented with various commercial fertilizers. Moreover, in recent years many farmers have shifted to cash-grain operations, eliminating most or all of their livestock. Thus, modern farming depends heavily on nutrients provided by fertilizers from off-farm sources.

On rangelands, erosion commonly removes more nutrients than are naturally replaced, Unlike crop farmers, however, rangeland managers generally do not try to replace deficient nutrients. Rather, they try to reduce erosion rates to conserve the natural supply.

Wherever most of a farm's production leaves the farm, or accelerated erosion occurs, nutrients are removed faster than nature can replace them, Short-term nutrient supplies can be maintained with commercial fertilizers, but the profitability of fertilizer use may decline in future years because the manufacture of fertilizer depends on increasingly expensive fossil fuel and other nonrenewable mineral resources.

Technologies to deal with the long-term deficit in nutrient supplies include erosion control, developing cropping systems that use the nutrient reservoir more slowly and efficiently, and using special crop varieties and soil biota to improve the availability of stored nutrients.

Benefits her Than Crops and Forage

Agricultural lands are managed to produce crops and forage, but other, less quantifiable services from the land are also vitally important to the Nation's well-being. These benefits are often taken for granted or assumed to come solely from nonagricultural land. The quality of air, water, ground water, fish and wildlife habitats, and esthetic and recreational areas is directly related to croplands, pasturelands, and rangelands.

Furthermore, an agroecosystem does not end at the edge of a field or pasture, but includes the boundaries—fences, hedgerows, windbreaks, nearby fallow fields, riparian habitats, and adjacent undeveloped areas. As the quality and quantity of these areas is changed by agricultural activities, the utilities obtained from the land also change,

Land resources help maintain water and air quality by cleansing water as it infiltrates into ground water reservoirs, discharging relatively clean water to streams and wetlands, cleansing air of pollutants, and reducing the dust content of air. To a large extent, conditions that enhance long-term productivity for crops and forage also enhance air and watershed quality. For example, fertilizers increase plant growth, thus increasing ground cover and reducing erosion. But there are tradeoffs. Chemical applications appropriate for sustaining production can pollute streams, wetlands, aquifers, or the atmosphere. Generally, existing data bases are inadequate for determining the best solutions to these dilemmas, Other significant utilities that society obtains from agricultural lands, such as recreational, scenic, and archeological resources, are even more difficult to measure but are affected by changes in land use and land quality.

SUSTAINING RANG=LAND PRODUCTIVITY

There are approximately 853 million acres of rangeland in the United States. Excluding Alaska's 231 million acres, over half the Nation's rangelands are seriously degraded and suffer from reduced productivity caused by overgrazing, mismanagement, and erosion. Only 15 percent of the ranges in the contiguous States are rated in good condition.

Current range problems have their roots in early U.S. history. Throughout most of the arid and semiarid regions in the West, overgrazing damaged productivity within a few decades of initial use. Because overgrazing effects are most severe in dry areas where the land is least resilient, range conditions now are worst in the Southwestern States. Data are inadequate to assess broad trends in range conditions. The available erosion data, the findings of environmental impact statements, and the testimony of experts suggest that productivity is still being degraded and that present range management practices may not sustain productivity, Overall, Federal ranges are in worse condition than private and State ranges because the Federal Government owns more land that is inherently less resilient and more arid. Generally, the Federal ranges are in static condition or are continuing to deteriorate, while range condition is improving on better situated non-Federal lands,

Demands for rangeland products and services are expected to increase sharply in the next two decades, and these demands can only be met through improved range management. A variety of management technologies has been developed to improve and maintain deteriorated rangeland. Broadly categorized, these include:

- adjusting livestock numbers,
- Q controlling animal use with grazing systems,
- promoting desired plant species, and
- controlling noxious plant and animal species.

Used in integrated systems with improved fencing and water development methods, these range management technologies could improve and help sustain the Nation's range resources.

Managing rangeland productivity for multiple uses is the stated goal of Federal range efforts, In practice, however, livestock production is usually the dominant objective on both Federal and non-Federal ranges. Translating general multiple-use, sustained-yield objectives from laws into achievable field objectives is extremely difficult, especially when two or more legitimate uses of the land are in conflict. However, there are some technologies available that focus on other than livestock production. These include fish and game management techniques, erosion control to decrease sedimentation of streams and reservoirs, and vegetation manipulation to increase watershed yields. Little information, however, is available on the opportunities and problems offered by such technologies.

SUSTAINING CROPLAND PRODUCTIVITY

The United States has about 413 million acres of cropland, including about 230 million acres of prime farmland. Productivity on these lands can be damaged by a variety of processes including compaction, salinization, inadequate drainage, subsidence, changes in the chemical composition of the soil, and erosion. These problems can be caused or aggravated when crop production is increased.

But agricultural production does not have to be harmful to the quality of the land resource. On the contrary, production and conservation can be mutually reinforcing if appropriate technologies are developed and used, For many sites, innovative farming techniques are available that maintain or even enhance inherent land productivity without sacrificing short-term profits,

These innovations are in various stages of development. Conservation tillage, the most promising of the new technologies, is being adopted rapidly in certain parts of the country. Multiple cropping is already used to expand production in many regions. Organic agriculture, drawing on both old and new knowledge, offers alternative farming systems with important conservation potentials. Computer technologies and other developments in communications, education, and farm planning are rapidly gaining importance, Cropping perennial grains, on the other hand, is unlikely to be practical before the 21st century. Similarly, breeding crops for salt and other stress tolerance is primarily a laboratory technology at present. Eventually other new productivity-conserving crops might come into use as methods and markets develop.

Although various innovative approaches to conserving land productivity will become increasingly important in the future, existing conservation technologies will continue to play a key role in good land stewardship. Contour farming, stripcropping, shelter belts, crop residue management, tillage management, terraces, and other traditional approaches to conservation have had and can continue to have a widespread beneficial influence on many acres of farmland.

Cropland Acreage

1 Dot = 25,000 acres

SOURCE USDA, 1978

TECHNOLOGY ADOPTION

Developing and diffusing new agricultural systems is a slow process. Advances in science can accelerate the development of a new technique, but it still must be tested and adapted to site-specific conditions before it can be recommended to farmers. This need for extensive testing and evaluation partly explains why proponents of new technologies often consider agriculture overly conservative. The conservatism is also explained by chronic shortages of research funds, facilities, and personnel, * Although agricultural scientists are besieged with new and different ideas, practicality forces them to concentrate their limited resources on promising avenues of research,

“Chronic funding shortages, research priorities, and other research management issue\ arc analyzed i n a recent OTA assessment, ,411 .*Assessment of the* United *States Food and Agricultural Research System,* OTA-F-I 55 (Washington, DC.: U.S. Government Printing office, Decemher 1981).

which generally means on marginal improvements in conventional technologies,

Unfortunately, this approach can limit innovation. Scientists are protective of existing projects and funding and seem reluctant to test new ideas, especially if they come from outside the United States or from the trial-and-error experience of farmers, For example, drip irrigation techniques developed abroad were initially treated with great suspicion and little research here. It was only after many farmers had begun using drip systems that USDA tested the method and began to assist its development. Similarly, rigorous testing of organic farming techniques is still resisted by some agricultural scientists.

Thus, while work on mainstream research problems and priorities should continue, a need exists for more rapid development of new and innovative technologies. If this is to occur, improved mechanisms must be developed to screen and test new ideas. At present, such ideas cannot compete for funding with the major existing crops and systems that have powerful constituencies among the electorate and scientists.

Some conservation practices, such as conservation tillage, have proven profitable, low cost, and low risk, yet are not used by many farmers whose land is suitable for and in need of these practices, Many factors, including the personal characteristics of the farmer or rancher and the attributes of the technology, influence this decisionmaking process,

Methods to encourage the adoption of conservation practices include: 1) information and education programs; 2) economic programs using subsidies, loans, privileged access to resources, investment credits, and tax incentives; and 3) regulations with economic and legal sanctions. In many cases, these approaches have failed to motivate widespread adoption because they have not been adapted to particular groups of farmers with special social, economic, resource, and management capability circumstances.

GOVERNMENT'$ ROLE

Government policies and programs that affect agricultural technology use and land productivity generally fall into one of two categories: 1) those that promote economic goals, either by developing and promoting production technologies or by manipulating short-term economic factors; or 2) those that promote conservation of natural resource productivity, either by developing and promoting conservation technologies or by subsidizing investment in conservation. The two types of Government activities often operate simultaneously. Both influence farmers' decisions about technology use and about resource conservation, but the two influences are not always compatible.

Historically, economic programs supported prices primarily by keeping land out of crop production; hence no major effort was required to integrate production and conservation policies. Now, with economic goals shifting to full production, additional erosive or otherwise fragile land is coming into production, making the need for integration much more significant.

A number of hypotheses exist about how commodity price supports, credit and insurance programs, and tax policies interact with technology decisions and with the long-term trends in land use that affect conservation. For example, agricultural support programs are said to be a cause of land price inflation, This leads to increased debt, which reduces the economic flexibility that farmers and ranchers need to invest in conservation technologies. Some experts believe that commodity price supports and disaster insurance programs have promoted unsustainable uses of fragile land. It also appears that some tax and credit policies make agriculture an attractive tax shelter for nonfarmer investors, encouraging absentee ownership and tenant farming. Although these kinds of relationships between policy and productivity are often discussed, policy anaIysts and program administrators have few analytical tools to predict how specific economic programs will influence land productivity in the future.

Congressional mandates exist that direct long-term resource appraisals to plan the development of cropland and rangeland resources. These processes are important for formulating the policies that influence land productivity. Both the Resources Planning Act (RPA) and the Resources Conservation Act (RCA) processes are gradually becoming more useful for these purposes. Political controversy over the findings has been a constraint, as has the sometimes narrow scope of the appraisals. For example, the RPA report scarcely mentions rangeland soil erosion and the RCA process failed to evaluate major Federal conservation programs,

A major effort supporting conservation has been the Agricultural Conservation Program, a cost-sharing program that has distributed $8 billion since it was started in 1936. But Federal cost-sharing programs for conservation practices are controversial, They have been criticized for supporting production rather than conservation and for not directing funds to the most susceptible land. The cost effectiveness of programs to prevent soil erosion and productivity degradation could be improved if more resources were directed toward those lands that have the highest risk, However, such redirection would be very imprecise until scientists learned to assess more accurately the relative effects of various productivity-degrading processes.

One widely discussed proposal for integrating conservation policies with policies designed to manipulate production is to make participation in the subsidy, insurance, and tax programs contingent upon adoption of conservation practices. This "cross-compliance" strategy loses force when strong export markets make price support programs less significant. However, greater constraints on the accessibility of disaster insurance and agricultural credit programs could contribute to some conservation objectives. Any conservation strategy that uses incentives or penalties must be responsive to changing economic conditions, to the need for continuous (v. single-year) conservation management inputs, and to the special circumstances of the farmers who work fragile lands.

Some mathematical models exist to simulate the interrelated aspects of the U.S. agricultural system, and these can improve understanding of the relationships between economic and conservation policies. But these models are not sufficiently developed or widely used for rigorous, comprehensive assessment of policy alternatives. If resource sustainability is set as an explicit goal of both the Government-funded technology development programs and the commodity and credit programs, and if production enhancement is made an explicit goal of the programs to develop and implement conservation technologies, it should become possible to improve agricultural production and inherent land productivity simultaneously.

- *Conservation and production need not conflict Profitable technologies exist that maintain high levels of production while conserving long-term prod~ctivity of the land, More such technologies could be developed,*
- *Federal conservation programs have been poorly coordinated with other Federal programs that manipulate the economics of agriculture.*
- *Data and analysis on how erosion and other processes enhance or degrade the productivity of land under various management systems are inadequate for making the best possible decisions on national agricultural policies.*

ISSUES AND OPTIONS

Congress has two main channels to affect how technologies are developed and used to sustain inherent land productivity: *1)* through legislation, including budget appropriations, to establish new programs or to change existing ones; and 2) through committee oversight of how existing laws and programs are administered. This assessment found that existing agricultural legislation does provide a sound base for the Government activities that are needed to accelerate the development and promotion of productivity-sustaining technologies. Consequently, many of the options for congressional activity are related to congressional guidance and oversight functions rather than new legislation.

Opportunities for congressional action can be categorized under five policy issues.

Integrating Conservation Policy With Economic Policy

Because agricultural production and conservation of inherent productivity are not mutually exclusive, it should be possible to establish farm economic policies that include conservation goals and to analyze the interactions of current and proposed conservation and economic programs. Options for accomplishing these ends include: 1) accelerating the development of analytical policy models that could be used in the existing RCA and RPA programs to evaluate policy alternatives, and 2) establishing a policy analysis office within USDA that would develop a systematic process to assess how agricultural policies affect inherent land productivity.

Improving the Effectiveness of Federal Conservation Programs

The Government's conservation investments could be more effective if they were concentrated on land where productivity degradation is greatest and on the most effective technologies. However, there is political resistance to redistributing program efforts and funds, and substantial debate is likely to continue. The redistribution of Federal conservation efforts now occurring is expected to concentrate efforts on those sites where soil loss is highest. Improved analysis of the site-specific relationships among erosion, other productivity-degrading processes, yield, and associated variables eventually should enhance the cost effectiveness of the program redistribution.

Conservation practices and production technologies with proven effectiveness for sustaining productivity are not being used on many sites where they are needed. Farmers and ranchers often are not convinced that available conservation practices or productivity-sustaining approaches are profitable or technically feasible for their particular situations. The problem is one of demonstration and education; therefore, Congress could improve program effectiveness by mandating in-service training and other programs that would enhance the capabilities of Federal, State, and private sector agents to transfer technologies.

Enhancing Federal Capabilities To Dovelop Innovative Technologies

Farmers and ranchers correctly perceive that there are many sites that simply cannot sustain profitable use with the conservation technologies now available. Hence, there is a great need for technology innovation and Congress could act to accelerate the development of productivity-sustaining technologies. Congress' options include: 1) encouraging the federally sponsored research network to make resource sustainability an explicit goal for their research programs and projects, and 2) directing particular USDA agencies and programs to evaluate and test innovative technologies that may be outside the scope of mainstream research efforts.

Reducing Pressure on Fragile Lands

Some land now in row crops and small grains, and some overgrazed rangelands, will not be able to sustain their current uses but could be converted to uses more compatible with the land's inherent capability. However, short-term profits from the sustainable uses are often so low that farmers cannot afford the conversion. Thus, Congress has the option to establish a limited set-aside program to compensate farmers for such conversions. The program could pay farmers the difference between what the land would earn from its most profitable, productivity-sustaining use and what it now earns from the resource-consumptive use. In the long run, as new technologies are developed, the need for such a subsidy could decline. Another long-term option that could reduce pressures on fragile lands would be to encourage agricultural development of resilient potential croplands and grazinglands that are in other uses now or are virgin.

Encouraging State initiatives

Since soil erosion was recognized as a critical issue in the 1930's, most efforts in soil conservation have been organized at the Federal level. Recently, however, several States have taken important initiatives and have developed effective programs in cost sharing and other conservation approaches. The Federal Government is cooperating in these efforts, but there are other opportunities to enhance existing State programs and to encourage similar developments in other States. The options range from low-cost efforts that would facilitate communication among States to funding arrangements that would reimburse States for part of the cost-sharing expenses.