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Soil, Water, and Related Resources on Nonfederal Land in the United States

Analysis of Condition and Trends

Review Draft

RCA

SOIL AND WATER RESOURCES CONSERVATION ACT

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The Second RCA Appraisal

Soil, Water, and Related Resources on Nonfederal Land in the United States

Analysis of Condition and Trends

United States Department of Agriculture

Public Review Draft
July - August 1987

NATURAL RESOURCES IN A GLOBAL CONTEXT: A PREFACE

Congress requires that USDA conduct a continuing appraisal to provide a basis for conservation policy and programs. This document reports the status, condition, and trends of the nation's soil, water, and related resources on the nonfederal lands of the United States. Effective resource use and conservation in the future, however, will require more than resource data.

Agricultural production and related resource use in the United States are influenced more by economic factors stemming from the agricultural and trade policies and activities of the world community than at any other time in history. An understanding of the influence of the world community on U.S. agricultural production and resource use must antecede analysis of soil and water conservation planning or policy prescription. Export sales represent a large proportion of the demand for farm commodities and therefore affect prices and farm incomes in a major way. Equally important are the effects of international economics and of the policies of other countries on domestic factor and capital markets. The influence of the global community fosters a resource-use environment that is not well controlled with the traditional domestic policy tools.

The policies of other nations and the general economic forces that are outside the control of the U.S. agricultural sector can only be affected by national and joint international policy and economic actions. As information technology improves and as transaction costs continue to decline, the world economy will continue to have ever greater dominance over resource use and conservation. "From now on any country...that wants to prosper will have to accept that it is the world economy that leads. Domestic policies will succeed only if they strengthen ...the country's international competitive position (Drucker, p. 791)."

Current Agricultural Production Situation. The most conspicuous aspects of our present agricultural production situation are the surpluses of U.S. commodities that overhang the market, depressed commodity prices, and reduced farm incomes. These conditions apply to our major crops, to dairy production and to the cattle industry.

We have a resource abundance at this time. World supplies also are abundant and demand for our production is depressed. This situation is particularly difficult for those farm operators who have accumulated large debts and high interest costs along with reduced cash flow. We have more land in crop and forage production than the markets call for. There are no easy short-term answers to the problem of excess production capacity and depressed markets and prices. The Food Security Act of 1985 promises some transitional help.

Current U.S. Agricultural Export Situation. U.S. farm exports rose nine percent in value per year from 1971 to 1981. In 1986, the value of farm exports was down 27 percent from peak levels and the volume was down 22 percent. Further reductions are expected in 1987.

During the 1970's, U.S. producers demonstrated their ability to expand production rapidly in response to sharply rising world food and fiber demands. Because U.S. market prices were generally above support levels, the farm sector was operating largely in a free market environment. A cheap dollar, however, was an important factor in allowing the United States to capture the lion's share of the growth in agricultural trade.

It took 75 million acres more cropland in 1981 than in 1971 to satisfy export demands. That increase more than offset the 28 million-acre decline in land needed to meet domestic demands; that decline occurred as a result of improvements in agricultural productivity. Grain exports in the last decade averaged over one-third of total production. Their rapid rise in the 1970's caused severe adjustment problems in the farm sector and stress on the resource base. Their rapid decline in the 1980's caused adjustment problems in resource use and stress on the farm sector.

The Agriculture and Food Act of 1981 raised price supports or loan rates for the major program commodities. That action was influenced by a continuing bullish outlook for growth in world food demands and U.S. exports as well as by the expectation of further rises in production costs due to inflation. Given a perception of the United States as a world price leader, increased minimum loan rates essentially guaranteed foreign importers and exporters that world prices would not fall below those higher levels for 4 years. If prices dropped to the loan level, U.S. Government purchases of commodities would preclude prices from falling to market-clearing levels.

Thus, in the early 1980's, importing countries had an increased incentive to raise their own production and seek greater self-sufficiency in food production. At the same time, world commodity demands fell in response to a worldwide recession and a serious debt problem in many importing countries. So, compared to world demand levels, world supplies became relatively more abundant. Foreign exporters lowered their prices below the rigid U.S. loan rate. This reduced demands for U.S. exports. The U.S. competitive situation was further weakened by the appreciation of the U.S. dollar compared to currencies of importing countries. As a result, U.S. commodities became relatively more expensive to purchase and less competitive with those of other exporters. These factors combined to increase world supplies and reduce demands for U.S. exports.

Over the longer period extending back to the sixties, the rest of the world and particularly the Third World countries were developing their capacity to increase productivity and production more rapidly than had been anticipated. Today, many traditional importers have increased their production; some have become self-sufficient, and others have become net exporters.

Agricultural export demand, as the last few years have shown, is volatile through time, depending on global product, factor, and capital markets, world climate and weather patterns, and international economies and policies of other countries. The rapid expansion of U.S. exports in the seventies was followed by a rapid decline in the years following. The

export rise was fueled by world economic growth, expansion of credit, new trade with previously closed economies, and a weak dollar. The collapse followed a global recession in 1981 that served to strengthen the dollar, foster trade barriers, and force restructuring of Third World debt (one condition being forced austerity and reduced Third World imports). At the same time, world competition increased because of improved productivity abroad. This productivity resulted partly from Green Revolution technological advances and partly from agricultural policies offering price incentives and subsidies to farmers. Twenty-five countries now have farm surpluses, including Finland, Indonesia, and Saudi Arabia. Eastern Europe has increased its production and reduced imports, partly as a result of credit restrictions. The European Economic Community (EEC) has increased agricultural output per capita by more than 15 percent in the last decade. This has shifted the EEC from the world's largest farm importer to the world's second ranking farm exporter. China is now more a competitor than a U.S. customer, particularly in Asian markets.

Domestic Policies of Other Countries. Upon emergence, many Third World nations embarked on a program of rapid industrialization, very often at the expense of their own agricultural sectors. Petrochemical and manufacturing plants absorbed capital that could have been used for agricultural production, storage and transportation systems, research and education. Additional capital paid for food imports, many of them coming from the United States. More recently, many countries have undergone a policy shift as they realized that a viable agricultural sector is very often a precursor to economic development. Government incentives for enhanced productive efficiency and for employing new technology, again, much of it imported from the United States, served to reverse the malaise in much Third World agriculture.

Wealthy nations, too, have designed policies to foster agricultural production, Saudi Arabia for example. The motives seem to lie in the worldwide food shortage expectations of the seventies. Stronger policies for food production came as an outgrowth of national security policy. For example, the State of Kuwait, alarmed by the Iraq-Iran war, embarked on a "food security" policy in the early eighties, seeking technology from USDA and other American and European consultants.

The EEC, too, has developed policies resulting in overproduction and subsidized exports. The Soviet Union and Japan remain major food importers, but many other countries developed policies specifically to tap these markets. Among them are Australia, New Zealand, Argentina, South Korea, Thailand, and Indonesia.

Capital Markets. Trading in money, credit, and capital among nations is on the order of 36 times greater than the exchange of goods and services worldwide. These transactions represent a profoundly greater influence on domestic interest, savings, and investment than do exchange rates determined solely by trading in goods and services. The American agricultural sector, highly capitalized and indebted, is virtually

without means to control these important variables, yet must live in the financial environment created by them.

Another factor in the international capital arena is the federal deficit, which tends to keep interest rates high. The high interest rates attract foreign liquid funds which in turn support the trade deficit (Drucker, p. 783). This is another area where there is little the U.S. agricultural sector can do, but the effects of higher interest rates are strongly felt by highly indebted farmers in every region of the United States.

The Long-Term Outlook for World Food Demands and U.S. Production. For the world economy, the outlook to 2000 is for continued population growth and improvement in overall world productivity. That means increased disposable income per capita and increased demand for all commodities and services. A world population growth of 1.6 percent a year, combined with higher per capita incomes, will induce shifts in some countries to more consumption of livestock products compared to crop products and will foster improved distribution of food to lower income classes. This outlook suggests an increase of aggregate world food consumption of 2.0 to 2.5 percent a year. That rate of growth translates to a 30 to 40 percent increase in aggregate world food needs by 2000.

This bullish outlook for world agricultural commodity demands is accompanied by strong views among experts that the resource base, technology improvements, social adjustments and national policies of individual countries will develop in ways that will enable them to meet that demand with relative food abundance. That would indicate generally declining prices for farm commodities in the world markets.

Other experts have expressed equally strong views that demands would grow faster than production and induce rising prices. In the past two decades, a great deal more was heard about this scenario for increased relative scarcity than is heard at present. Actual longer term world production performance and the current situation suggest that both extremes have low probability for the long run. A more probable outcome appears to be moderate increases in per capita and total food supplies, enough to bring some downward pressure on real prices received by farmers in the longer term. This outlook for the future indicates that reducing the direct costs of production needs to be a primary objective of all U.S. farmers who wish to participate in or find themselves dependent upon world markets.

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THE AVAILABILITY AND FUTURE USE OF NATURAL RESOURCES: An Overview

In enacting the 1977 Resources Conservation Act (RCA), Congress found "there is a growing demand on the soil, water, and related resources of the Nation to meet present and future needs." Congress then declared that "the conduct of programs administered by the Secretary of Agriculture for the conservation of such resources shall be responsive to the long-term needs of the Nation" as determined by the results of a continuing resource appraisal.

This is the second report of that continuing appraisal, succeeding the first one published in 1981. Both reports assess the national status and conditions of soil, water, and related resources and analyze the trends of resource use against long-term needs. However, the second appraisal was conducted in a vastly different economic and resource-use environment than was the first appraisal.

Cycles of Pessimism and Hope

When the RCA was enacted in 1977, prices, crop acreage, sod breaking, wetland drainage, and erosion were on the increase (fig. 1-1). U.S. grain stocks were depleted from 1972 onwards, reaching a low in 1974. Exports and news stories of famine overseas were on the rise. There was widespread concern about world resource degradation. The first RCA appraisal report, in analyzing resource use over the long term, reflected the sharp upward trends of commodity demands and resource degradation that began in 1972. In 1981, these trends just as sharply reversed.

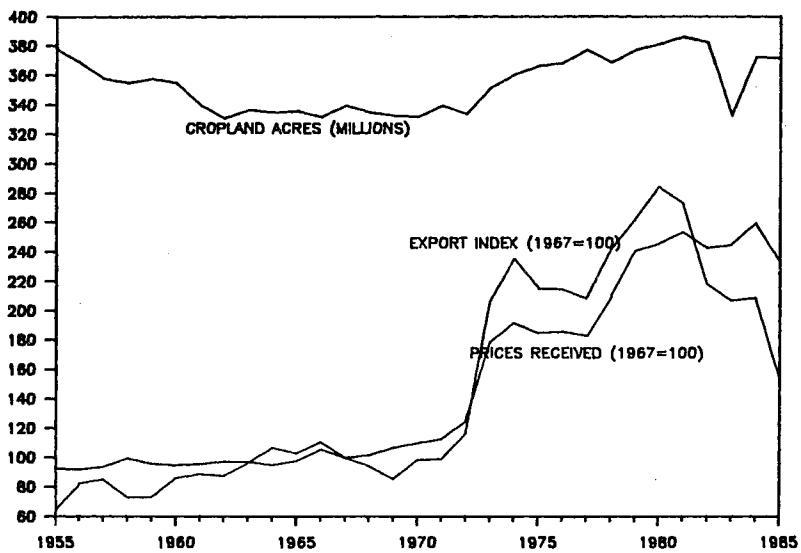

Figure 1-1.--Farm prices, exports, and cropland acres, 1955-85.

What we have witnessed in the past 15 years is a cycle of "food pessimism" (Ruttan), followed by complacency (if not optimism), the sixth such cycle in 200 years. In 1798, Malthus wrote that scarcity and eventual famine were inevitable, given our predilection for procreation. This prediction was averted by the opening of new land for settlement and by the industrial and agricultural revolutions. The second cycle began in 1898; the third, after World War I. Three more followed World War II. Ruttan presents a plausible case that another cycle will occur before the end of the century. These cycles are occurring with increasing frequency. This is a manifestation of the increasing interdependence of the world economies: trade, capital flows, information links, and feedbacks among nations have become nearly instantaneous. The world at large did not learn of China's famine in the early 1960's--which killed 20 million--for two decades. Today, starvation in Africa is on the nightly news.

These cycles occur because national need (demand) and resource use (supply) are constantly changing, interdependently but not in unison. Fueled by increases in world population and economic growth, supply and demand move in the same direction but not necessarily at the same time. These temporal lags result in the cyclical short-term extremes of resource stress such as that witnessed in the 1970's.

The Food Security Act of 1985 attests to the brevity of the latest "food pessimism" cycle. Concluding that a surfeit of commodities and cropland was creating both economic stress and resource damage, Congress provided for the retirement of up to 45 million acres of highly erodible cropland in a conservation reserve. In addition, the Act discourages the conversion of highly erodible land or wetlands to cropland and encourages the use of conservation systems on existing cropland after 1990.

Projections: Will Our Resources Meet Future Needs?

For the first and second RCA appraisals, national commodity needs (domestic and export), converted to resource needs, were projected to 2000 and 2030 using essentially the same techniques. Major factors influencing resource use were projected independently with an accounting of their interactions estimated by a linear programming model at Iowa State University's Center for Agricultural and Rural Development (CARD). Resource projections from the first appraisal, however, differ markedly from those shown in the present study. The 1981 RCA appraisal report incorporated long-range projections indicating that the pessimism of the preceding decade was well founded. Under the intermediate conditions assumed in this second appraisal, cropland needs are projected to be significantly lower than those projected in the first appraisal and lower than the acreage in use today. These strikingly different results are tied directly to differences in the productivity projections used in the two analyses.

The tone of the first appraisal report can probably best be highlighted by the following quotation: "Without significant technological break-

throughs and increased investment in research and extension programs, the rate of growth in productivity will probably continue to decline" (USDA, 1981; Part 2, p. 21). In contrast, Tweeten (1984, p. 574) summed up the 1982 symposium from which the productivity projections used in the second appraisal were taken: "The symposium authors tend to view favorably the opportunities for continued technological progress in crop and livestock production as well as in resource conservation." This view of the future found additional support at a 1986 National Academy of Sciences Conference on agricultural productivity.

The first appraisal projected crop productivity increases of 1.1 percent per year from 1980 to 2000 and 0.8 percent per year thereafter. The second appraisal projected average increases ranging from 1.0 percent per year to 2.6 percent per year (alfalfa and soybeans, respectively) to 2000, and from 0.7 percent per year to 1.2 percent per year (alfalfa and feedgrains) thereafter. These differences, when compounded over a 50-year period, resulted in marked differences in projected average crop yields (fig. 1-2 and table 1-1). But they mirror the vastly changed view of the future which has developed during the past decade.

Projected national needs, as measured by quantities of agricultural commodities demanded for domestic and export markets, were similar in total for the first and second appraisal reports, although varying in composition (fig. 1-3). For the large-acreage crops--corn, sorghum, soybeans, and wheat--quantities demanded are higher in the second appraisal report because projected export demands are higher in that

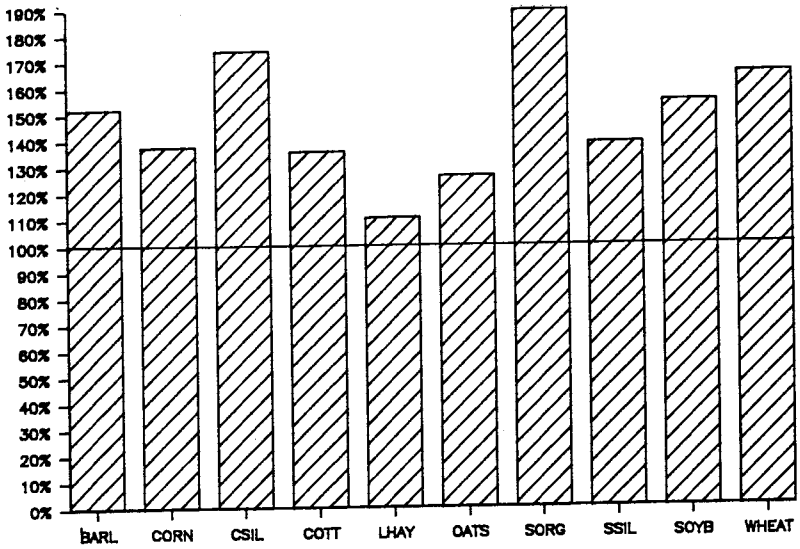

Figure 1-2.--Second Appraisal: Average yields, 2030. First Appraisal yields = 100. See appendix table A1-1.

analysis. For other crops, particularly feedstuffs, quantities demanded are lower, largely because projected feed efficiency rates are very high, and much greater use of pasture and range forage is projected, and also, to a lesser degree, because per capita consumption of red meat is projected to decline.

Ruttan chides the pessimistic tone of the food demand and supply projections of the 1970's, finding them excessively swayed by short-run trends and events: "It seems quite clear that the model builders and futures simulators were influenced by an intellectual environment that would have regarded more optimistic projections as out of touch with reality."

The same criticism, in reverse, can be directed at the analysis reported here. It is entirely possible that these projections of land resource use are overly optimistic, that the analysts were influenced more by the recent accumulation of commodity surpluses and by reports of new breakthroughs in technology than by the implications of a continuation of long-term historic trends. The possibility of bias and error in the projections led to the development of a broad range of demand and productivity scenarios, described in chapter 12 of this report. One is a "high-stress" scenario; this scenario assumed extremely high commodity demands, low increases in productivity, and high rates of conversion of land to nonagricultural uses. The analysis found that the high levels of demand could be met even under these very stressful conditions.

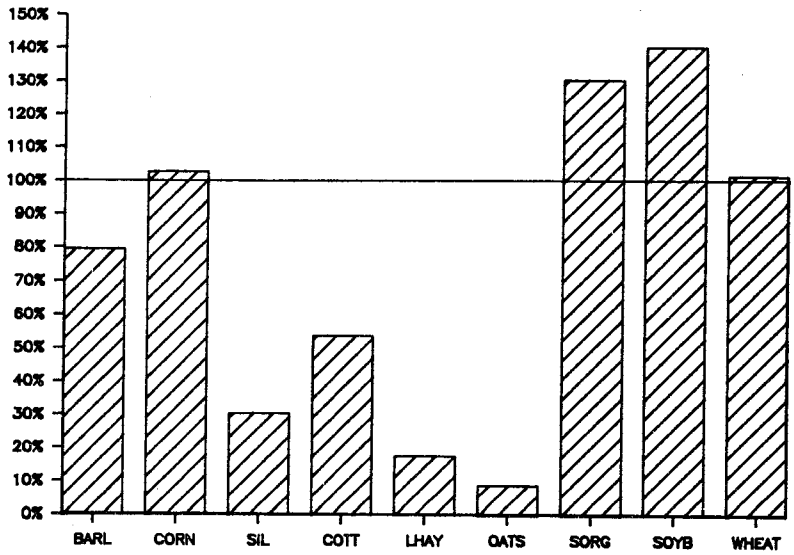

Figure 1-3.--Second Appraisal: Total demands, 2030.
First Appraisal demands = 100.

However, the projected consequences for the nation's resource base are worth reporting. Projected erosion rates on cropland in 2030 average twice as much for the high-stress scenario (7.6 tons per acre annually) as for the intermediate set of conditions (3.8 tons per acre). Because 128 million more acres would be cropped under the high-stress conditions, the total amount of cropland soil moved annually by erosion is projected to be 2.6 billion tons, more than three times as much under the intermediate conditions (0.78 billion tons). Both scenarios include the conservation reserve among their basic assumptions, but the intermediate scenario also includes restrictions on the amount of erosion allowed on cropland to simulate the effects of the conservation compliance feature of the Food Security Act of 1985. The high-stress scenario does not include any constraints on erosion but does include the constant high energy prices that make conservation tillage the least-cost production method under all scenarios.

Irrigated acreage used for the major crops is projected to exceed 55 million acres under the high-stress conditions, and 119 million acre-feet of water would be withdrawn for cropland use. Three-fourths of the water would be drawn from groundwater sources. Under the intermediate scenario, less than 17 million irrigated acres would be used for the major crops and 31 million acre-feet of water would be used for irrigation. Almost 60 percent would be groundwater.

During the last cycle of "food pessimism" in the 1970's, millions of acres of erosion-prone land were plowed up for the production of crops, only to be abandoned within a few years. Severe erosion compromised the long-term productivity of this land. When again brought into production during the next cycle, or the one after, this land will not be as responsive to national need as it once was. Because of short-term resource stress and because of long-term risk associated with reliance on historic trends, the need to maintain the quality of the resource base is the important message of the Second RCA Appraisal.

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SUMMARY

The United States Department of Agriculture prepared this appraisal of the nation's nonfederal soil and water resources in response to the requirements of the Resources Conservation Act of 1977 (RCA).

The Act directs the Secretary of Agriculture to appraise the soil, water, and related resources of the nation. The Act further directs that programs administered by the Secretary of Agriculture for the conservation of soil, water, and related resources be responsive to the long-term needs of the nation, as determined by the appraisal. USDA issued the first RCA appraisal in 1980 and, after conducting extensive public participation activities, implemented the National Conservation Program in 1982.

RESOURCE STATUS: COULD IT BE IMPROVED?

The Act directs that the appraisal include data on the quality and quantity of soil, water, and related resources and on the capability and limitations of those resources for meeting current and projected needs. The first appraisal documented that our soil and water resources are both abundant and high quality. This second appraisal, therefore, has focused on conditions that have potential for limiting the capability of our resources to meet our needs. Analyses addressed three broad questions:

- Is the productive capacity of our land being maintained?
- Are we making optimal use of the water available for agriculture?
- Are public health and our environment adequately protected?

The following paragraphs summarize the appraisal findings for each question raised. The appraisal shows that degradation of some of our land resources continues, that water demand and supply are not in balance, and that processes intensified by agricultural production do pose possible threats to environmental quality and public health. The appraisal also shows that these problems are not unavoidable or insolvable. Improved management, increased application of conservation measures, and better long-range planning of land and water resource use could significantly improve current conditions and reduce the potential for problems in the future.

Is the Productive Capacity of Land Being Maintained?

Under current use and management, the productive capacity of some agricultural land is not being maintained:

- About 1.5 million acres of agricultural land, most of them prime farmland, are irreversibly removed from production and converted to nonagricultural use each year.
- Sheet and rill erosion or wind erosion exceeds the tolerable level on more than 173 million acres of cropland.
- A total of 57 million acres of cropland and pastureland are affected by excess soluble salts or adsorbed sodium.
- Nearly 250 million acres of nonfederal rangeland are in less than good condition.

Changes in Land Use Can Diminish Resource Productivity

A total of about 1.5 million acres of agricultural land are converted to all nonagricultural uses annually. Nearly 64 percent of these acres are cropland. When agricultural land is converted to nonagricultural uses such as urban use, mining, or water storage, it is irreversibly removed from the agricultural base. Assuming the current rate of conversion continued, the cropland base would be reduced by nearly 48 million acres, or 12 percent, between 1982 and 2030, the period for which this appraisal projects resource conditions.

Changes in land use may have an enormous effect at the local level without becoming a problem that requires specific action at the national level. In the 1970's, however, rapid urban development occurred in many areas of the country at the same time that world demand for food and fiber was increasing rapidly and the acreage cropped was expanding rapidly to meet those demands. These trends focused attention on the potential consequences such changes might have for the productive capacity of our agricultural land and on the environment of the nation as a whole.

Economic changes in the early 1980's have slowed the rate of urban growth in some areas. About 1 million of the acres currently being converted to nonagricultural uses each year are used for urban development. This is about half the rate at which land was converted to urban use during the 1970's. Even at the current rate, however, the nation's urban land would double in the next 50 years.

Furthermore, the effects of conversion, not only on local and regional farm income and production patterns but on the nation, may be understated if only the number of acres converted is considered. Much of the urban growth will occur on prime farmland in counties in or near metropolitan areas. Although counties in fast growth areas include less than 15 percent of all cropland, they account for nearly 30 percent of the dollar value of the nation's farm output.

Conversion of farmland to nonagricultural uses has implications for future agricultural production because the land available for conversion to cropland, should the need arise, is not unlimited. In 1982, only 35 million acres of land not used for cropland were rated as having high potential for conversion to cropland. Another 118 million acres had medium potential. Much of this potential cropland has lower capability as cropland than the land now in crops. In addition, most of it is now used as pasture or range. Converting it to cropland would result in a significant reduction in grazing land and forest land and, in some places, serious losses of wildlife habitat.

Erosion Is Reducing Productivity of Some Soils

Soil erosion can reduce onsite capability of the soil to produce crops and can increase the costs of farming. In 1982, sheet and rill erosion moved more than 3.4 billion tons of soil on nonfederal rural land, and wind erosion moved 2 billion tons. More than 286 million acres of nonfederal land are eroding at rates greater than the soil tolerance --that is, the rate at which sustained economic production is assured.

Although a permanent cover of grass or trees generally provides adequate protection against erosion, about 18 percent of our rangeland, 9 percent of our pastureland, and 6 percent of our forest land are eroding at rates above tolerance. Cropland is far more vulnerable to erosive forces--about 173 million acres or 40 percent of all cropland is eroding at rates of sheet and rill or wind erosion that exceed the tolerable rates. About 23 percent of cropland is eroding at twice the tolerable rate.

Sheet and rill erosion and wind erosion are not the only forms of erosion threatening agricultural land. Gully erosion and the concentrated-flow erosion called "ephemeral gully" erosion on cropland can also be highly destructive.

Erosion can cause both short-term and permanent damage. A definitive quantification of the costs of erosion cannot be made. Few data are available on short-term costs of erosion--those costs that result from damage to the growing crop. Estimates of the current cost of permanent damage to the soil are partial and preliminary. Resources for the Future estimates that the sheet and rill erosion that occurred over the past 30 years on land planted to corn resulted in soil damage costs of nearly $700 million in 1982. This estimate includes costs of loss of productive capacity and increased fertilizer and fuel use.

A new computer model (EPIC) estimates that 100 years of sheet and rill and wind erosion, under 1982 management conditions, would reduce productive capacity 1.9 percent nationally. This loss is the equivalent of losing production worth more than $9 billion at 1980 prices. The estimated loss of productivity varies greatly among regions, ranging to as much as 60 percent along the Central California Coast Range and as much as 50 percent in the Great Valley of Virginia. Simulations using a linear programming model of the nation's agricultural sector indicate that the productivity loss would mean that an additional 6 million acres of cropland would be required to meet demands in 2030 because of the loss of productivity, changes in relative costs of production, and regional shifts in production that would result from erosion.

Soils differ in their sensitivity to erosion and therefore in the kind of management required to protect them from damage. Sheet and rill and wind erosion are not hazards on some soils; about 94 million acres of cropland

have almost no susceptibility to damage by these forms of erosion. On 277 million acres of cropland, erosion is a hazard but damage can be prevented if resource management systems are used. On about 45 percent of that land, however, current management is permitting erosion to exceed tolerance. About 50 million acres of cropland are so highly susceptible to erosion damage that preventing damage is nearly impossible. If converted to grass or forest land, however, these soils would maintain their usefulness indefinitely.

Salinization Is Damaging Some Soils

Salinization is a problem in arid and semiarid areas where precipitation is insufficient to leach salts from the soils. Saline or sodic (excessive sodium) conditions are lowering productivity on 10 percent of the nation's cropland and pastureland, including nearly one-fourth of the irrigated cropland and pastureland. Six of the western water resources regions have salinity problems on one-third or more of their cropland and pastureland.

If the soil moisture around plant roots contains too much salt, most crops cannot absorb the water and nutrients they need to germinate and grow well. When soil salinity increases, the productivity of the land is reduced. Yields decrease, and farmers may be forced to switch to salt-tolerant crops or to abandon cropping altogether. Irrigating with saline water or poor management of irrigation water can cause salinization of irrigated land. Some cropping practices on nonirrigated land can cause saline seeps. Seeps occur where salt-bearing ground water emerges on the surface of a slope.

Efforts to deal with salinization must be carefully planned to ensure that the problem is reduced, not just moved to another area. If farmers apply excessive amounts of irrigation water to leach salts and sodium from the soil, the salts and sodium lower the quality of water available to downstream water users. Water supplies may be rendered unfit for people or animals to drink and may cause high mortality of fish and other stream organisms.

Treatment of saline and sodic soils involves careful control of the salt balance. In principle, the salts should be moved down just below the root zone of the crops. In practice, it is acutely difficult to maintain this delicate balance. Because irrigation water usually contains varying amounts of salts, drainage must be provided to keep saline ground water from accumulating. It is easy to inadvertently apply too much irrigation water and thus propel the salts into a stream.

Rangeland Resources
Need Protection

There are more than 406 million acres of nonfederal rangeland. Between 1977 and 1982, there was little national change in the extent of nonfederal rangeland; in some states, however, there were significant changes. Extensive acreages in Montana, Colorado, and South Dakota were converted to cropland.

Range vegetation is an important renewable resource that is an integral part of the resource base. The health of rangeland is measured by range condition. Much of our rangeland was severely abused by early settlers unfamiliar with the fragility of range ecosystems, but range scientists report that rangeland has generally been improving in condition since the 1930's. In spite of that trend, 61 percent of nonfederal rangeland remains in less than good condition.

Approximately one-third of the nonfederal rangeland was adequately protected in 1982. On another one-third, improved management would improve range condition. The other one-third was in need of more drastic conservation treatment, such as brush management, range seeding, or erosion control.

Continued good management to maintain the improvement achieved so far is important because it is more costly to restore productivity than it is to maintain rangeland in good or excellent condition. Good management of rangeland increases forage for livestock, improves habitat for wildlife, and can increase the quality and quantity of the water supply that originates in rangeland watersheds. An economic analysis of the range livestock industry showed that the rangeland resource is more responsive to intensive management practices than to capital-intensive practices.

Are We Making Optimal Use of Water Available to Agriculture?

In arid regions, crop production depends almost entirely on irrigation. Irrigated agriculture accounts for more than 40 percent of all freshwater withdrawals in the United States and consumes nearly three times as much water as all other uses combined. In subhumid and semiarid regions, agricultural production depends on water storage and distribution systems. Even in humid areas, droughts during the growing season are common and can significantly reduce yields.

Under current use and management, water shortages occur in all regions. Shortages are most common and acute in the arid regions. The imbalance of supply and demand can have immediate or long-term effects--or both. Inadequate water supplies for irrigation and other offstream uses can result in the loss of a season's crops or eventually changes in land use and shifts of irrigated farming from one region to another. Diminished streamflows can interfere with hydropower generation and navigation

without causing more than temporary hardship, but if aquatic life and fish habitat are even briefly affected, recovery may be lengthy and difficult. Overdrafts (mining) of ground water soon increase the economic and energy cost of the water, with repercussions that work their way through the regional economy. If ground water mining results in a substantial decline in the permanent water table or in the water pressure within an aquifer, the change is not likely to be reversed.

Although localized or wide-scale problems of water availability are occurring in many areas, most problems could be minimized with careful planning. Improved management of irrigation water, improved management of soil moisture, and increased storage to increase dependable supply can bring supply and demand into better balance.

Irrigation Water Can Be Used More Efficiently

Farmers have increased their efficiency in using irrigation water; a national average of 47 percent of the water withdrawn from surface or ground sources for irrigation was consumed by the crop in 1982 as opposed to 41 percent in 1975. In 1975, an average of 78 percent of the water withdrawn for irrigation reached the farm: in 1982 the average improved to 81 percent. In 1975, an average of 53 percent of the total withdrawn was applied to the crop; this on-farm efficiency increased to nearly 59 percent in 1982.

Expansion of irrigation has slowed in the last 5 years. According to the Census of Agriculture, farmers reported irrigating a million acres fewer in 1982 than in 1978; twelve of 14 states that irrigate over a million acres irrigated fewer acres in 1982 than in 1978. Reduction of the acres irrigated affects regional economies because irrigated farming is highly productive.

Better Management of Soil Moisture Can Make More Water Available to Crops

On nonirrigated land, especially in areas of limited rainfall, farmers can make more water available for their crop by increasing infiltration and reducing runoff. Use of practices for soil conservation/soil moisture management can reduce erosion and increase net returns. Such practices tend to have greater effect on the costs of production than on yields, according to computer simulations.

Effective use of soil moisture conservation practices requires careful management and accurate soil information, however. Practices that increase soil moisture retention in dry years also tend to retain water in wet years. Increases in movement of soil moisture to ground water may affect water quality, because soluble nutrients and pesticides tend to move with water through the root zone into the ground water.

Improving Drainage in Cropland Can Increase Efficiency

Excess water, rather than too little water, is the major water management problem in some soils. In the 1982 NRI, USDA identified about 24 million acres of nonirrigated cropland and 2.6 million acres of irrigated cropland where drainage is the main improvement needed.

Installing drainage on wet cropland soils generally increases yields and makes farming operations easier. When drained, many wet soils are highly productive. Nearly 47 percent of all wet soils are prime farmland.

However, the costs of providing drainage and the effects of drainage on the environment must be considered before drainage is installed because in some cases the benefits do not outweigh adverse effects on wildlife habitat and water quality.

Are Public Health and the Quality of the Environment Adequately Protected?

Under current use and management of our soil and water resources, public health and the environment are threatened as a result of flooding; impaired water quality; deposition of sediment eroded from cropland, forest land, and rangeland; and reduced air quality. Habitat for fish and wildlife is undergoing change. New and better methods are being developed, however, to study these conditions, quantify the damages, and evaluate strategies for dealing with problems.

Upstream Flood Damages Are Increasing

Annual costs of flooding are as high as $5 billion, and this figure shows a steady trend upward to a projected $9 billion by the year 2030 (1980 dollars). This is a faster rate of increase than was projected just 5 years ago. This estimate does not take into account the lives lost and the physical and mental trauma caused by floods.

Damages in upstream watersheds account for half of all flood damages, and 80 percent of upstream damages occur in rural areas. About 14 percent of the nation's cropland is on flood-prone lands. Flood-prone lands will remain in agricultural use, both because of restrictions on more intensive development on flood plains and because flood-prone lands are highly productive as cropland. Crop production can be expected to continue on these lands and to decrease on lands where erosion is a severe hazard or water is not available for irrigation. Damages are also projected to increase because existing cropland is being cropped more intensively. Even so, damages to cropland and pastureland will not increase as rapidly as damages to urban areas and damages to rural land in other uses.

The effects of flooding can be addressed in three ways: by controlling floodwaters through structures such as dams and reservoirs; through policies that regulate the type of activities permitted on the flood plain and through disaster preparedness and warning systems; and through flooding insurance, tax adjustments, and post-flood recovery programs that reduce the costs individuals must bear.

Atmospheric Deposition Is Causing Popular Concern

Acid deposition contributes to acidity in lakes and is suspected as a causative factor in the decline of productivity of forests in the eastern United States. Acid deposition has not been documented to cause damage to cropland. Studies have demonstrated, however, that plants are injured and crop yields are decreased by the presence of above-normal levels of ozone in the surrounding air. Ozone decreases agricultural production by 5 percent annually.

This appraisal reviewed findings of studies of the effects of atmospheric deposition on crops, forests, soils used for agricultural purposes, and surface water. This chapter does not include data on potential agricultural contributions to atmospheric deposition such as pesticide drift or acid fog.

Offsite Damages Caused by Erosion and Runoff Exceed Onsite Damages

Water erosion and runoff from agricultural land cost the nation between $3.2 billion and $13 billion (1980 dollars) annually. Wind erosion imposes additional costs. These costs result from damage to water, land, and air quality.

Erosion and runoff from agricultural land reduce water quality in streams, reservoirs, and lakes. Major nonpoint source pollutants in surface waters are suspended particles of solid material, nutrients, waste-related bacteria, pesticides, and dissolved salts. Water infiltrating agricultural lands can carry soluble nutrients and chemicals into ground water.

Sedimentation decreases water storage capacity in lakes and reservoirs, clogs streams and drainage channels, causes deterioration of aquatic habitat, damages water distribution systems, and decreases cropland productivity. Sixty percent of all sediment delivered to the nation's waters is from agricultural lands.

Blowing soil resulting from wind erosion lowers air quality. It aggravates respiratory ailments in humans and animals, reduces visibility for drivers and airplane pilots, clogs machinery and filters, and permeates homes and workplaces. When dust covers plants, it inhibits photosynthesis, and the quality of crops is reduced.

Potential sources of agricultural nonpoint source pollution.--Pollution from nonpoint sources is reported to be the major remaining cause of reduced water quality in 6 of the 10 EPA regions, and agricultural activities are the most pervasive nonpoint sources in all regions. USDA has rated the potential for agricultural nonpoint source pollution in the nation's watersheds.

The effect that reducing erosion on cropland might have on water quality has been analyzed using the national water network model developed by Resources for the Future. The analysis suggests that controlling cropland erosion would improve water quality enough to meet the recommended EPA standard for phosphorus in many areas in the East and Midwest but that, in the West, erosion would have to be controlled on other land as well as cropland. In some areas, erosion control is not needed to improve local water quality or would not improve local water quality enough to meet the standard but is required to improve water quality farther downstream.

Costs of offsite damage of erosion.--Methods to precisely estimate all types of offsite damages have not been developed. Costs of sediment and associated chemicals moved offsite by water erosion have been described as instream and offstream damages. Best estimates are that sediment and sediment-associated contaminants cause damages of more than $4.2 billion annually (not including damage to aquatic habitat) when they are suspended or deposited in waterways. Offstream damages are estimated to exceed $1.9 billion. Wind erosion damages are estimated to be at least as great as damages resulting from water erosion.

Water erosion and runoff from cropland are estimated to cause about one-third of total offsite damages, about $2.2 billion annually. This amount is much higher than the cost of the permanent damage to cropland soils that erosion causes in any single year. The costs of the first year's permanent loss of productivity, based on computer simulation of 100 years of sheet and rill erosion, is $17.3 million.

These estimates of onsite and offsite damages are not entirely comparable, however. The offsite estimate includes both long-term damage and short-term damage; much of the short-term damage could be quickly corrected if the erosion were prevented. The onsite estimate does not include short-term costs such as increased operating costs or annual yield losses. The onsite estimate represents the long-term loss of productivity and is of concern because it is permanent and cumulative.

Ground water contamination.--In 1984 reports to EPA, 35 states reported some problems with contamination of ground water. The most commonly reported sources of contamination are industrial and municipal. Ground water contamination from use of pesticides and nutrients in agricultural operations is also being reported. Many states have only limited information about pesticides and nutrients in ground water. Numerous efforts are underway to collect more data to identify current problems and determine the potential for future contamination.

Damage to aquatic habitat.--Although most of the nation's streams provide suitable habitat for some aquatic species, various factors are reducing the quality of the habitat for more than four-fifths of the nation's fish communities. Agricultural nonpoint sources of pollution are reducing water quality in 29 percent of all streams. Agricultural diversions, primarily for irrigation, are reducing water quantity enough to damage habitat in 14 percent of streams.

Wildlife Habitat Has Been Altered

When people use land for agriculture, they can change the quantity and quality of the habitat the land provides for wildlife and, therefore, the number and species of animals that can live there. The habitat can be considered a "structure" composed of one or more of seven layers of vegetation. The diversity of the structure of the existing habitat can be compared to that of the natural vegetation of the site. The structure of the habitat has been changed to the greatest degree in the regions where we use the land most intensively. Wildlife habitat in the Midwest has less than one-third of the structural diversity that it had before people began to use the land. In some other parts of the nation, the land still provides habitat not greatly changed from its natural state. The value of the layers as habitat is affected by, and therefore can be improved by, the management practices that farmers apply.

Wetlands Have Been Lost

Wet areas may interfere with agricultural operations. Because the cost of draining these areas can, in some regions, be offset by the value of timber from mature hardwood stands and because of the profitability of crops grown on these sites, farmers have continued to drain wetlands in spite of federal and state restrictions and regulations. Areas where conversion is most likely to occur are in the South Atlantic-Gulf region and the Upper Midwest. Both the bottomland hardwood forests of the former and the prairie potholes of the latter regions are important wildlife habitat. "Swampbuster" provisions of the Food Security Act of 1985 will discourage further conversion for production of agricultural commodities.

RESOURCE PROJECTIONS: WHAT MIGHT THE FUTURE HOLD?

USDA made projections of future conditions in response to the Resources Conservation Act of 1977, which directs USDA to analyze resource capability and limitations for meeting projected demands. USDA first analyzed the major forces that affect future demands on our soil and water and made separate projections of the highest and lowest rates of change that could reasonably be expected in each of these forces and of an "intermediate" rate. These forces are commodity demands, demands for

land and water for nonagricultural uses, development of new production technology, productivity losses stemming from soil erosion, and the policies and institutions that affect resource use. The separate projections were then combined and their interaction analyzed using a linear programming model of the nation's agricultural sector developed by the Center for Agricultural and Rural Development (CARD) at Iowa State University. The CARD analysis determined patterns of land and water use based on the least-cost method of production and transport. Future availability of, use of, and potential competition for resources were evaluated to 1990, to 2000, and to 2030.

The "Intermediate" Conditions:
Increasing Productivity
Reduces Resource Requirements

Natural resources readily available to the agricultural sector are projected to decrease slightly in the years ahead and total commodity demands are projected to increase considerably, but resources are projected to be adequate to meet demands. The amounts of cropland and irrigation water needed are projected to decline significantly by the year 2000 and to level off after that date. In 2030, the analysis projects that demands for food and fiber could be met on 218 million acres of cropland, 30 million of which would be irrigated.

The decrease in projected land and water requirements results from the projection that yields per acre would double by 2030 and that the efficiency of livestock feed use would more than double. In 2030, the acreage required to meet projected export demand would approximately equal the acreage projected to be needed to produce actual export demand in 1982; the acreage required to meet domestic food demand would be three-fourths of that projected for 1982; and the acreage required to produce feed for livestock would be less than half that projected as needed in 1982. The reduction in cropland acreage required to produce livestock feed is accompanied by an increased use of nonfederal pasture/range forage: from 237 million tons in 1982 to 453 million tons in 2030.

Because the acreage of cropland is projected to decline, resource problems are projected to decline:

- This analysis assumes that the 40 million acres of highly erodible land placed in the Conservation Reserve authorized by the Food Security Act of 1985 would not be returned to the cropland base during the period for which the analysis was made. Therefore, the acreage of cropland classified as unsuited to cropping (land in capability classes V -VIII) is projected to decline. Assuming the "intermediate" rates of increase in demand and productivity and full implementation of the conservation provisions of the Food Security Act of 1985, the cropland base in the year 2030 is projected to include only 2 million acres in classes V and above.

- The projected reduction in cropland results in a projected 50-percent reduction in gross soil erosion for the major commodity crops. Total erosion on cropland is projected to decline to less than 1 billion tons in 2030. Wind erosion is projected to decline because the acreage of cropland in areas subject to wind erosion is projected to decline. Sheet and rill erosion is projected to decline primarily because it is assumed that economic considerations will make some form of conservation tillage near-universal by 2030 and, to a lesser degree, because the conservation compliance provisions of the Food Security Act of 1985 will encourage some additional use of conservation practices and some shifts to less-erodible land.

- Projections did not consider the effects of salinity on cropland availability or productivity. Assuming that high percentages of cropland in the western half of the nation, both irrigated and dryland, are removed from production as the analysis projects, however, it is likely that salinity problems would be reduced also. Continued availability of sufficient land for special crops grown in areas with current or potential salinity problems was assumed but not analyzed.

- Projections of future developments based on the CARD model indicate that, under all except the most extreme conditions, fewer acres would be irrigated and therefore less irrigation water would be needed in the future. Assuming "intermediate" rates of increase in export demand and crop yields and full implementation of the conservation provisions of the Food Security Act of 1985, slightly more than 30 million acres are projected to be irrigated in 2030, compared to 49 million in 1982. Assuming "intermediate" conditions in the absence of the conservation efforts mandated by the Act, fewer acres would be irrigated.

The CARD analysis projects irrigation only to increase yield, not to reduce risk, and therefore may underestimate irrigated acreage in a few areas. Data are not yet available to indicate whether or to what extent ground water mining could continue even as the acreage irrigated is projected to decline.

- Removal of extensive acreages from cultivation and application of conservation tillage on most cropland could be expected to improve wildlife habitat.

- Reduction in erosion would reduce the sediment delivered to waterways and therefore the costs of offsite damages.

Conditions May Vary

The "intermediate" scenario depicts a future of moderate resource use. Two other scenarios were analyzed. Under the low stress scenario --increased resource availability, lower demands, higher technology-- the projected demands could be met with even fewer acres than are projected for the "intermediate" conditions. The high stress

scenario--a combination of reduced resource availability, higher export demand, and lower technology--requires that all cropland available in 2030 be cropped, with the exception of the 40 million acres in the Conservation Reserve. Under the "high stress" scenario:

- virtually all of the nearly 8 million acres of cropland in classes V through VIII not assumed to be entered in the Conservation Reserve would be cropped.

- 68 million acres, all of the irrigated land considered available in the analysis, would be irrigated.

- more than 77 million acre-feet of irrigation water would be consumed by the crops considered in the CARD model and an additional 22 million acre-feet would be consumed by other crops.

- projected wind erosion in 2030 would remain at the 1982 level and sheet and rill erosion would decline only slightly.

Other Studies Have Projected Different Results

The first RCA appraisal assumed slightly lower levels of demand and significantly smaller annual increases in yield, based on conditions before 1977. As a result, that analysis projected that 389 million acres of cropland would be needed in 2030. USDA's NIRAP model, using the same demand assumptions as the second RCA appraisal and using productivity assumptions coordinated with the appraisal, projected cropland needs very close to the first appraisal results--385 million acres.

Land Use Decisions Affect Productivity

Maintaining the productive capacity of agricultural land requires, as pioneer soil conservationist Hugh Hammond Bennett said, that people "use land according to its capability and treat it according to its needs." These two aspects of soil conservation interact--land used within its capability is less likely to be damaged and therefore needs less protection than land in uses for which it is not suited. Although most nonfederal agricultural land is used within its capability, considerable acreage is not. Much of this land is being damaged and consequently damages other land and water resources.

Land use is constantly changing, though the net change in the acreage in each use is slight in any single year. Changes from one agricultural use to another or to a nonagricultural use can affect the environment and people far from the scene of the action. Changes in land use may have enormous effect at the local level without becoming a problem that requires action at the national level. In the 1970's, however, rapid urban development occurred in many parts of the country at the same time that the acreage of land cropped was expanding in response to rapidly increasing world demand for food and fiber. These trends focused attention on the potential consequences such changes might have for the productive capacity of our agricultural land and on the environment of the nation as a whole.

Economic changes in the early 1980's have slowed the rate of urban growth in many areas and have lowered the demand for agricultural products. The most-discussed problem in land use is no longer the possibility of future shortages but the reality of current excess capacity. Projections of future developments made for this appraisal suggest that, barring events not considered in the analysis (such as changes in climate or massive disruption of historic trends), the shortages of productive capacity that seemed possible just a few years ago are not likely to occur. The change in outlook is based on the considerable increases in productivity that agricultural researchers now believe will be achieved in both crop and livestock production.

This analysis assumes that the 40 million acres placed in the Conservation Reserve authorized by the Food Security Act of 1985 would be permanently removed from the cropland base. Therefore, the acreage of cropland classified as unsuited to cropping (land in capability classes V -VIII) is projected to decline in the future. Assuming intermediate rates of increase in demand and productivity and full implementation of the conservation provisions of the Food Security Act of 1985, the cropland base in the year 2030, much reduced in extent, is projected to include 2 million acres in classes V and above. Assuming greater increases in demand and smaller increases in productivity, virtually all of the nearly 8 million acres of cropland in these classes not assumed to be entered in the Conservation Reserve would be cropped.

Use of the nation's nonfederal land is overwhelmingly rural and agricultural in nature (fig. 3-1). Because geology and soils differ across the nation, soils--and uses of land--differ among regions (fig. 3-2).

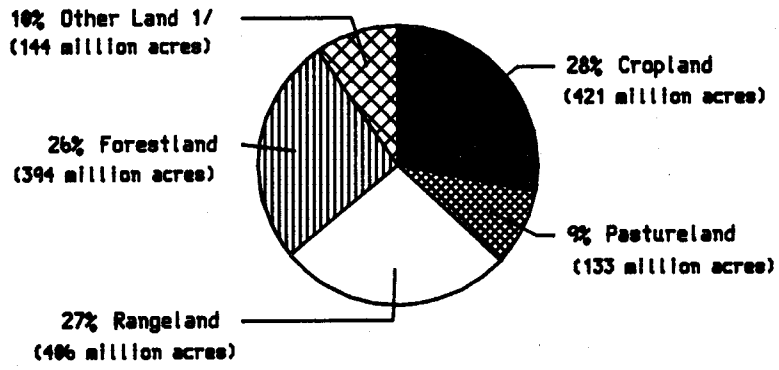


Figure 3-1.--Use of the nation's nonfederal land (1982 NRI). Nonagricultural land includes urban and built-up, rural transportation, and small water areas. For more complete data, see Appendix table A3-2.

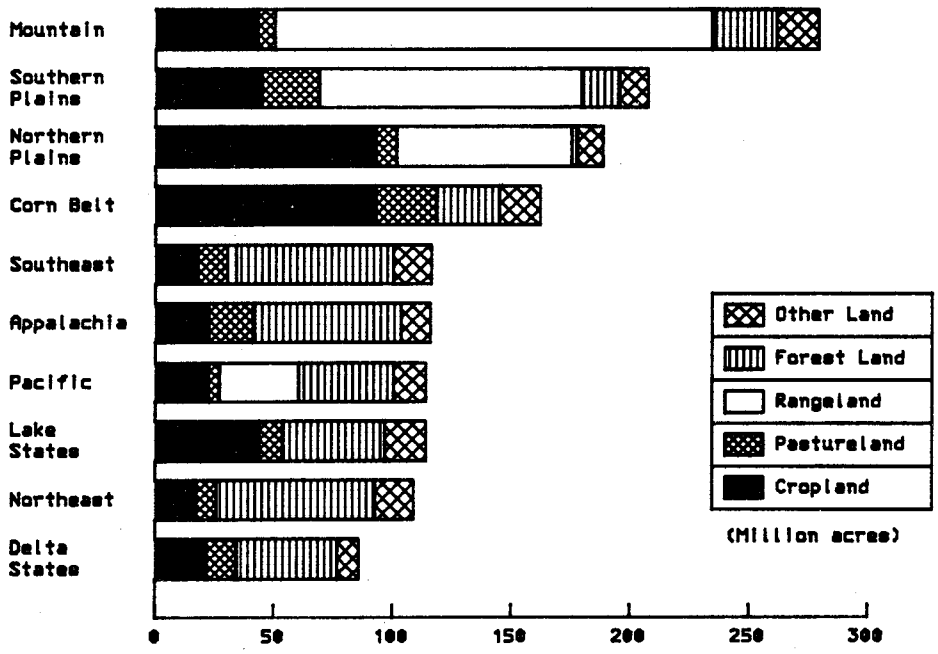


Figure 3-2.--Use of nonfederal land, by farming region (1982 NRI).

CHOICES IN LAND USE: Are we using our land wisely?

Evaluating land: Land Capability Classification

USDA's Land Capability Classification System is the most widely used method for judging the suitability of land for agricultural uses. The system has eight classes and four subclasses.

Figure 3-3 shows the distribution of nonfederal rural land in the eight land capability classes, which are the broadest categories of the system. Soils within a specific class have about the same degree of restrictions in use for crops and pasture or the same degree of risk of damage when used for crops. The soils in a class are similar only with respect to degree of limitation; each class includes different kinds of soil with different kinds of limitations.

The higher the class numeral, the greater are the limitations of the soils in the class and the narrower the choices for their use. Soils in classes I, II, and III are suited to cultivated crops. Soils in class IV can be used for crops, but only if crops are chosen with care or soil is managed with extra care. Soils in classes V, VI, and VII are, for the most part, not suited to cultivation but will produce pasture, range forage, trees, certain special crops or provide habitat for wildlife. (Applying pasture management practices, however, generally is not feasible on class VII land.) Land in class VIII has limitations that restrict its use mostly to recreation, wildlife habitat, or water supply.

All classes except I are divided into subclasses. Soils in a given subclass have the same kind of dominant limitation for agricultural use. There are no subclasses in class I because the soils have no significant limitations to use. The four subclasses are:

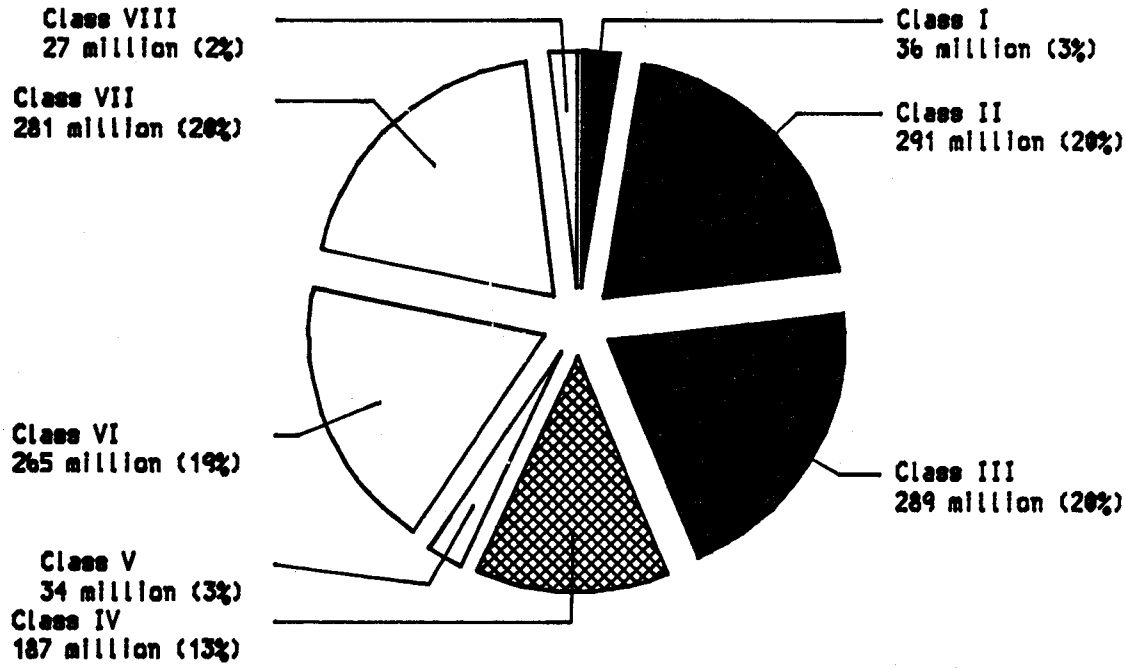
e--soils where susceptibility to erosion is the dominant hazard.

w--soils where excess water is the dominant hazard or limitation to use. Excess water may be caused by poor soil drainage, high water table, flooding (including stream overflow, tidal inundation, ponding, and runoff from higher areas), or seepage.

s--soils with limitations in the root zone. The root zone may be shallow or stony, have low moisture-holding capacity or low, difficult-to-correct fertility, or contain salts or exchangeable sodium in amounts toxic to plants.

c--soils where the climate (temperature or lack of moisture) is the only major hazard or limitation.

The capability classification system was designed to assist farmers in planning the use and conservation of their land. The class designation is a rating of the land, not of the limitations. Therefore the class rating is not a measure of the severity of the limitation indicated by the subclass symbol. For example, land in class IIIe is not in all cases more susceptible to erosion than land in class IIe. Some other limitation may make the class IIIe land of lower quality than the class IIe land.



Classes I-III: Land suitable for continuous cultivation
Class IV: Land suitable for occasional cultivation
Classes V-VIII: Land unsuitable for cultivation

Figure 3-3.--Capability classification of nonfederal rural land (1982 NRI). For more complete data, see Appendix table A3-1.

Figure 3-4 shows the acreage of nonfederal rural land in each subclass and class. Data on subclasses for classes V and VIII were not collected in the 1982 NRI. Land is classified according to its major limitation. Some soils have more than one limitation. These soils are assigned to a subclass based on the most restrictive limitation. For example, where wetness is a severe problem and the risk of erosion is moderate, soils are classified as "w" subclass. Where two kinds of limitation are essentially equal, the subclasses are given the following priority: e, w, s, c. For example, a few soils in humid areas have both a hazard of erosion and a limitation caused by excess water; these soils are assigned to subclass e.

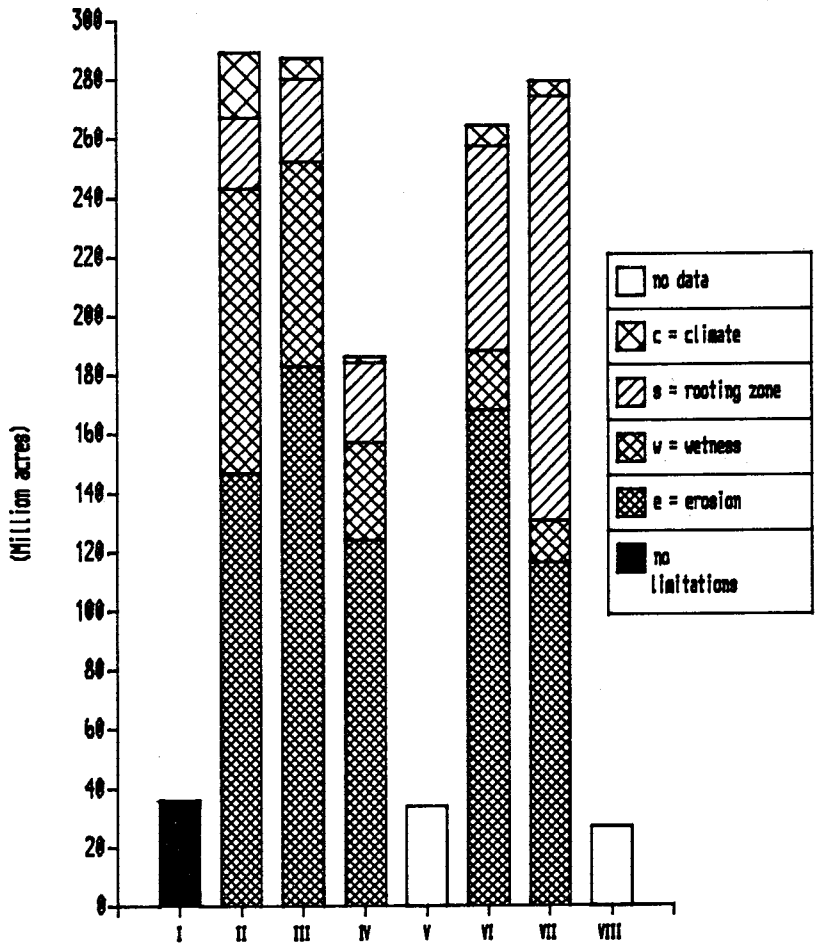


Figure 3-4.--Acreage of nonfederal rural land, by capability class and subclass (1982 NRI).
For more complete data, see Appendix table A3-1.

USE OF NONFEDERAL LAND: Are we using land within its capability?

Farmers generally use their land in a manner consistent with its capability (fig. 3-5). Almost all class I land, with soils that are level, deep, well drained, and easy to work, is being used as cropland. Because there is relatively little class I land, most cropland is in classes II and III. These are suitable for crops but need protection with conservation measures when they are cultivated. Most land in classes V through VIII is used for pasture, range, forest, or other suitable uses. About 19 million acres in these classes, however, are planted to crops even though land in these classes generally is not suitable for cultivation.

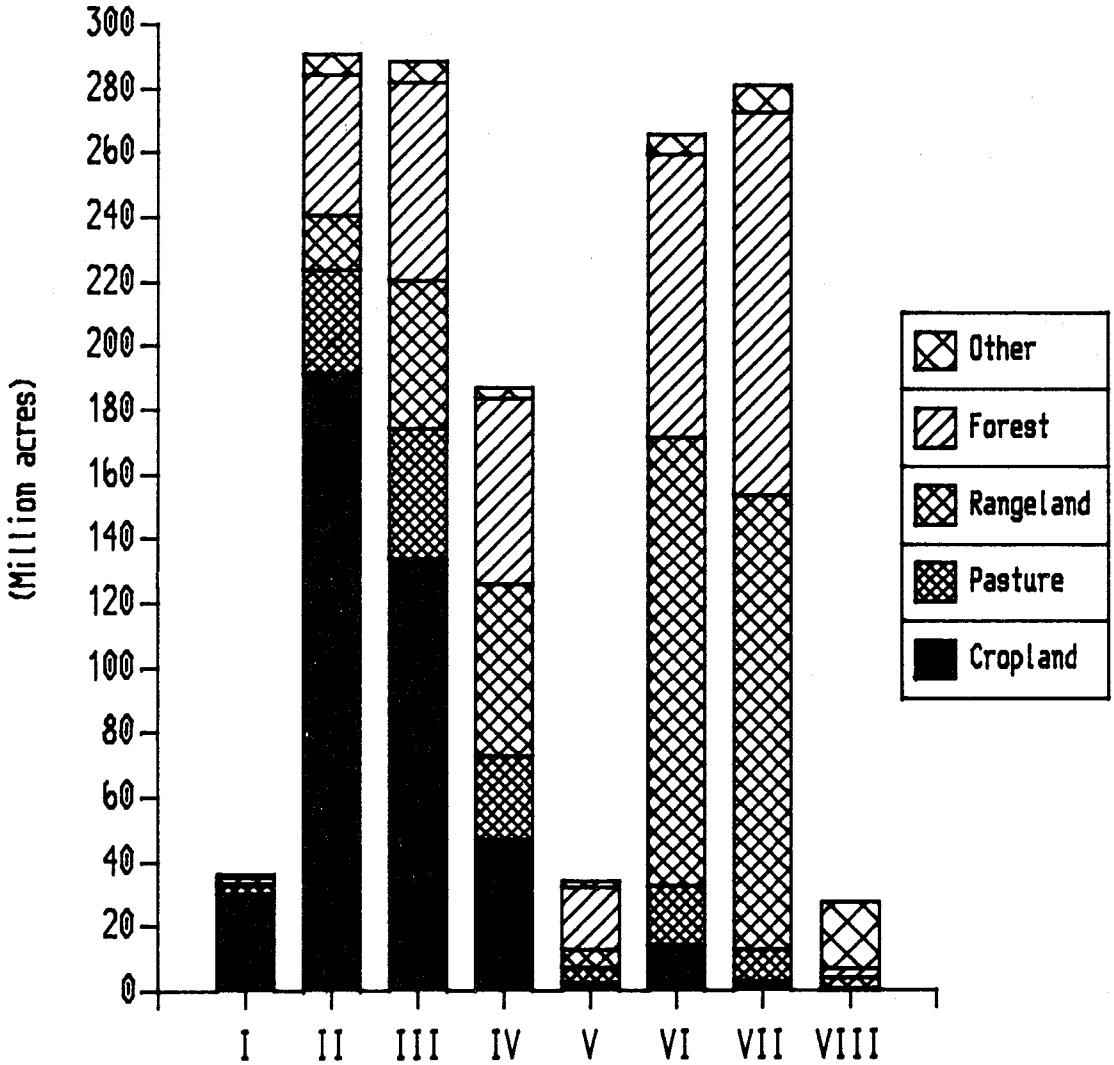


Figure 3-5.--Use of nonfederal rural land, by capability classification. For more complete data, see Appendix tables A3-1 and A3-3.

Patterns of use are not static, however. The use of privately held land is constantly changing. Farmers plow grassland and clear forest land so that they can plant crops. They allow land that was in crops to return to grass or trees. Developers build houses and shopping centers across what was farmland. Units of government convert cropland to water storage areas to provide flood protection for downstream areas, hydroelectric power, or water to irrigate other land.

Changes in land use are an inevitable and desirable part of a dynamic society. Not all changes in land use are desirable or beneficial, however. If large acreages of prime farmland are converted to urban use, larger acreages of less productive land may be needed to replace it. Where fragile or highly erodible land is planted to cultivated crops, erosion rates increase and so does the resulting damage to the soil onsite and the land and water downstream or downwind.

Such changes in land use may have sizable effect in a local area or region while not appearing to require specific action at the national level. Nevertheless, localized changes could affect a specialty crop, which might well attract nationwide attention should supplies decrease or prices climb. During the 1970's, however, rapid urban development in many areas of the country led to concern about the effects of continued development on the productive capacity and the environment of the nation as a whole. In the same period, much land was cleared and plowed for crops, reversing a decades-long trend. Not all the new cropland was suitable for cultivation, and many conservationists feared that the demand for more cropland, coupled with the loss of some of the best cropland, would result in greater damage both onsite and offsite. Economic changes in the early 1980's slowed the rate of urban growth in many areas and lowered the demand for agricultural products, reducing concern about the effects of land use changes in the short-term but not the need to study such changes and prepare to deal with conditions that may develop over the long-term.

URBAN SPRAWL: How rapidly is it occurring?

It is difficult to determine precisely the annual rate of conversion of land from agricultural to urban uses. Data on the acreage of land in various uses are collected by USDA and by the Bureau of the Census. Differences in definitions and procedures have caused widely differing estimates of the rate of conversion (fig. 3-6).

Several social and economic changes over the past 25 years have influenced the rate at which land is converted to urban uses. Population growth and changes in age distribution, the economy, and transportation have contributed to changes in land conversion rates.

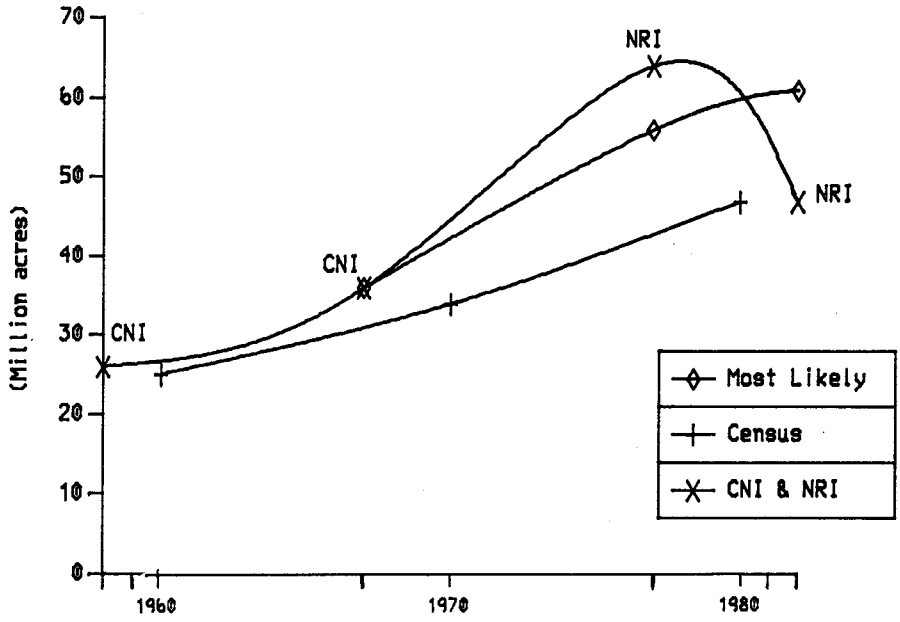


Figure 3-6.--Conversion of land to urban uses, 1958-82.
"Most likely" refers to an adjusted estimate explained on page 3-11.
USDA studies cited: CNI (Conservation Needs Inventory); NRI (National Resources Inventory).

For most of the 1960's, between 0.9 million acres (Bureau of the Census) and 1.1 million acres (USDA inventories) per year were converted to nonagricultural uses. Factors influencing this conversion were the increase in new housing starts, expansion of urban areas, improvements in rural transportation, and the beginning of the interstate highway system.

Between 1967 and 1977, the rate of conversion of agricultural land was 1.8 to 2.1 million acres per year, highest in the history of the United States. A number of factors contributed to the high rate of conversion. The interstate highway system was expanding rapidly (fig. 3-7). This permitted people to live farther from their place of work, encouraging expanded suburbs. The maturing baby-boom generation pushed the average annual rate of housing starts to its highest rate (fig. 3-8). The federal government increased its assistance to state and local governments for construction of sewage, water, and transportation systems--on land that had been farmland (fig. 3-9).

From 1977 to 1982, the average annual rate of conversion to urban uses returned to between 0.9 and 1.1 million acres per year. This decrease can be attributed to high interest rates, which sharply reduced new construction; local, state, and federal programs to control urban sprawl; completion of the interstate system; a sluggish economy; and higher transportation costs.

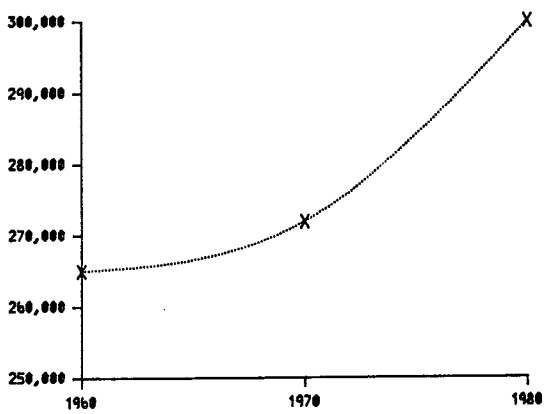


Figure 3-7.--Primary highway miles, 1960-80.

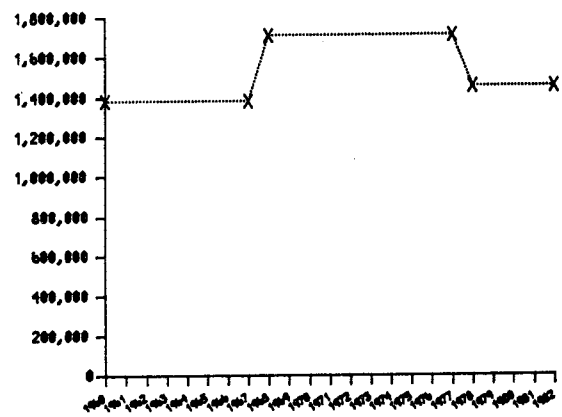


Figure 3-8.--Average annual new housing starts, 1960-80.

USDA Inventories of Urban Land

Conservation Needs Inventory/National Resources Inventory (CNI/NRI).--SCS has conducted four major inventories of soil and water resources in the last quarter century. The definition of "urban and built-up land" was similar for all four. However, neither the purposes of the surveys nor the procedures for estimating the extent of urban land were identical. As a result, the 1977 and 1982 NRI estimates of urban and built-up land are not comparable.

The 1977 NRI and the 1975 Potential Croplands Study were designed to answer questions about the adequacy of resources, questions that had been asked because export demands were rising rapidly. The focus was on the amount and quality of land available for future use. Because land zoned for development or included in developing areas was considered unlikely to remain in agricultural use over the long-term, such land was not counted as part of the cropland base.

Figure 3-9.--The same area in Santa Clara County, California, in aerial photographs taken 28 years apart. Farmland, mainly citrus orchards, in left photo is nearly covered with housing at right.

Some areas counted as urban and built up in 1977 included land on which development had not yet occurred. If future urban development were largely confined to filling in such areas, considerable development could occur without great effect on land still in agricultural uses. In this situation, more precise data were needed to track the rate and location of land conversion and its effect on local areas and the nation. The 1982 NRI was designed to provide data that could be used as a base line for measuring future changes. In the 1982 NRI, therefore, land was not considered "urban and built-up" unless it was completely developed. This criterion resulted in an estimate of urban and built-up land lower than the 1977 estimate and lower than estimates produced by other studies based on other data. It is even lower than the 1980 Census, which does not count all land the NRI includes as agricultural land. Analysis suggests that had the 1977 and 1982 NRI involved identical methodology and purposes, the 1977 estimate of urban and built-up land and rural transportation land would have been about 82 million acres rather than 90 million, and the 1982 estimate would have been about 88 million acres rather than 74 million. These adjusted NRI figures are the "Most likely" values shown in figure 3-6.

National Agricultural Lands Study (NALS). The NALS examined and attempted to account for shifts in uses of land from agriculture to nonagricultural uses. It also accounted for shifts among agricultural uses and from agricultural uses to water storage and distribution, rural transportation, rural housing, and other nonagricultural uses. The NALS counted land idled near urban centers but not yet built on as having been converted to nonagricultural uses. The NALS agreed with the original 1977 NRI estimate that approximately 2.9 million acres of all lands capable of agricultural production had been converted to nonagricultural uses annually between 1967 and 1977. Adjusted to correct for overcounting in the 1977 NRI, the NALS estimate is 2.1 million acres per year. The NALS was conducted by USDA and the President's Council on Environmental Quality, with support from 10 other federal agencies. The NALS used data from the Census of Agriculture and the General Census, the SCS 1977 National Resources Inventory, the SCS Potential Cropland Study of 1975, the Forest Service's Renewable Resources Assessment of 1975, and other sources.

LAND LOST TO AGRICULTURE: Most likely to be prime farmland

Prime agricultural land is more likely than marginal farmland to be converted to nonagricultural uses (Dillman and Cousins, 1982; Vining, et al., 1977). That is because agriculture was the basis for most permanent inland settlements in the United States. Settlements were located in the center of the most fertile areas and near rivers that offered a source of water and transportation. As the agricultural enterprises prospered, the settlements grew outward. Because the industrial revolution demanded large concentrations of people, industries were founded in the larger settlements. Most U.S. cities and larger rural towns, therefore, are surrounded by productive agricultural land and any expansion must occur on such land.

Eighty percent of the cropland likely to be converted to nonagricultural uses in the next 50 years is estimated to be prime farmland--land on which crops can be produced for the least cost and with the least damage to the resource base (USDA Economic Research Service [ERS], 1984). Of the agricultural land converted to nonagricultural uses between 1982 and 2030:

63.8 percent will be from cropland
17.5 percent will be from pastureland
13.0 percent will be from forest land
5.7 percent will be from other agricultural land (USDA ERS, 1976).

Conversion of land from agricultural to nonagricultural uses is most likely to occur in the nation's 676 metropolitan counties and the 787 adjacent counties because the growth of rural population has slowed from the pace of the 1970's. During the 1970's, population increased at a higher rate in rural areas than in metropolitan areas. From 1980 to 1982, however, metropolitan areas continued to grow at about 1 percent per year, while growth in rural areas decreased to an average of 0.8 percent.

Metropolitan counties contain about 20 percent of the nation's cropland and 20 percent of the land with high and medium potential for conversion to cropland.

NEW CROPLAND: Are we sowing new problems?

For most of the period since 1930, acreage of cropland has been decreasing. As increasing export demands in the 1970's brought higher prices for agricultural commodities, the acreage under cultivation began to expand again (fig. 3-10). The increase in demands for crops and resulting increase in land cropped introduced concerns that had not existed when low prices induced farmers to reduce the acres they planted. Was the slow progress toward removing marginal, erodible land from cultivation to be wiped out? Were damages to land and water likely to increase rapidly as a result of high erosion rates in new cropland? The NRI, which is the most reliable source of natural resources data on nonfederal lands, does not provide statistically reliable national data on the quality of land that has been converted to cropland in the past few years. In some states, there is evidence that fragile or highly erodible land has been plowed. NRI data on potential cropland, which present a reflection of land being converted, indicate that in most areas expansion of cropland must mean bringing lower quality land into cultivation.

Figure 3-10.--Charred logs and white ash heaps remain after a controlled burn on North Carolina's coastal plain. The trees had been felled and chopped to clear the land for crops.

Potential Cropland

The 1982 NRI estimated that in that year slightly under 1 billion acres of nonfederal rural land were not used as cropland. In the 1975 Potential Cropland Study and the 1977 and 1982 National Resource Inventories, USDA estimated the acreage that had potential for conversion to cropland in the short-term. Most land not used as cropland has very little potential for conversion. About 118 million acres have medium potential for conversion, according to the criteria in the 1982 NRI. Only about 35 million acres have high potential.

Potential cropland in the NRI means land that might be converted to cropland in the next 10 to 15 years, based primarily on commodity prices, development costs, and production costs in the year preceding collection of data. Land was rated as having high potential for conversion to cropland if there was evidence that similar land had been converted during the preceding 3 years.

Potential cropland is not evenly distributed across the nation (fig. 3-11 and 3-12). Half of the land with high and medium potential for conversion to cropland is in only 10 states: Texas, Missouri, Oklahoma, North Carolina, South Dakota, Montana, Kansas, Nebraska, Alabama, and Georgia.

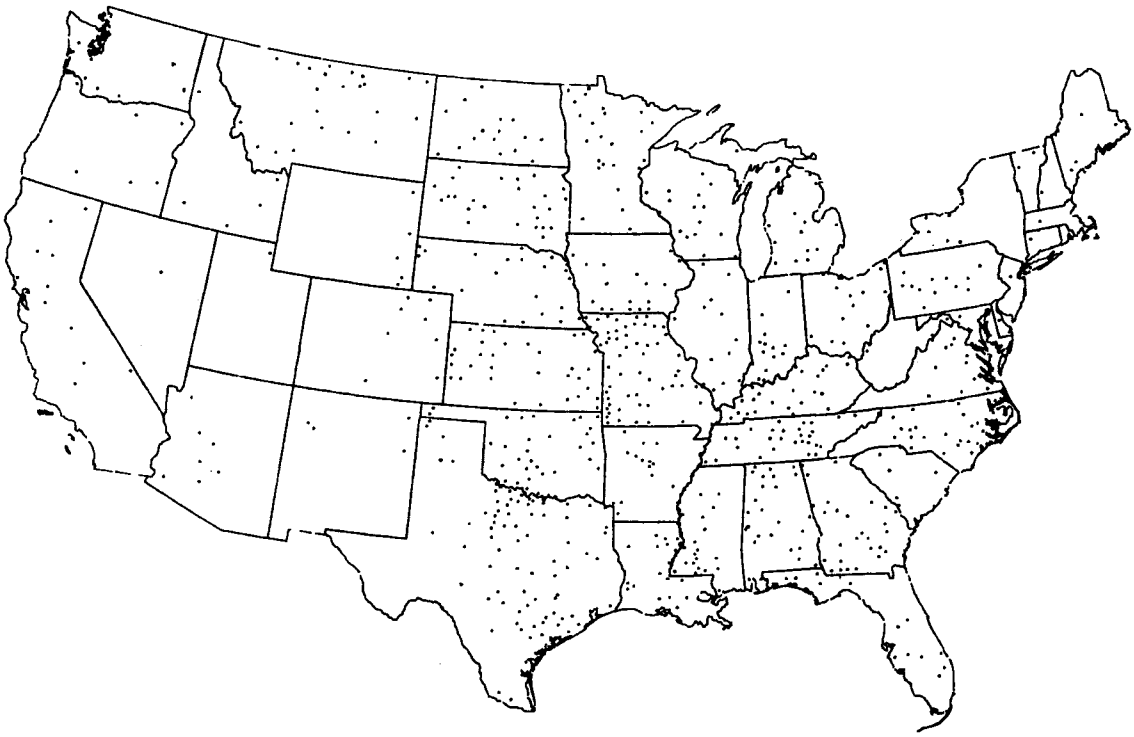


Figure 3-11.--Land with high potential for conversion to cropland (1982 NRI). Each dot represents 50,000 acres. For more complete data, see Appendix table A3-4.

Most of this potential cropland is not idle; it is in other uses and generally is highly productive in those uses. Converting land in other uses to cropland would significantly reduce grazing land, forest land, and in some places, wildlife habitat. For example, if all 49 million acres of rangeland with high and medium potential for changeover (12 percent of all rangeland) were converted to cropland, range forage production likely would be reduced 19 to 24 percent. Grazing of crop residues on converted cropland could offset only a small part of that loss.

Because it is similar to the land that has been converted, potential cropland is an indicator of the quality of land being converted to cropland. Table 3-1 compares the distribution of cropland and potential cropland among land capability classes. On a nationwide basis, land with high potential for conversion differs only slightly from existing cropland. Land with medium potential for conversion, however, includes a far greater percentage of land in more limited capability classes. In general, therefore, overall cropland quality could be expected to decline if substantial new acreages were brought into cultivation.

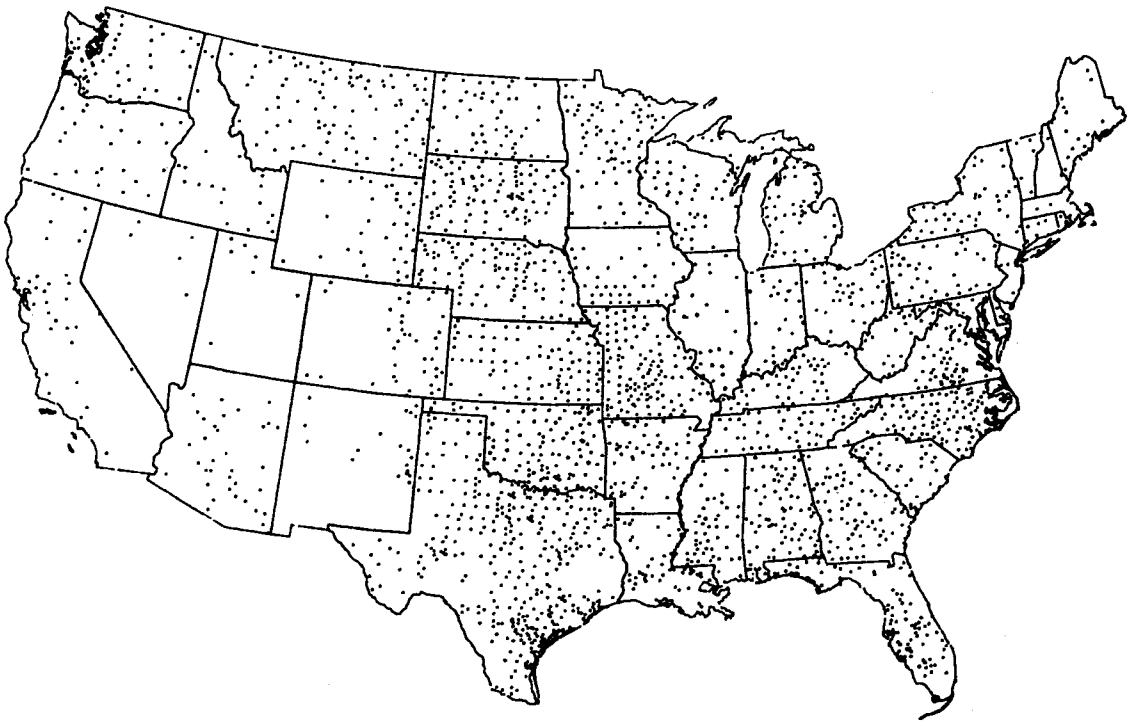


Figure 3-12.--Land with medium potential for conversion to cropland (1982 NRI). Each dot represents 50,000 acres. For more complete data, see Appendix table A3-4.

Table 3-1.--Quality of present and potential cropland, as indicated by percentage distribution among land capability classes

Class	Cropland in 1982		Land with potential for conversion to cropland: High		Land with potential for conversion to cropland: Medium	
	million acres	percent	million acres	percent	million acres	percent
I	30.2	7	1.7	5	1.5	1
II	191.3	45	17.0	48	31.6	27
III	133.7	31	11.6	33	43.9	37
IV	47.0	11	3.2	9	25.8	22
V	2.4	1	0.3	1	2.4	2
VI	14.1	3	1.2	3	11.1	9
VII	2.8	1	0.3	1	1.4	1
VIII		---		---		---
Total 1/	421.4		35.3		117.6	

Source: 1982 NRI
1/ Totals are not exact due to rounding.
For more complete data, see Appendix table A3-5.

Erosion Is Reducing the Productivity of Some Soils

In 1982, sheet and rill erosion moved more than 1.8 billion tons of soil on cropland and wind erosion moved 1.2 billion tons. More than 173 million acres of cropland are eroding at rates greater than the soil tolerance--that is, the rate at which sustained economic production is assured. About 23 percent of cropland is eroding at twice the tolerable rate. Gully erosion and the concentrated-flow erosion called "ephemeral gully" erosion are also damaging cropland.

Soil erosion can reduce onsite capability of the soil to produce crops and can increase the costs of farming. Erosion can cause both short-term and permanent damage. Various methods have been used in efforts to quantify the degree of soil damage or the cost of erosion. Results of all such efforts must be regarded as preliminary and incomplete at present. A new computer model (EPIC) estimates that 100 years of sheet and rill and wind erosion, under 1982 management conditions, would reduce productive capacity 1.9 percent nationally. This loss is the equivalent of losing production worth more than $9 billion at 1980 prices. The estimated loss of productivity varies greatly among regions; it is as high as 60 percent in a few areas.

USDA has developed a system for indexing the sensitivity of soil to erosion damage. This "EI" system indicates the need for erosion control more precisely than other systems of classifying soil erosion hazards. Most of the acres eroding at rates greater than tolerable are moderately sensitive to very highly sensitive to erosion damage. Moderately sensitive land can be protected against erosion. Very highly sensitive land generally can be protected only by maintaining permanent vegetative cover.

Projections of future developments made for this appraisal suggest that erosion rates on land in major crops can be expected to decrease significantly. Assuming intermediate rates of increase in demand and productivity, total erosion on cropland in commodity crops is projected to decline to less than 1 billion tons in 2030. Wind erosion is projected to decline because the acreage of cropland in areas subject to wind erosion is projected to decline. Sheet and rill erosion is projected to decline primarily because it is assumed that economic considerations will make some form of conservation tillage near-universal by 2030 and to a lesser degree because the conservation compliance provisions of the Food Security Act of 1985 will encourage use of less-erodible land. Assuming higher demands and smaller increases in productivity, and less effort to control erosion, projected wind erosion in 2030 would remain at the 1982 level and sheet and rill erosion would decline only slightly.

The natural process of erosion has been important in shaping the landscape in which we live. Natural, or geologic, erosion generally occurs slowly and is not generally a problem from the human standpoint. However, erosion can be accelerated by human activities that alter the plant cover protecting the soil. This accelerated erosion can make both the land where it occurs and land and water downstream or downwind less productive or less suitable for human use.

Erosion can cause short-term damage (damage to crops) or long-term damage (damage to soil). This chapter reports data on the long-term effects of erosion on the soil where it occurs. Because erosion on cropland accounts for half of all wind erosion and more than half of all sheet and rill erosion on all rural nonfederal land, most of the data and analyses in this chapter concern erosion on cropland. Complete and reliable data on the amount of the damage that erosion is causing onsite are not available. This chapter describes where sheet and rill erosion and wind erosion are causing damage to agricultural soils and reports the best estimates available on the extent of the damage. Gully erosion and "ephemeral gully" erosion on cropland are not included in these estimates. Chapter 13 of this report describes the methods used to study erosion.

When erosion damages the plants growing on agricultural land, it costs the farmer or rancher. Sheet and rill erosion can force farmers to replant fields where high rates of erosion have washed away seeds or emerging seedlings. It can mean smaller yields because young plants were smothered under heavy layers of sediment. Wind erosion can also smother plants under deposited material or cause injury that reduces growth and yields. In addition, erosion can affect the cost and ease of managing land. Gully erosion may cut up land in such a way that it can no longer be farmed. Ephemeral gully erosion on cropland may cut deep channels that can damage machinery. Data on the costs imposed by these damages have not been collected, however, and estimates of erosion damages reported in this chapter do not include them.

When soil is carried away from the site, it can reduce air quality, water quality, or land productivity and cause hazards to human health and to wildlife. It also can increase flood damages and increase operating and maintenance costs for many kinds of industrial activities and transportation. Offsite damages likely cost more than onsite soil damages and directly affect far more people. Offsite damages caused by erosion and runoff from agricultural land are discussed in chapter 10 of this report.

Erosion Occurs in Several Distinct Forms

In sheet and rill erosion, raindrops loosen soil particles, which are then carried to new locations by rainwater flowing over the field. Fast-moving water cuts small channels, or rills, that join to become larger channels. On cropland, these channels are called "ephemeral" gullies because the channels disappear when the field is tilled. But each year they reappear in the same area after the first heavy rainfall. Eventually they deepen and widen into gullies (fig. 4-1), which can divide land into pieces too small to farm. Wind erosion occurs when the force of wind blowing over unprotected soil overcomes gravity.

Figure 4-1.--Severe gully erosion in northwestern Idaho. Although the costs of damage caused by this form of erosion are not described in this report, gullying is an extremely destructive form of erosion.

All forms of accelerated erosion can impair the soil's ability to produce healthy and abundant crops. Erosion can reduce productivity not only where it removes topsoil from a field but also where the eroded soil is deposited. In addition, it can reduce productivity when it moves soil around within a field even if little soil actually leaves the field.

Removal of topsoil reduces soil productivity by depleting the soil of nutrients and reducing its ability to absorb and store water and to serve as a seedbed for plants.

Erosion also damages land by moving soil around, removing it from some parts more than others. This makes the fertility of land more variable, so that it requires more fertilizer in some places than in others. Since machines are used to apply fertilizers, the farmer is faced with the choice of fertilizing the eroded parts too little and cutting potential production or fertilizing the uneroded parts too much and increasing fertilizer costs. The effectiveness of herbicides may also be affected by increased soil variability.

Deposition of eroded material over fertile soils can also reduce productivity. Although deposition may, in a few areas, initially increase fertility and produce increased plant growth, additional deposits usually have no further benefits.

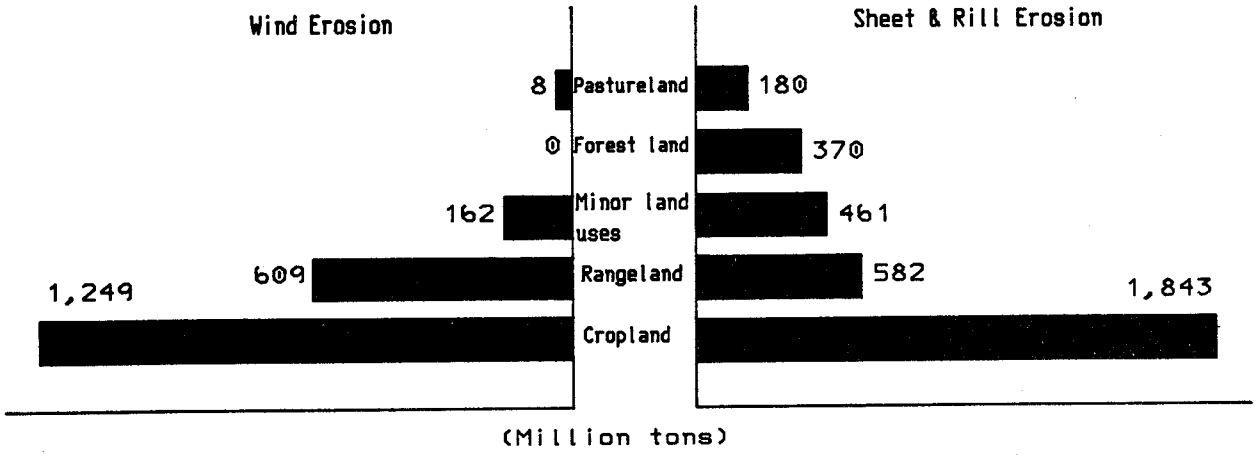


Figure 4-2.--Estimated average annual sheet and rill and wind erosion on nonfederal rural land, by land use, million tons (1982 NRI). Appendix tables A4-1 and A4-2 give additional data, by state.

Erosion's Effects Vary

Erosion is measured in tons of soil moved per acre per year. Figure 4-2 shows the estimated tons of soil moved on eroding land by sheet and rill erosion and by wind erosion, as estimated in the 1982 National Resources Inventory (NRI). The figure does not include ephemeral gully or gully erosion. The NRI estimates represent not the precise erosion in 1982 but the anticipated average rate assuming that land use and management observed at the time of the inventory were unchanged for 30 years.

The areas where average erosion rates are highest or where the most tons of soil are eroded are not necessarily the areas where erosion is causing the most severe damage to soil properties and to yields. In many instances, yield response to erosion is not closely related to the average annual rate of erosion. For example, on some soils of the Midwest formed from loess, the subsoil is very similar to the surface soil in physical and chemical characteristics but contains less organic matter. Erosion of these soils removes some plant nutrients and organic matter, but does not cause much loss in productivity until a sufficient volume of soil has been lost to cause significant reduction in the remaining soil's water-holding capacity. In a few places, for example near the bluffs of the Mississippi River, this occurs only after many feet of soil have been removed.

In most places, however, bedrock or some soil layer that is impenetrable to plant roots is closer to the surface, and a much smaller soil loss reduces soil productivity. Many soils in the southeastern United States, for example, have a very thin topsoil. Below the topsoil is a subsoil that is clayey and very low in organic matter and plant nutrients. This subsoil fixes phosphorus, making it unavailable to plants, and in many cases also contains toxic elements, such as aluminum. As the soil erodes, plowing mixes more and more of the subsoil into the surface layer. The result is a surface soil that has unfavorable chemical characteristics and reduced infiltration capacity.

The maximum rate of erosion that can occur on a soil without reducing the soil's capacity to support sustained economic production is called the "T value" (for "soil loss tolerance"). T values for cropland, pastureland, and forest land range from 1 to 5 tons per acre annually. On rangeland soils, which are generally thinner and more fragile, T values do not exceed 2 tons per acre annually. T values consider in a general way the long-term effects of erosion on fertility, tilth, structure, and water-holding capacity. Figure 4-3 shows the percentage of land eroding at rates greater than T.

T values are subject to change as more is learned about the relationships between soil properties and erosion processes. Some researchers using computer simulation have suggested that annual erosion rates greater than 5 tons per acre are tolerable on many deep soils and that higher T values should be assigned to such soils. The 5-ton limit on T values is based, however, on the observation that conditions permitting sheet and

rill erosion at more than 5 tons per acre also create a severe hazard of gullying and that, at rates greater than 5 tons per acre, so much soil is moving that damage to the crop or offsite sediment delivery is probable. Results of calculations by the Erosion/Productivity Impact Calculator (the EPIC model) and Erosion/Productivity Index Simulator (the EPIS model) indicate that even with sheet and rill erosion reduced to less than T, some soils would lose some productivity (Williams et al., 1983; Williams et al., 1984; Putman, Dyke, and Wistrand, 1986). EPIC results suggest that some land in "e" subclasses 1/ east of the Mississippi River, excluding the coastal plains of the Southeast, could begin to lose productivity within 100 years even if average annual rates of sheet and rill erosion were less than T. About one-half of such cropland on the West Coast could also lose some productivity.

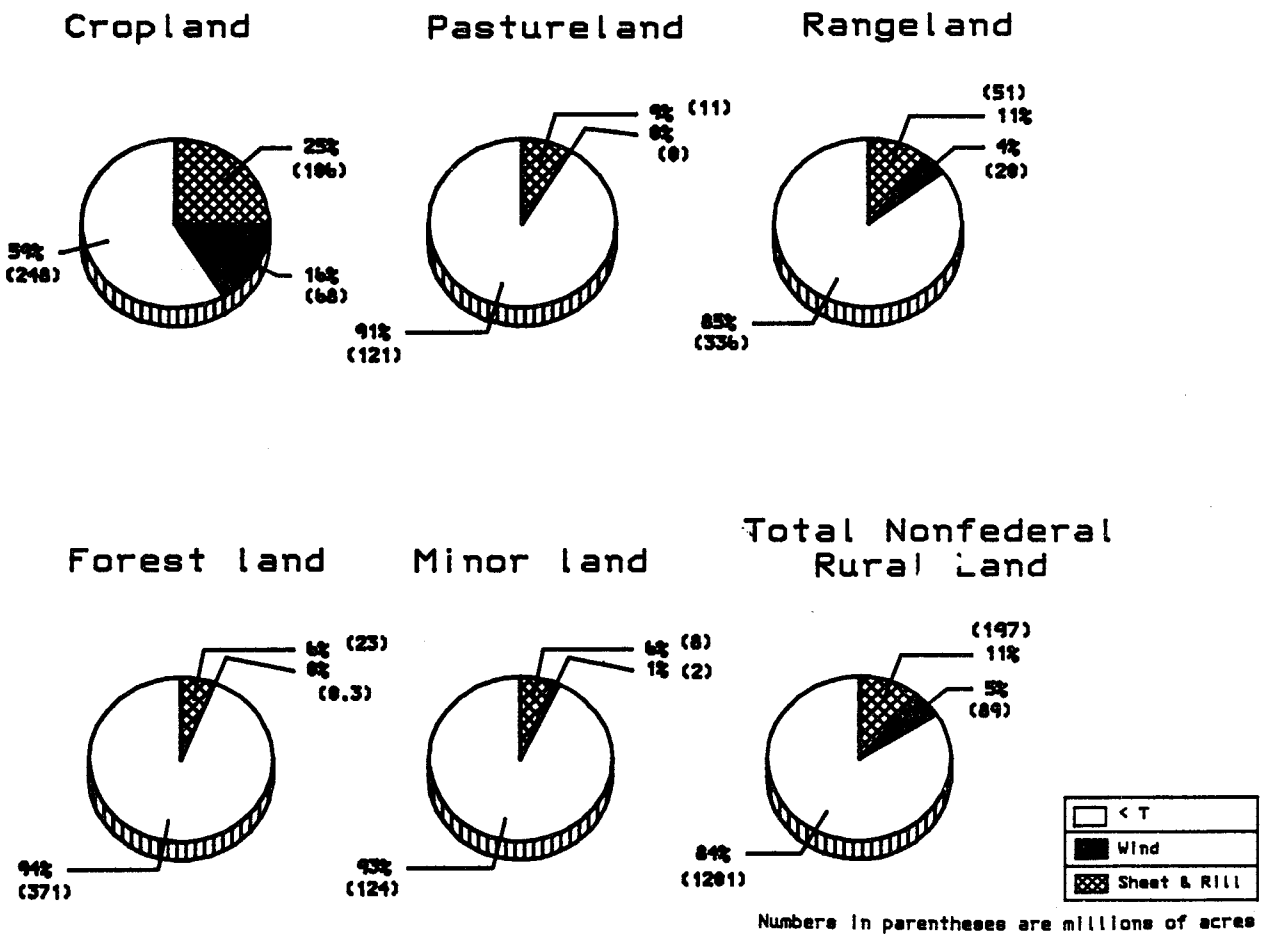


Figure 4-3.--Acreage and percentage of rural nonfederal land eroding at greater than T (1982 NRI).

1/ The classes and subclasses of USDA's land capability classification system are described in chapter 3 of this report.

Cropland: Where is Erosion Causing Damage?

Figure 4-4 summarizes the 1982 NRI data comparing the estimated erosion rate to the T value for the soil. On about 173 million acres (40 percent) of the nation's 421 million acres of cropland, either sheet and rill erosion or wind erosion is greater than T. About 67 percent of the tons of soil moved by sheet and rill erosion and 80 percent of the soil moved by wind is moved on land where the erosion rate exceeds T by 1 ton or more (appendix table A4-3).

Figure 4-5 shows the acres of cropland eroding at rates greater than T in each farming region. As the figure shows, the largest acreage of soils eroding at these rates is in the Corn Belt. The regions with the highest percentages of their cropland eroding at damaging rates, however, are the Mountain States and the Southern Plains, where sheet and rill erosion or wind erosion exceeds T on more than half the cropland.

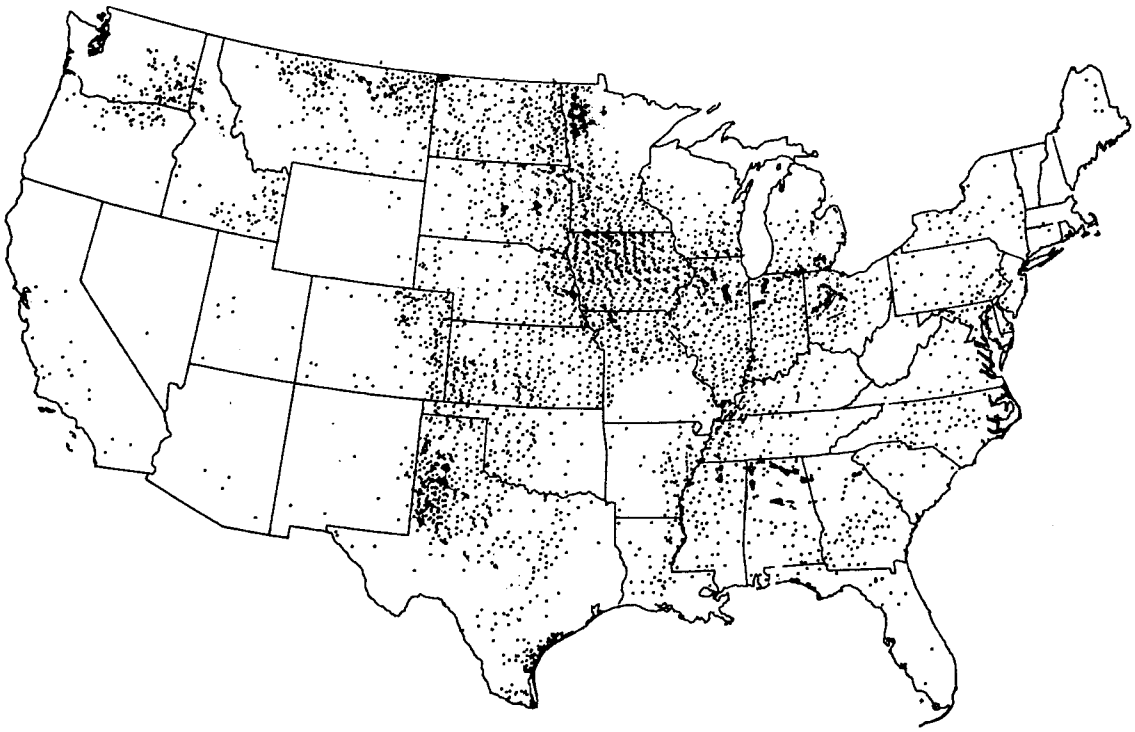


Figure 4-4.--Cropland where sheet and rill erosion or wind erosion is greater than T. (See also appendix table A4-3.)
Each dot = 50,000 acres.

The acreage eroding at rates greater than T includes 116 million acres of land in the "e" subclasses of USDA's land capability classification system (land on which the erosion hazard is the primary limitation) and 57 million acres of land in other subclasses or in class I. 1/ For the nation as a whole, average sheet and rill erosion rates and wind erosion rates on cropland exceed T on land in capability classes IV, VI, and VII. Since land in class IV is not suited to continuous cultivation and land in higher classes generally is not suited to cultivation, the high erosion rates are not surprising. Cropland in classes VI and above makes up only 3 percent of the nation's cropland, however. Most land eroding at rates that will not permit sustained production is in capability classes IV and below.

1/USDA's land capability classification system is defined in chapter 3.

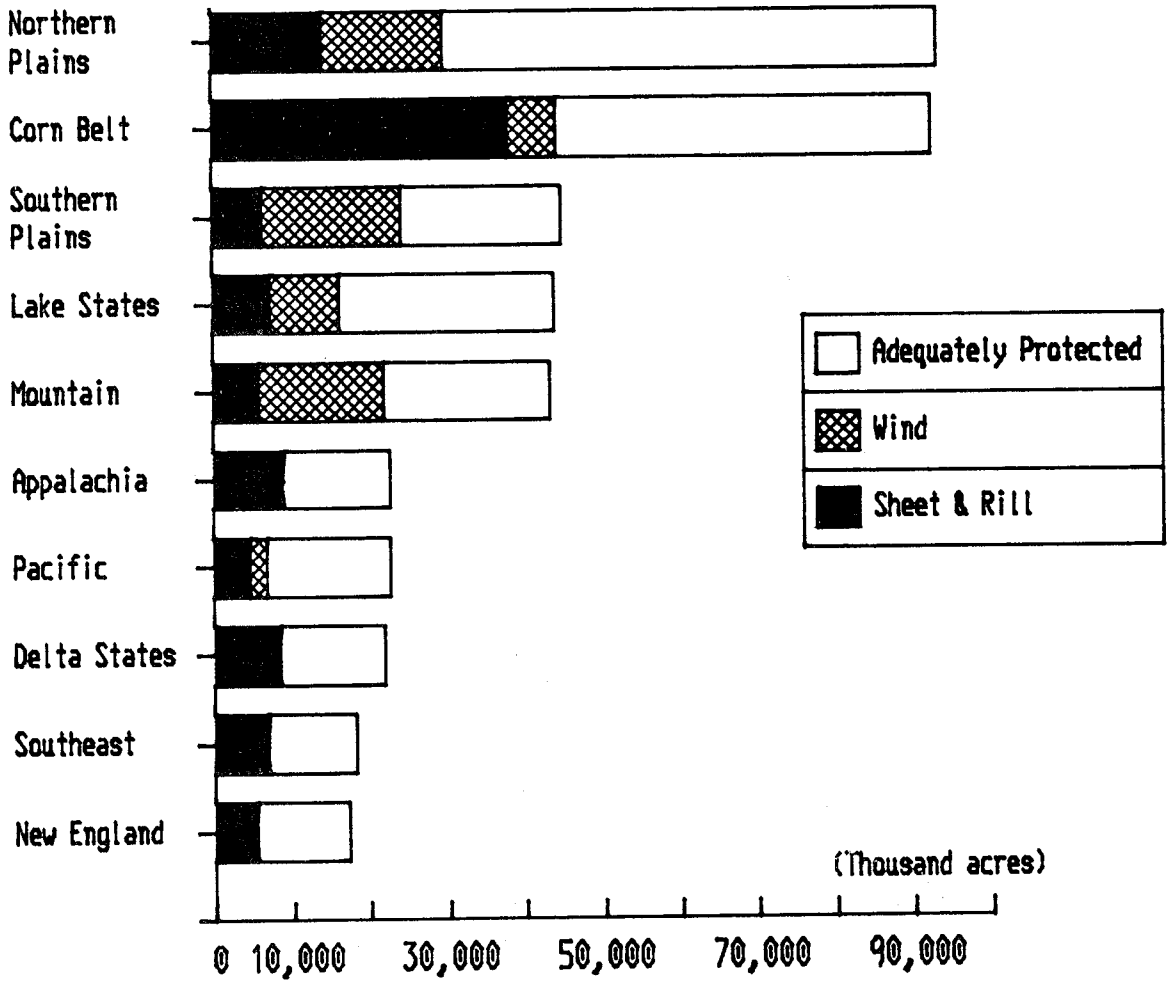


Figure 4-5.--Cropland eroding in excess of T, by farming regions (1982 NRI). Appendix tables A4-4 and A4-5 give additional data, by state.

How Much Productivity Is Eroded Annually?

Quantifying erosion damage is difficult. Erosion reduces yields when it is severe. Yield reductions of up to 50 percent have been observed in crops grown in eroded soil as compared with those on slightly eroded soils. Generally, however, only a very small amount of soil is moved in any given year. The resulting annual loss in productivity is so small that it is hidden by differences in the weather or in the management farmers apply from year to year. In many soils, yields may not appear to decrease even if erosion is excessive because the farmer has switched to improved, more productive varieties of crops or is applying more fertilizer or controlling pests more effectively. Erosion may be reducing the increase that these improvements produce; that is even harder to measure than slight real decreases. Farmers may become aware of erosion damage only when erosion has so severely reduced the soil thickness that technology can no longer give increased yields.

A study by Pierre Crosson of Resources for the Future (RFF) used regression analysis to calculate the effect of sheet and rill erosion in reducing the increase in corn yields between 1950 and 1980. RFF estimated that, because of sheet and rill erosion, corn yields in the counties studied increased 0.13 bushel per year less between 1950 and 1980 than they would have otherwise. Assuming that the effect of erosion on all the nation's 73.2 million acres of corn land would have been the same as on the 46.7 million acres studied, RFF estimates that national corn production capacity in 1982 was reduced by $679 million because of sheet and rill erosion. This was equal to 3.5 percent of the total value of corn produced in 1982.

Although neither past nor current erosion damage can be quantified with precision, the development of computer technology has made it possible for researchers to project future damages. The computer can rapidly simulate the effects of many years of erosion on many kinds of soil under various climatic conditions and management systems.

Table 4-1 summarizes the results of computer simulations of the effects on yields as certain soil properties are altered by erosion. The models that provided the data are EPIC (Erosion/Productivity Impact Calculator) and EPIS (Erosion/Productivity Index Simulator). 1/ The EPIC/EPIS analysis estimates that 100 years of sheet and rill and wind erosion, at 1982 erosion rates, would reduce productivity nationally by 1.9 percent.

The projected national percentage of loss is low because many soils are not losing any productivity under current management. Productivity loss is concentrated on soils eroding at several times the T value or on very fragile soils where even slight erosion results in significant yield reductions. On some of these specific soils, loss of productivity is projected to be quite high. Loss of productivity after 100 years is projected to be as high as 60 percent along the Central California Coast Range and as high as 50 percent in the Great Valley of Virginia.

1/ The EPIC/EPIS system models and their limitations are described in the "Methods" chapter of this report.

Figure 4-6 summarizes the results of EPIC/EPIS simulations of the effects of sheet and rill erosion on cropland in subclass "e" planted to major crops, assuming 1982 conditions. Data were not available to display in a similar form either wind erosion losses or losses on cropland in other class/subclasses. As the map shows, EPIC/EPIS estimates of productivity loss are greatest for the Northeast and Appalachia because many of the soils in these areas developed from highly weathered sandstone and shale and are, therefore, infertile; are shallow over bedrock or have fragipans; are on undulating to very steep topography; and have been cultivated since at least the early 19th century.

The most severe losses shown on the West Coast are also on shallow, steep soils. For this analysis, only soils on which major crops are grown were included; the figure does not imply that loss of productivity will be high on California soils planted to high-value specialty crops such as citrus and nut trees or vegetables.

The figure shows EPIC estimates of the effects of sheet and rill erosion on 220 million acres of cropland. This acreage includes the soils in land capability subclass "e" and in classes VIs, VIIs and VIII used to grow major crops. The data for the figure were produced by choosing a representative soil for each of the "e" subclasses and for classes VIs, VIIs, and VIII in each major land resource area shown in the map. The estimates shown do not include loss of productivity on class I soils or soils in subclasses "w" and "c" and most soils in subclass "s". In a few cases, the figure may indicate lower losses than are actually occurring in a major land resource area if a considerable portion of the excessively eroding soils in the area are classified other than "e."

Table 4-1.--Estimates of percent loss of productivity resulting from erosion in 100 years, by farming region

Farming region	Sheet and rill	Wind
Northeast	5.08	0.03
Lake States	0.73	0.90
Corn Belt	2.83	0.15
Appalachia	3.70	*
Southeast	1.03	*
Delta States	1.39	*
Northern Plains	0.44	0.28
Southern Plains	0.15	1.09
Mountain States	0.23	0.88
Pacific States	1.93	0.44
United States	1.46	0.42

Source: Erosion/Productivity Impact Calculator (EPIC).
Modified USLE erosion rates assumed, on 421 million acres of cropland (1982 total).
* = less than 0.01 percent.
See appendix table A4-6 for further data.

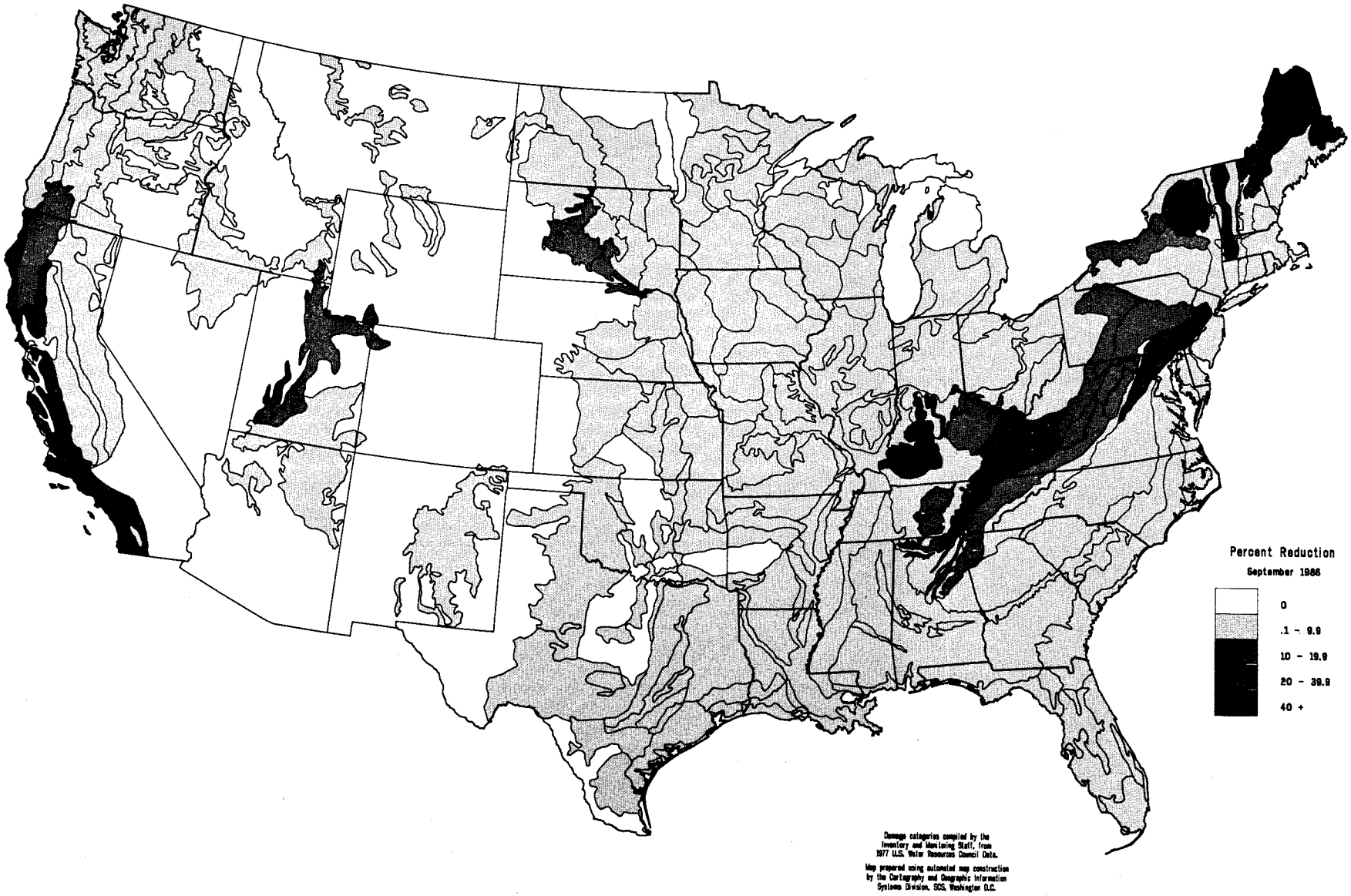


Figure 4-6.--Estimated loss of productivity resulting from 100 years of sheet and rill erosion under 1982 management, by major land resource area. Includes cropland in all "e"subclasses and class VIs - VIIIs planted to major crops. (EPIC/EPIS).

The sheet and rill erosion rates used in EPIC/EPIS are not identical to those reported in the 1982 NRI because EPIC uses a modified form of the USLE (Onstad and Foster, 1975). Appendix table 4-3 compares NRI estimates and EPIC estimates of average erosion rates for land considered in EPIC, by farming region. The modified USLE used in EPIC considers runoff and therefore generally estimates higher erosion rates in the Northeast and higher rates for class VI through VIII land in most eastern regions than does the NRI.

The EPIC/EPIS system provides a static analysis of erosion's effects, beginning at the time when each soil was in the condition described in the soil data base and assuming that crops, management, and technology would remain unchanged for 100 years. In the real world, of course, conditions do not remain unchanged. Therefore, a companion analysis was made to estimate the possible effects of erosion under changing conditions. A linear programming model of the nation's agricultural sector was used to estimate the effects of erosion over 50 years. 1/ Assumptions were made of how rapidly demand and yields would increase in the future. The model estimated the acreage of land needed, regional patterns of production, inputs required, and costs of production occurring in a dynamic economy. Two simulations were made; one included the gradual loss of soil productivity as estimated by EPIC and the other assumed that no loss of soil productivity would occur.

Comparison of the two simulations indicates that as a result of erosion, production costs would be higher and relative profitability among regions would be affected, resulting in regional shifts in production, use of more land for crops, and greater erosion and, therefore, more potential for degradation of the environment.

Because of the loss of productivity resulting from erosion and the shifts in production those losses cause, meeting demands for food and fiber in the year 2030 would require 6.3 million more acres of cropland than would be required if productivity remained constant, according to the linear programming model.

Figure 4-6 indicates the soil's loss of productivity but not the effect the loss might have on the production of an area or a state, because the estimates make no distinction between loss in an area where cropland is an important land use and in areas where there are very few acres of cropland. Table 4-2 shows the estimated loss expressed as "equivalent acres" in each state. "Equivalent acres" are not the number of acres on which damaging erosion occurs but the number of additional acres that would be needed, after 100 years of erosion, to match current production levels. The greatest number of equivalent acres would be needed in the Corn Belt, where millions of acres used for growing feed grains are projected to sustain moderate losses in productivity.

1/ See chapter 13 for a description of the CARD model.

Table 4-2.--"Equivalent acres" 1/ required to replace productivity lost as a result of 100 years of sheet and rill erosion, by state

State	Acres (1,000)		State	Acres (1,000)	
	Sheet and rill	Wind		Sheet and rill	Wind
Iowa	617	*	Arkansas	47	*
Illinois	568	*	Michigan	47	0.1
Missouri	413	*	Texas	46	380
Indiana	389	0.3	New Jersey	42	*
Kentucky	358	*	Maine	28	*
Pennsylvania	333	*	West Virginia	25	*
Ohio	310	*	Louisiana	15	*
New York	261	*	North Dakota	13	2
Nebraska	246	19	South Carolina	12	*
California	235	3	Montana	11	108
Tennessee	190	*	Utah	6	0.9
Washington	139	76	Oklahoma	5	19
Virginia	115	*	Vermont	4	*
Wisconsin	114	0.1	Connecticut	4	*
Mississippi	109	*	Massachusetts	4	*
Minnesota	103	2	Florida	3	*
Alabama	92	*	Delaware	1	*
North Carolina	89	*	New Hampshire	1	*
Maryland	82	*	Colorado	*	128
Idaho	71	66	Rhode Island	*	*
South Dakota	68	50	Wyoming	*	3
Kansas	59	43	New Mexico	*	10
Georgia	53	*	Nevada	*	31
Oregon	49	9	Arizona	*	*

Source: Erosion/Productivity Impact Calculator--Erosion/Productivity Index Simulator.
Data base includes only cropland in e subclasses and in classes VIs, VIIs, and VIII.

* Less than 100 acres.

1/ Equivalent acres are the number of additional acres needed, after 100 years of erosion, to produce the amount of crops currently produced. They are calculated by multiplying the percentage of productivity loss by the acres of cropland in a major land resource area (MLRA) and then by an index of productivity that considers both the acreages of major crops in the MLRA and the average yield for each crop.

Erosion Reduces Fertility

The changes that erosion causes in topsoil depth and in texture and chemical properties are essentially permanent. Erosion also removes organic material in the topsoil and removes nutrients in solution or attached to sediment. This loss of soil fertility is not necessarily permanent. Farmers can add soil amendments to compensate for some kinds of damage to soil properties. They can apply more fertilizer to compensate for loss of soil nutrients, apply more lime to correct erosion-induced declines in soil pH, and use more tractor fuel in plowing to prepare the seed bed where erosion reduces tilth. In practice, however, many farmers do not take these actions to correct damage because fields do not erode evenly and adjusting management to accommodate the differences is not worthwhile. EPIS estimates the average annual amount of nitrogen, phosphorus, and lime required to replace the lost fertility (table 4-3).

Table 4-3.--Estimated increase in average annual fertilizer requirements, by farming region

Farming region	Sheet and rill erosion					
	Nitrogen		Phosphorus		Lime	
	-%-	lbs/acre	-%-	lbs/acre	-%-	lbs/acre
Northeast	3.20	1.70	5.63	3.40	11.99	66
Lake States	0.81	0.50	2.19	1.69	4.00	22
Corn Belt	4.03	2.90	12.43	6.90	20.16	22
Northern Plains	0.57	0.30	1.35	0.40	2.00	0
Appalachia	3.18	1.50	8.36	3.40	19.80	154
Southeast	2.19	0.90	6.40	2.20	12.14	110
Delta States	3.34	1.00	10.14	3.10	23.91	20
Southern Plains	0.17	0.10	0.16	0.00	0.77	0
Mountain States	0.31	0.10	1.04	0.10	0.27	0
Pacific States	1.99	0.80	4.97	0.60	1.63	0
United States	1.60	0.90	4.42	2.10	7.41	44

Farming region	Wind erosion					
	Nitrogen		Phosphorus		Lime	
	-%-	lbs/acre	-%-	lbs/acre	-%-	tons/acre
Northern Plains	0.20	0.11	0.39	0.06	0.52	0.00
Southern Plains	14.08	8.34	9.33	1.16	59.89	0.03
Mountain States	6.76	2.20	9.27	0.89	10.67	0.00
Pacific States	0.63	0.59	2.08	0.79	0.40	0.00
United States	2.08	2.44	4.69	0.57	15.70	0.00

Source: EPIS

CONTROLLING CROPLAND EROSION: HOW MUCH ARE WE ACCOMPLISHING?

Figure 4-8 shows EPIC/EPIS estimates of the percentage loss in productivity in each major land resource area that would result over 100 years if no conservation practices were applied.

Table 4-4 shows the value of the soil productivity maintained by soil conservation practices on subclass e cropland in 1982, as estimated by the EPIC/EPIS system. The table shows estimates of the loss caused by sheet and rill erosion expressed as "gross product loss." "Gross product loss" is calculated by multiplying the equivalent acres by $198, which is the national average value of production of the major crops (yield times normalized prices). The table shows the value of the productivity reduction estimated with "no conservation" applied and that estimated for the crops and rotations, conservation practices, and erosion rates recorded in the 1982 NRI. The difference between the two estimates is one measure of the onsite benefits of present conservation efforts. Data are not available at present to compare "no conservation" and 1982 conservation measures for wind erosion control.

"No conservation" means that only conventional tillage would be used and no supporting practices--contouring, strip-cropping and terraces--would be in place. The table assumes that the crops and rotations grown would be the same for both alternatives, however, and therefore the "no conservation" estimates do include the effects of any conservation rotations in place in 1982.

The table shows only the value of the permanent loss of productivity that would result in the absence of conservation practices. It does not include the cost of the additional fertilizer and lime that would be needed to compensate for lost fertility, nor does it attribute any value to crop damage prevented by the conservation measures.

Table 4-4 and figure 4-8 show that, in monetary terms, the greatest effect from controlling sheet and rill soil erosion would occur in the land resource regions that account for most of the acreage in Kentucky, Tennessee and West Virginia and parts of Indiana, Ohio, and Pennsylvania. In these regions many of the soils tend to be shallow to moderately deep, are on undulating to steep slopes, and have suffered excessive soil loss over the period that the land has been cultivated. Additional sheet and rill erosion will severely inhibit the ability of the soils to maintain crop productivity, thus costing the farmer in lowered yields, not to mention additional fertilizer and lime added as soil amendments.

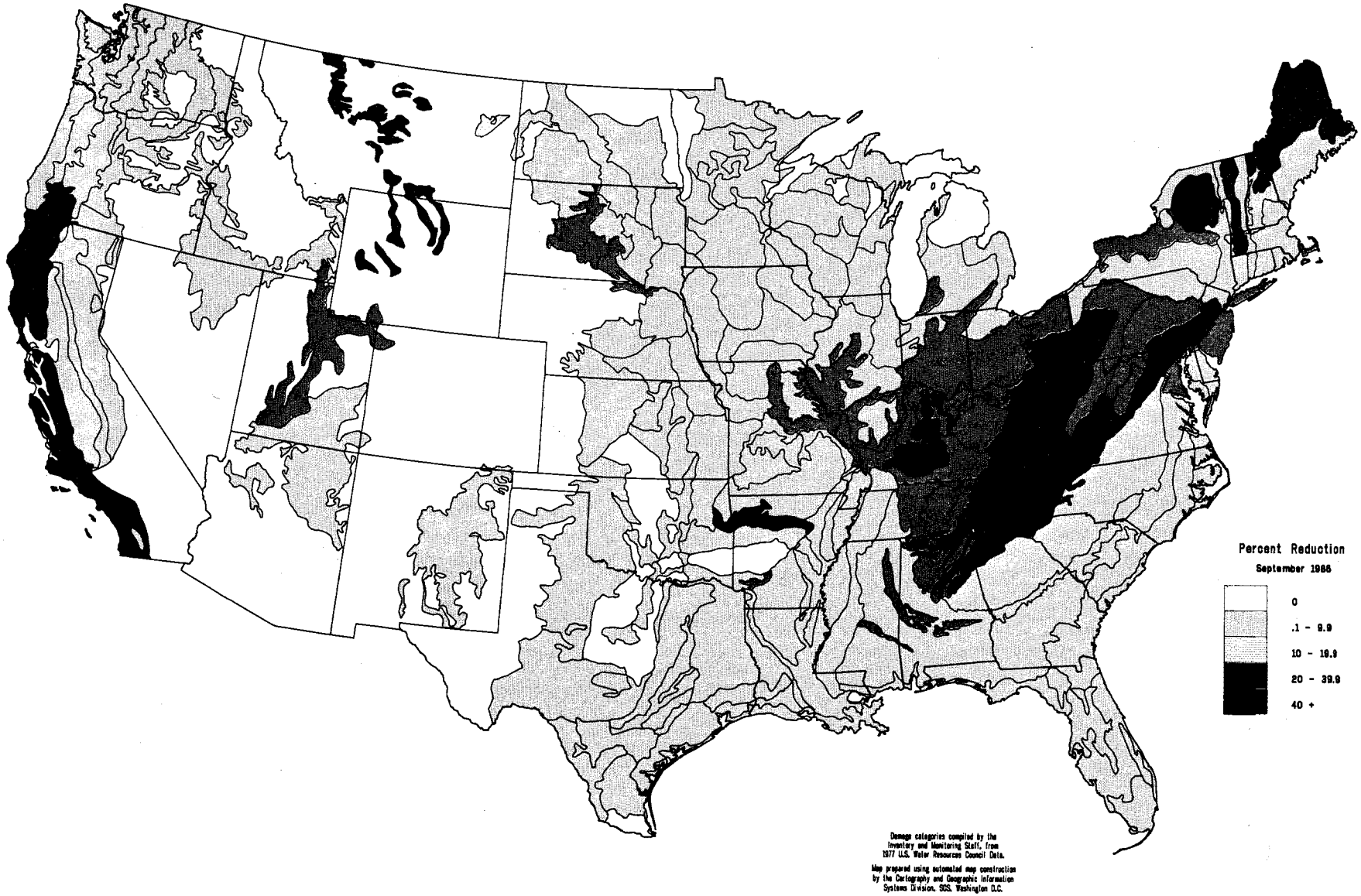


Figure 4-8.--Estimated loss of productivity resulting from 100 years of sheet and rill erosion if no conservation practices were in place, by major land resource area. Includes cropland in all "e" subclasses and in classes VIs - VIIIs planted to major crops. (EPIC/EPIS).

Table 4-4.--Present value of productivity maintained by sheet and rill erosion control practices in place in 1982, by state

State	Net present value of "Gross product loss" over 100 years, "no conservation"	Net present value of "Gross product loss" over 100 years, 1982 conditions	Value of productivity maintained by existing conservation practices
	($1,000)		
Ohio	820,284	360,187	460,097
Pennsylvania	818,062	387,134	430,928
Kentucky	799,399	415,965	383,434
Montana	334,671	12,415	322,257
Indiana	770,021	452,709	317,312
Nebraska	573,423	286,467	286,956
Washington	424,971	162,042	262,929
California	503,403	273,634	229,769
Iowa	937,275	717,640	219,635
Tennessee	433,697	220,752	212,945
Wisconsin	324,712	132,489	192,223
Maryland	244,802	95,815	148,987
Illinois	806,613	660,570	146,043
West Virginia	168,406	28,622	139,784
Kansas	200,449	69,182	131,267
South Dakota	204,079	79,142	124,937
Virginia	254,087	133,687	120,400
Alabama	212,398	107,508	104,890
Oregon	150,476	57,303	93,174
Texas	146,462	53,824	92,638
Missouri	571,945	479,982	91,964
Mississippi	212,608	126,275	86,332
North Carolina	171,059	103,413	67,646
Oklahoma	68,728	5,864	62,864
New York	303,443	244,697	58,745
Georgia	119,748	61,270	58,478
Wyoming	45,796	0	45,796
New Jersey	85,390	48,751	36,639
Michigan	88,787	55,011	33,777
Minnesota	149,069	119,876	29,192
South Carolina	36,592	14,078	22,514
Maine	52,730	32,078	20,652
Florida	23,235	3,304	19,931
Nevada	18,244	0	18,244
Vermont	18,977	4,968	14,009
Idaho	82,637	68,753	13,885
Delaware	14,753	1,140	13,613
North Dakota	28,203	15,335	12,868
Arkansas	67,251	55,115	12,135
Colorado	12,345	477	11,868
Connecticut	14,509	4,724	9,785
Utah	14,416	7,051	7,365
New Mexico	7,342	0	7,342
Massachusetts	11,705	4,421	7,284
New Hampshire	7,865	756	7,109
Louisiana	22,560	16,952	5,608
Rhode Island	617	279	337
Arizona	23	0	23
United States	11,378,267	6,181,6	5,196,611

Source: Erosion/Productivity Impact Calculator--Erosion/Productivity Index Simulator.

Figures have been rounded to nearest $1,000.

Net present value calculated at 4 percent over 100-year period.

REDUCING EROSION: INDEXING IDENTIFIES EXCESSIVE HAZARDS

Erosion is the major limitation to use of cropland. Nearly 52 percent of cropland is classified in the "e" subclasses of USDA's land capability classification system, meaning that erosion is the major hazard or limitation to use of the soil as cropland. Erosion is also a hazard on some cropland in other subclasses, because the land is much more prone to damage than the capability classification indicates.

USDA has developed a new classification system using T values and the factors of the erosion estimation equations to rate the susceptibility of soils to erosion damage. This system is referred to as the "erosion-sensitivity index" or EI. The erosion-sensitivity index indicates the probability that the soil will be damaged by erosion. It is thus a more precise tool for identifying soils on which erosion control efforts should be focused than is provided by either the land capability classification system or estimates of current or potential erosion rates based on the erosion equations alone. (Appendix table 4-7 shows the relation between capability classification and EI.) The EI, however, does not take account of the effects of gully erosion or ephemeral gully erosion (fig. 4-9).

Figure 4-9.--Ephemeral gully erosion. This erosion is not counted in estimates of sheet and rill erosion and therefore is not considered in damage estimates given elsewhere in this report. Nor is it considered in assigning the EI of a soil.

The EI is derived by dividing the physical and climatic factors (the RKLS factors of the Universal Soil Loss Equation or the CI factors of the Wind Erosion Equation) by the T value assigned to a soil. (These equations are explained in chapter 13.) This procedure provides an index tying a soil's inherent erodibility to its susceptibility to damage caused by erosion, which makes it possible to compare the effects of erosion on different soils. For example, two soils for which RKLS equals 50 would each erode at a rate of 50 tons per acre per year if they were continuously in clean-tilled fallow. If one soil were deep and had a T value of 5 tons per acre, that 50 tons would represent a rate of 10 times T value. The soil would have an index of 10. If the other soil were shallow and had a T value of only 3, the 50 tons would represent a rate of more than 16 times the T value; that soil would have an index of 16. If both soils were managed in the same way, the second would be damaged more quickly than the first soil. If cultivated for the same number of years, it would be more severely damaged than the first.

Using these index values, soils can be grouped according to the relative ease with which they can be protected against erosion damage (fig. 4-10). Soils with a low EI are very slightly susceptible to damage and are very easy to protect when they are cropped. Soils with a high EI are very highly susceptible to damage and are quite difficult to protect if used as cropland. Soils in intermediate classes can be cropped safely if conservation is applied, but adequately protecting them gets harder as the index increases.

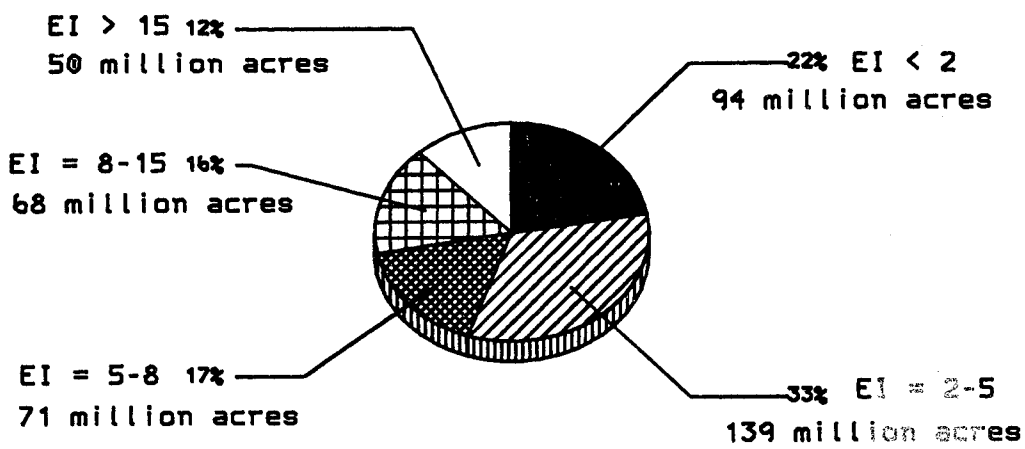


Figure 4-10.--Acres and percentage of cropland in each EI category

The distribution shown in the figure is based on both sheet and rill erosion and wind erosion. A soil's susceptibility to one type of erosion is generally significantly greater than its susceptibility to the other; see appendix table A4-8. Soils are classified as being "very slightly sensitive to erosion" only if both indexes are less than 2. Soils are classified as "very highly sensitive to erosion" if either index is greater than 15 or if both are greater than 10. For intermediate classes, soils are classified on the basis of the higher of the indexes.

Some soils don't need much protection. Soils with a low index (fig. 4-11) could not erode at a rate greater than twice the T value even in continuous clean-tilled fallow. Since most crops will provide sufficient cover for enough of the year to reduce erosion to half the rate that would occur if there were no crop or other cover on the soil, these soils need very little protection against sheet and rill or wind erosion other than that provided by the growing crop. This 22 percent of cropland can safely be used indefinitely for crop production.

Conservation practices are generally not needed on these soils to prevent damage from either sheet and rill or wind erosion. That doesn't mean, however, that no conservation is needed at all. Grassed waterways may be needed to remove excess water even in some very gently sloping fields. Terraces may be needed to conserve water rather than soil. Drainage systems may be needed to prevent salinization from reducing productivity. Grass field borders and other measures may be needed to trap sediment if runoff from the field delivers sediment directly to a sensitive waterway.

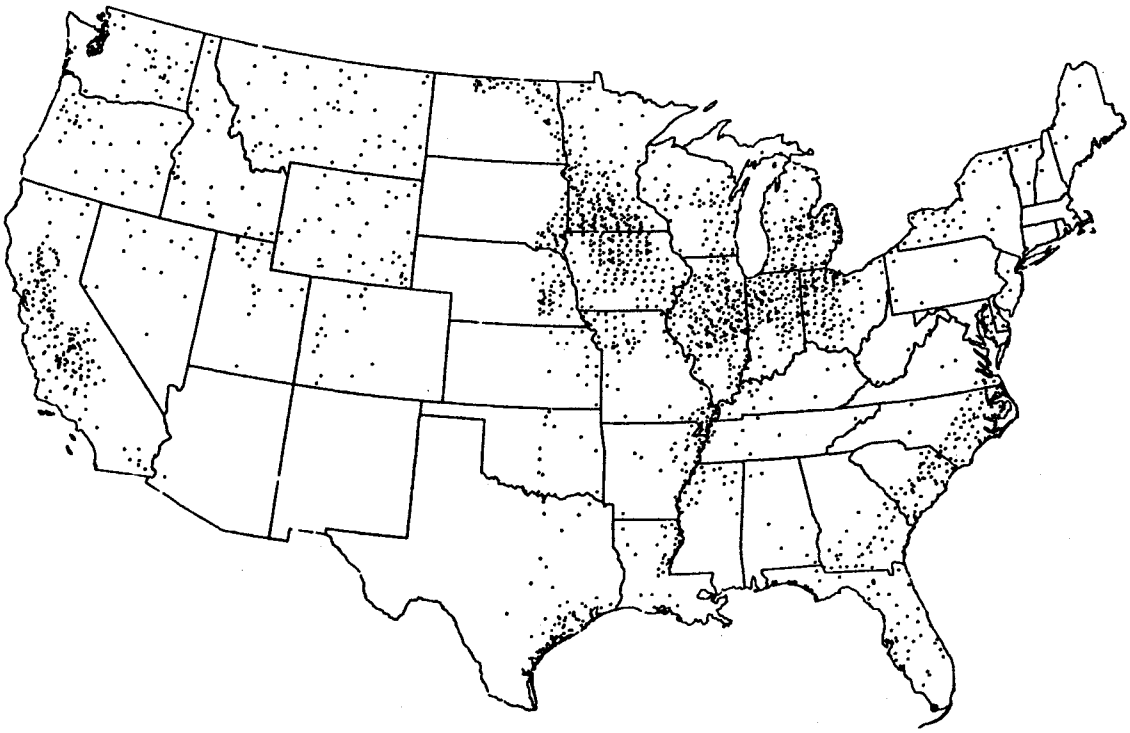


Figure 4-11.--Cropland with "EI" less than 2 (1982 NRI).
See also appendix tables A4-9 and A4-10.
Each dot = 50,000 acres.

Some soils are almost impossible to protect. Cropland that is "very highly erodible" (fig. 4-12) is very difficult to cultivate without severe damage. The maximum possible erosion rate that could occur if these soils were bare is 15 times the T value or more.

In 1982, 50 million acres of land in this category were cropped. Three-fourths of these acres were eroding at more than T and 64 percent was eroding at more than 2T. More than two-thirds of the total are highly susceptible to damage from sheet and rill erosion. This land is highly concentrated; Iowa and Missouri together have one-fourth of all the cropland that has a very high RKLS/T index. Texas has 30 percent of all cropland that has a very high CI/T index.

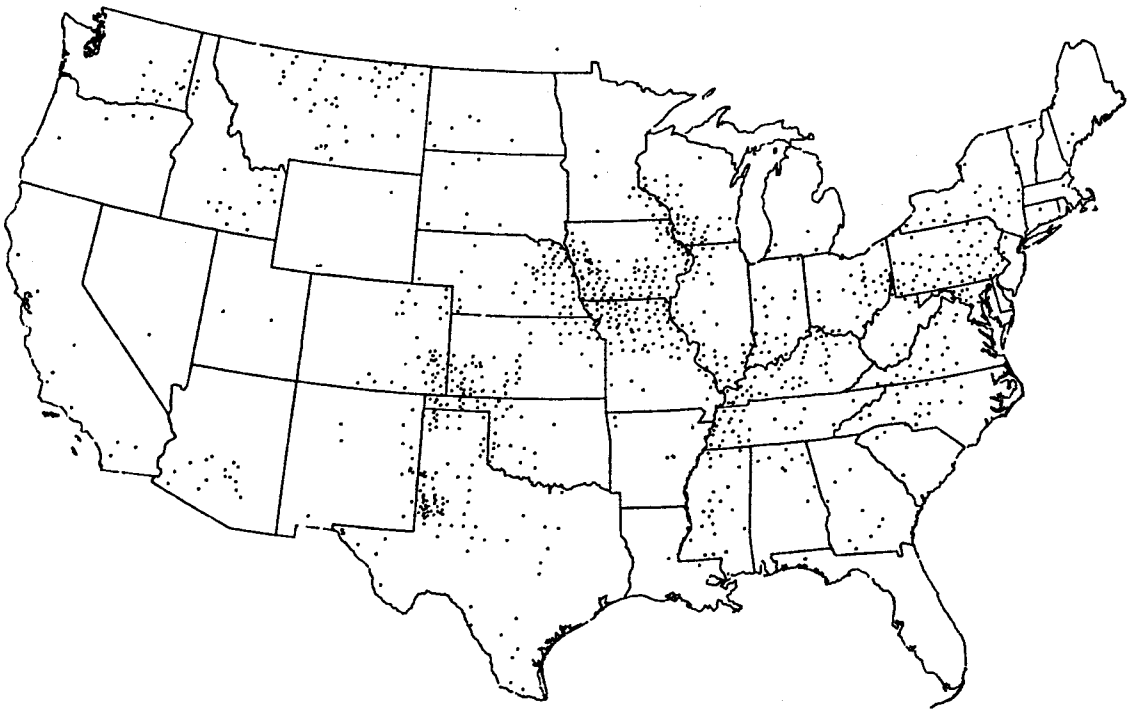
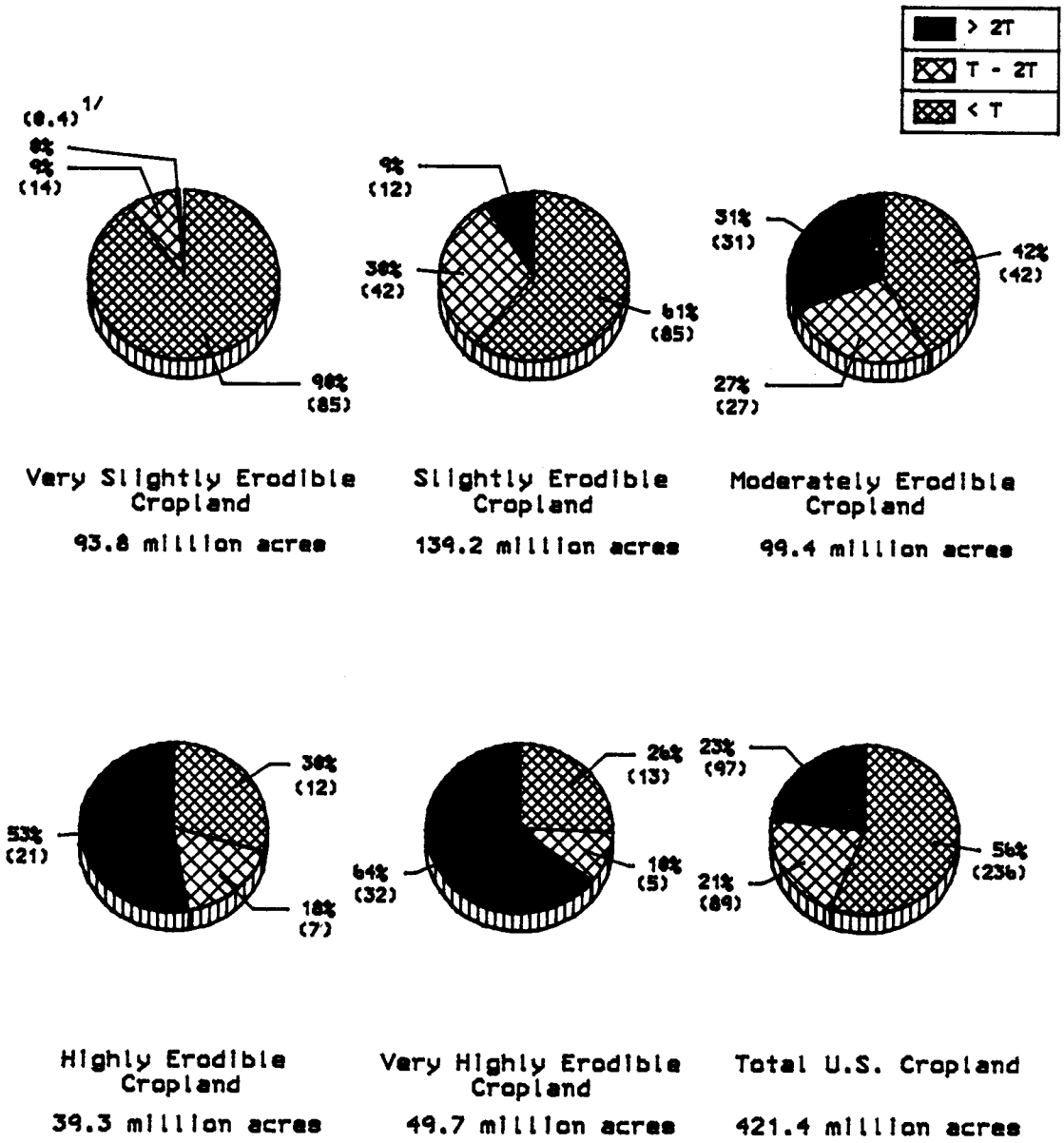


Figure 4-12.--Cropland with "EI" greater than 15 (1982 NRI).
See also appendix tables A4-9 and A4-10.
Each dot = 50,000 acres.

Figure 4-13 shows the percentage of cropland eroding at rates greater than T in each "EI" category. About 91 percent of the cropland that is very slightly susceptible to erosion damage is eroding at less than T;



1/ Numbers in parentheses are millions of acres.

Figure 4-13.--Erosion rates on cropland, by "EI" categories (1982 NRI).

only one-fourth of cropland that is very highly susceptible to damage is eroding at less than T. Table 4-5 gives the extent of conservation treatment needed to protect soils according to their susceptibility to damage by sheet and rill erosion.

Table 4-5.—Conservation management and practices needed to protect soils against damage resulting from sheet and rill erosion

Susceptibility to erosion damage	"Erodibility Index" (RKLS/T)	Treatment level required (CP)	Conservation management practices
Very slight	0 - 2	0.5 or greater	Conventional farming techniques generally adequate to control sheet and rill erosion and maintain productivity.
Slight	2 - 5	0.5 to 0.2	Practices needed may include maintenance of 30 percent cover of crop residue, contouring, or a combination of the two.
Moderate	5-8	0.2 to 0.125	Practices needed include maintenance of 30 to 50 percent cover of crop residue, contouring, terraces, contour strip-cropping, or some combination.
High	8 - 15	0.125 to 0.067	Practices needed generally include an intensively applied combination of two or more practices including maintenance of greater than 50 percent cover of crop residue, contouring, terraces, contour strip-cropping, and sod-based crop rotations.
Very high	15 and greater	less than 0.067	Permanent conversion to sod or trees, or long rotations with several years of sod.

The Universal Soil Loss Equation is: A = RKLSCP, in which A is the estimated soil loss. The first four factors (R, K, L, and S) represent the conditions of climate, soil, and topography existing at a site. The last two factors, C and P, estimate the degree to which use and management of the soil reduce erosion. Consequently, the value of CP must decline in reverse ratio to the rise of RKLS, if soil loss (A, the product of the whole) is to be held to a tolerable level. A more detailed explanation is given in chapter 13 under "Estimating Erosion."

EROSION ON PASTURELAND

Erosion is generally not a problem on well-managed pastureland. Healthy, productive vegetation provides protection against even severe storms. Erosion is greater than T, however, on more than 11 million acres of nonfederal pastureland (fig. 4-14). Two-thirds of all sheet and rill erosion on pastureland is occurring on less than 9 percent of the acreage; in fact, just 0.7 percent of pastureland is responsible for 46 percent of the tons of soil eroding in excess of T. Seven percent of pastureland is in capability classes VII and VIII, and on these soils erosion is a serious problem.

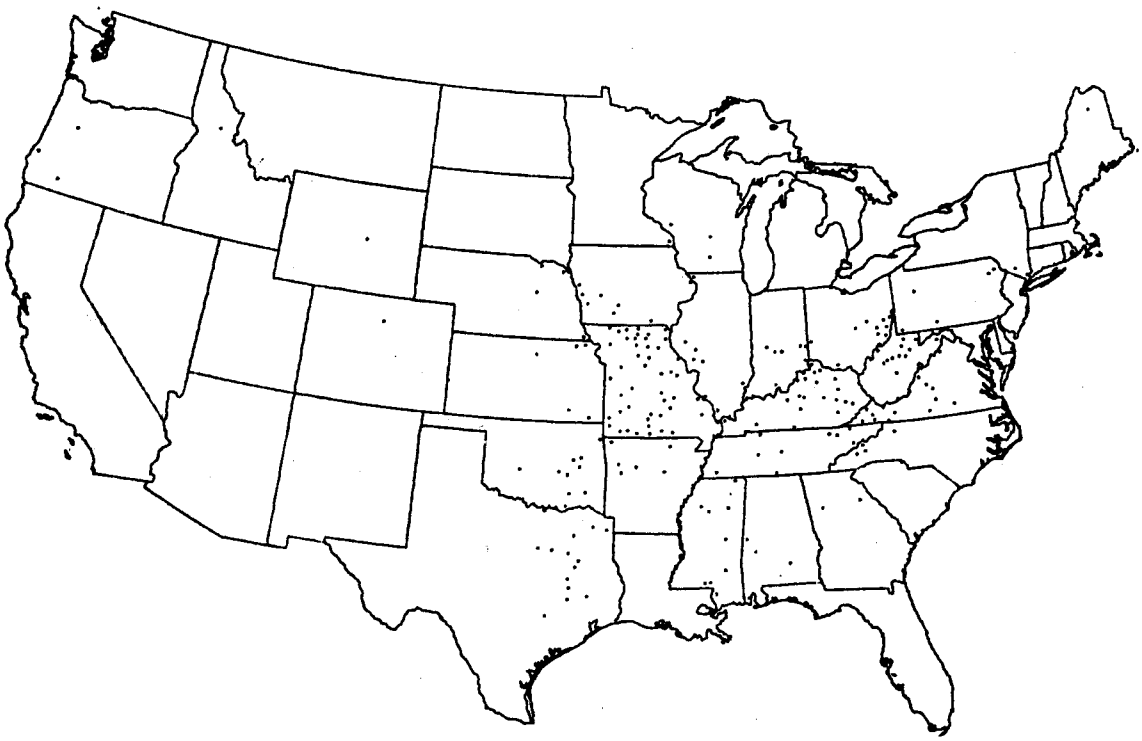


Figure 4-14.--Nonfederal pastureland eroding at rates greater than T (sheet and rill erosion).

Each dot = 50,000 acres.
See appendix table A4-11 for state data, and appendix table A4-13 for erosion rates and acreage.

EROSION ON FOREST LAND

Erosion is generally a problem on forest land only in areas where the cover has been disturbed by human activity. Activities related to timber and pulpwood harvesting increase erosion. Sheet and rill erosion rates exceed T on more than 23 million acres of nonfederal forest land. Most of that forest land is grazed. Nearly three-fourths of all sheet and rill erosion on forest land is occurring on less than 7 percent of the acreage. Wind erosion exceeds T on less than 1 million acres.

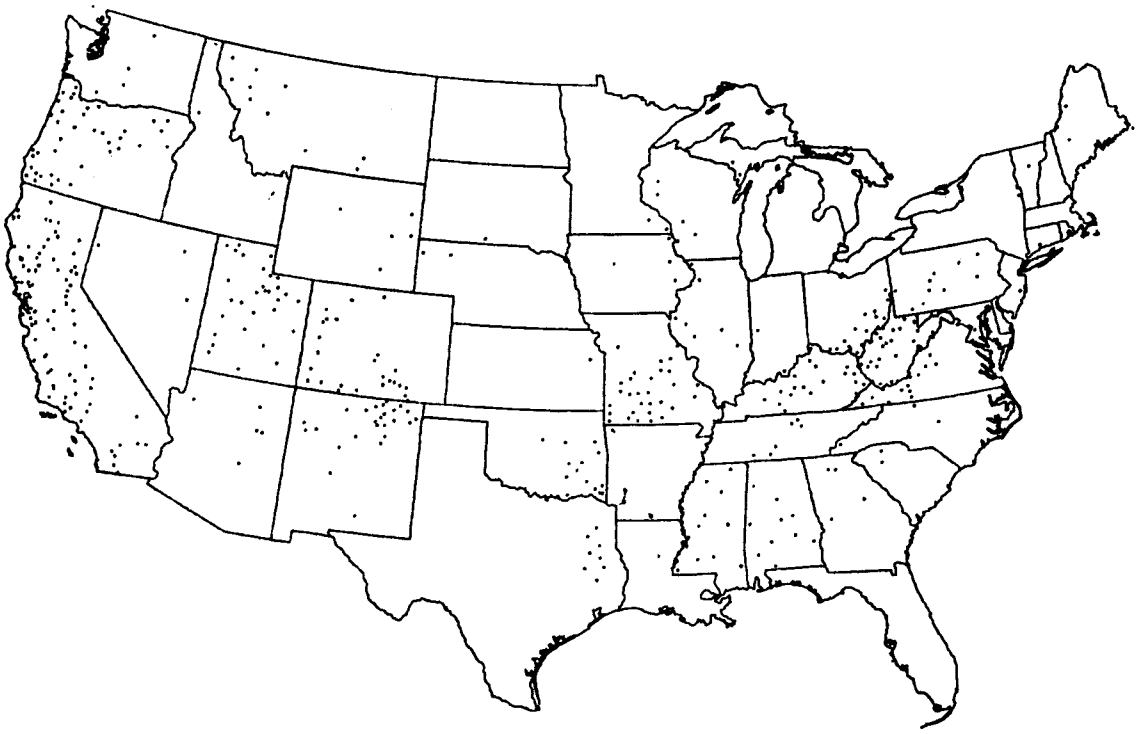


Figure 4-15.--Nonfederal forest land eroding at rates greater than T (sheet and rill erosion).

Each dot = 50,000 acres.
See appendix table A4-12 for state data, and appendix table A4-14 for erosion rates and acreage.

EROSION ON RANGELAND:

Where Is Erosion Causing Damage?

Either of two indicators may be used to identify soils where erosion damage is a hazard--range condition or T values. Range managers generally think that range condition is a better guide. See appendix table A4-16 for data on erosion rates in excess of T on rangeland. (Range condition is discussed in chapter 6 of this report.)

T values assigned to rangeland soils are lower than those for most soils used as cropland because most rangeland soils are limited by shallowness of the root zone and severity of the climate. T values for rangeland vary from one-half ton to 2 tons per acre. Even so, most range managers think that the T values assigned to most individual soils are too high to permit a high level of crop (climax vegetation) productivity to be sustained indefinitely.

If range condition and trend are used as the primary indicators, and if we assume that all rangeland in less than good condition is susceptible to erosion damage, erosion is a potential problem on 249 million acres (61 percent) of nonfederal rangeland.

If T values are used as the indicators, only about 70 million acres of nonfederal rangeland are eroding at damaging rates. Waiting until erosion exceeds T is poor range management, however. On range in good or excellent condition, a vigorous stand of adapted native vegetation provides effective protection against even severe winds and occasional torrential rainstorms. Erosion does not become visible on rangeland until the vegetation has been severely damaged. Reestablishing range vegetation under unfavorable climate and soil conditions requires years, if it is possible at all. During those years erosion continues to damage the fragile soil, further reducing the possibility that the range can return to its former productive state.

The relationship between range condition and erosion is apparent at the range site level. Table 4-6 shows this relationship for 16 randomly selected range sites in 14 states. In general, the data show increasing rates of erosion as range condition declines. With the exception of the Shallow Clay site in South Dakota, sites in excellent and good condition have little or no erosion problem. Sites in poor or fair condition generally have higher rates than sites in good or excellent condition, but they do not necessarily have high rates. Erosion may be slight on sites in poor condition if considerable cover exists, even if the cover is annuals or plants with little value as forage. In the long run, however, such sites are more susceptible to erosion because the cover is ephemeral and not dependable from year to year. No relation between condition class and erosion rate is apparent if data are aggregated to units larger and more varied than range sites.

Table 4-6.--Sheet and rill erosion rate, by range condition class, selected MLRA's and selected range sites

Range Site	MLRA	Excellent			Good			Fair			Poor			Not Applicable		
		#pts	Acres (x100)	Eros rate	#pts	Acres (x100)	eros. rate	#pts	Acres (x100)	eros. rate	#pts	Acres (x100)	eros. rate	#pts	Acres (x100)	eros. rate
KS - Limy Upland	76	48	425	0.8	333	4347	1.7	154	2038	3.6	36	501	5.4			
TX - Clay Loam	78	9	172	0.2	196	4580	0.4	541	12521	0.7	156	3559	0.9	21	534	0.3
TX - Low Stony Mill	81	2	38	0.1	113	2561	0.6	1233	31956	1.5	295	7168	2.9	9	148	1.0
TX - Low Stony Hill	85				12	213	0.7	164	2855	1.5	140	2515	2.5	8	49	1.8
OR - Loamy, 12-14"	8	5	86	0.2	9	220	1.3	17	300	1.5	13	256	2.0			
WA - Shallow, 15-19"	9	5	25	0.1	50	311	0.2	38	189	0.2	50	586	0.6			
AZ - Loamy, 12-16"	41	2	65	0.0	31	2310	0.4	38	3903	0.5	43	2922	0.5	5	278	1.1
SD - Shallow Clay	63A	35	1306	2.8	260	10526	3.1	67	2343	4.1	14	423	7.0			
NM - Loamy	70				30	3179	1.0	83	5126	1.3	11	1460	1.6			
ND - Shallow	54	20	510	1.3	137	2908	0.6	35	811	1.8	7	172	1.8			
NE - Sande	65	111	6508	0.5	419	29749	0.6	113	6530	0.5	17	941	1.4			
CO - Loamy Plains #2	67				22	1050	0.5	41	1607	0.5						
OK - Loamy Prairie	78	4	83	0.1	76	1496	0.6	141	2665	1.3	25	597	1.2	1	25	0.6
MT - Silty, 10-14"	58A	30	2164	0.2	132	9999	0.8	83	7381	0.6	7	773	0.2			
WY - Sandy, 10-14"	58B	1	5	0.2	21	1373	1.0	34	1818	2.0	1	6	0.3			
South FL Flatwood	155				20	279	0.4	260	4473	0.0	316	4612	0.0	6	114	1.0

Source: 1982 NRI.

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WHY DO FARMERS ADOPT CONSERVATION PRACTICES?

If we could answer this question, we could develop strategies for persuading more farmers, ranchers, and other landusers to adopt conservation practices. Although we do not yet know all the answers, recent research in the area of adoption of soil and water conservation has provided useful information. We know, for example, that those who adopt conservation practices are likely to be well-educated, full-time farmers who participate in many organizations. We know that landusers who possess the "conservation ethic"--that is, those who are concerned about preserving the land for future generations--are also more likely to practice conservation, although other factors, such as their willingness to take risks, may intervene. Landusers who use conservation practices are generally owner-operators; their families participate in the operation, and they realize that they have erosion problems on their land. Although most of this research has involved farmers, it may be possible to expand these generalizations to include ranchers with similar characteristics.

These research findings are supported by SCS evaluations of agency programs and activities. A recent evaluation of the SCS Conservation Technical Assistance (CTA) Program, for example, shows that, in most areas, half of CTA planning assistance in 1983 was provided to those who had been conservation district cooperators for at least 3 years. Owner-operators received almost three-fourths of CTA direct assistance. Where SCS had redirected its activities to focus on the most critical problem areas, a higher proportion of assistance was directed to landlords, nonfarmers, and those who were not conservation district cooperators.

Sociological research indicates that we may need to develop special strategies if we are to persuade more farmers and ranchers to apply conservation systems. The research confirms that the American farming community (and therefore, the conservation program clientele) is less and less the homogeneous group of full-time family farmers that comprise the popular American image of "farmer," and more and more a heterogeneous group that includes corporate farmers, part-time farmers, professional farm managers, and absentee landowners. Each of these groups has unique values, needs, and attitudes that influence their conservation decisions. Recent studies have provided information that can help in developing more effective strategies. For example, studies indicate that:

- Farmers and ranchers should be viewed as a segmented, rather than a mass audience.

- Farmers and ranchers need personalized information and technical assistance that will help them increase their awareness and recognize erosion as a problem on their own land.

- Farmers and ranchers need information and technical assistance that will help them evaluate the economic impacts of proposed conservation systems on their operation.

- More use should be made of the mass media, especially farm magazines, for the dissemination of conservation information.

- The role of the various agencies involved in conservation should be clarified, common goals among the agencies firmly established, and a teamwork approach of public and private organizations at the local level emphasized.

- Implementation strategies and marketing approaches should be targeted to the needs, abilities, and attitudes of different clienteles.

- Obstacles to conservation (such as tradition, assumptions about costs, reluctance to take risks) should be identified and dealt with.

- The best mix of technical, educational, and financial assistance should be considered in relation to the socioeconomic characteristics of the local community members.

- Potential and existing networks among farmers, ranchers, and other land users should be used to help disseminate conservation information and to expand participation among a wide variety of local groups.

What Sociological Research Tells Us

In the 1960's, researchers generally tried to explain farmers' use or non-use of conservation on the basis of the characteristics of individuals, without reference to other influences that might affect their behavior. This was known as the social-psychological approach, and concentrated on such individual characteristics as age, education, attitude toward conser-vation, years of farming, and off-farm employment.

More recently, researchers have suggested that farmers' behavior must be viewed within the context of numerous social, economic, political, and environmental factors that influence their decisions. The following is a brief summary of major findings of current research.

Characteristics of Farmers.--Researchers have found considerable variation in the relationships between age and conservation behavior. Some studies have found that older farmers are more likely to be SCS cooperators (Hoover and Wiitala, 1979; Lasley and Nolan, 1981); other studies have found no relationship between the age of the farmer and the use of conservation practices (Carlson et al., 1981). Since none of these studies was longitudinal, it is not known, for example, whether older farmers have become cooperators when older, or whether innovative older farmers were also innovative younger farmers. Some studies indicate that the number of years of farming is positively related to use of conservation practices, at least in the early years of farming (Abd-Ella

et al., 1981), while others show that more experienced farmers are more likely to rely on traditional tillage practices (Miranowski, 1981).

While age and experience do not appear to be closely related to application of conservation, there is apparently a clear and strong relationship between education and use of conservation practices (Ervin and Ervin, 1982; Carlson et al., 1981; Pampel and van Es, 1977). Highly educated farmers also are more likely to be aware of erosion problems (Ervin and Ervin, 1982; Taylor and Miller, 1978).

Researchers have found that farmers who adopt and use conservation practices tend to participate in many organizations (Abd-Ella et al., 1981; Korsching et al., 1981). On the other hand, farmers who are employed off-farm are less likely to adopt and use conservation practices (Ervin and Ervin, 1982; Taylor and Miller, 1978).

Attitudes.--Attitudes in four general areas have been examined in relation to use of conservation practices: stewardship, risk orientation, noneconomic orientation toward farming, and attitudes toward government involvement.

Stewardship, or the belief that farmers have a moral obligation to protect natural resources, is highly associated with the use of conservation practices (Ervin and Ervin, 1982; Nowak, 1981). However, at least one recent study has determined that other factors, such as economic returns, are far more influential in the adoption of practices (Carlson and Dillman, 1983).

Risk orientation, defined as the likelihood one will take chances, has been positively related to use of conservation practices (Ervin and Ervin, 1982; Nowak and Korsching, 1981). However, another study has found that farmers who were most concerned about environmental issues also were the least willing to take chances, and notes that risks associated with the adoption of conservation will probably have to be reduced before these farmers will use conservation practices (Napier et al., 1985).

Farmers who have a noneconomic orientation toward farming (that is, those who place a high value on being their own boss) are more likely to use conservation practices (Ervin and Ervin, 1982) and are significantly more concerned about soil erosion than other farmers (Buttel et al., 1981).

Farmers have mixed attitudes toward government involvement in agriculture On one hand, farmers generally do not support any type of legal pollution controls. Furthermore, if the economic situation for farmers worsens, they become even less supportive of government intervention that has a regulatory flavor to it (Marsh and Christenson, 1977). On the other hand, most farmers feel that government is responsible for funding conservation.

Farm Characteristics.--Researchers have also examined the relationship between the characteristics of the farm or ranch and the farmer's use of conservation practices. These characteristics include: size of operation, net income/farm sales, tenure, and farm specialization/diversification.

Most studies indicate that the larger the farm and the farm income, the greater the use of conservation practices (Ervin and Ervin, 1982; Nowak and Korsching, 1981; Abd-Ella et al., 1981; Carlson et al., 1981; Choi and Coughenour, 1979; Pampel and van Es, 1977; Coughenour and Kothari, 1962). Farmers who own their own farms are more likely to use conservation practices (Abd-Ella et al., 1981; Carlson et al., 1981), particularly when the practices are profitable (Pampel and van Es, 1977).

Family participation in the farm operation also appears to be related to adoption of conservation practices (Carlson and Dillman, 1983). When families have common aspirations regarding the future of the farm, use of conservation practices is significantly higher (Abd-Ella et al., 1981). Family size is related to the number of practices used, as are the degree to which married couples share in farm decisions and the degree to which the family is involved in gathering farm-related information (Abd-Ella et al., 1981; Pampel and van Es, 1977).

Research into the relationship between the degree of farm specialization/diversification and conservation practice use shows mixed results. One study found more specialized farms used significantly fewer practices and expended little effort in reducing soil erosion (Ervin and Ervin, 1982). Another found that, the more specialized a farm, the greater the number of practices used (Abd-Ella et al., 1981).

Environmental Factors.--Two factors must be considered in determining the effect the environment has on adoption of conservation practices: (1) actual soil erosion conditions, and (2) the farmer's perception of soil erosion conditions. Research findings are mixed, perhaps because of the variability in research techniques. Some researchers have calculated erosion rates on study farms using the Universal Soil Loss Equation (USLE); others have accepted the farmer's evaluation of erosion conditions.

Some studies using the USLE to evaluate erosion have found that erosion conditions do not explain behavior (Nowak and Korsching, 1981). In other words, farmers with the most severe erosion problems are not necessarily more likely to use more practices than farmers with less severe erosion problems (Ervin and Ervin, 1982). One study compared farmers' perceptions of their erosion problems with objective evaluations by SCS personnel over time. The study found that the evaluations of farmers and of soil conservationists differed considerably, but the differences decreased with intensified assistance. In 1978, only 1 percent of the farmers felt soil erosion was a "major problem" on their farm, while SCS personnel estimated that it was a problem on 85 percent of the farms.

Three years later, after SCS had provided information and assistance, 20 percent of the operators thought they had an erosion problem and SCS estimated that 57 percent of them did (Hoover et al., 1982).

Recent research has shown that perception of soil erosion is affected by the "proximity effect": that is, farmers and landowners are more likely to identify erosion as a problem somewhere other than on their own farm. Farmers are most likely to identify erosion as a problem in their county, somewhat less likely to identify it as a problem in their own community, and even less likely to identify it as a problem on their own farm (Bultena et al., 1984). There may be several reasons for this discrepancy. For one, the farmer may not have an erosion problem on his/her own farm. (The research on which the "proximity effect" hypothesis has been based did not involve actual, on-farm evaluations of erosion.) Second, the farmer may not be aware of the magnitude of erosion on the farm because sheet and rill erosion is not characterized by large gullies and dramatic instances of soil loss. Third, the farmer may deny the problem in order to reduce the psychological stress resulting from failure to correct the situation.

Not only do farmers underestimate the severity of erosion on their land, they also frequently overestimate the extent to which they are practicing good soil conservation. This is especially true in regard to conservation tillage. Researchers have found that farmers consider themselves to be using conservation tillage when they use conservation tillage equipment or reduce the number of passes over the field, even though residue on the field is far below the standard for conservation tillage (Nowak and Korsching, 1985).

Institutional Characteristics.--Of all the factors affecting the adoption of conservation practices, institutional characteristics may be among the most influential. Yet they are the least defined, the most difficult to document, and the least researched. The current trend in research, however, is to place more emphasis on these characteristics and less on individual characteristics of farmers and farms. There may be several reasons for this:

- Clear relationships have been found between such characteristics as education, ownership and off-farm employment, and there may be little to be gained by pursuing research in these areas alone.

- The simple relationships between farmer/farm characteristics and adoption explain only a small portion of the variation in conservation behavior, so other factors must be equally, or more, significant.

- The current economic and political climate in which the American farmer functions today is certain to affect conservation decisions, as it affects all other decisions made by the farm unit.

In 1982, social scientists participated in a national RCA Symposium on Future Agricultural Technology and Resource Conservation that was organized to determine the direction that American agriculture is headed, and the effects that modern farming practices have on land use, soil, and the environment. These scientists called attention to the inconsistencies and conflicts between conservation and production goals of USDA agencies, and called for research to evaluate and identify the institutional barriers to conservation (English et al., 1983). The Food Security Act of 1985 addresses some of these concerns with its "Sodbuster," "Swampbuster," and Conservation Reserve features.

RCA Symposium participants also cited a need to break down barriers among institutions involved in soil and water conservation by decentralizing program control and developing multi-agency planning at the local level. Recent research has shown that, although farmers cite conservation agencies as likely sources of needed conservation information, many are confused about the types of assistance available from individual agencies (Bultena et al., 1984).

In general, the higher the number of institutional contacts, the greater the likelihood farmers will use conservation practices (Nowak and Korsching, 1981; Abd-Ella, 1981). Farmers who are district cooperators or who have a conservation plan developed with SCS assistance are more likely to use conservation practices (Ervin and Ervin, 1982).

Although the influence of institutional factors on adoption of conservation practices remains a relatively unexplored area of research, there is considerable interest in the ways by which innovations and information about them are made available to individuals or households through the activities of organizations (in this case, public agencies). An agency emphasizing this aspect of the adoption process analyzes the characteris-tics and needs of its clienteles, and then develops strategies to address these characteristics and needs in order to "sell" the agency's programs. This is known as the "market approach" to adoption (Brown, 1981).

Results from studies of adoption in other sectors suggest that the market approach might achieve greater application of conservation practices. Several recent studies have examined information sources, relationships among conservation agencies and soil and water conservation districts, and characteristics of target clienteles (Bultena et al., 1984; Korsching et al., 1985). They have documented the importance of seeing farmers as a "segmented" rather than "mass" audience and of tailoring information and technical assistance to sub-groups based on their common needs, characteristics, stages in decision-making, etc. This approach may be particularly relevant as conservation agencies focus their assistance on areas with the most critical resource problems where it may be necessary to work with a variety of client groups, some of whom may be unfamiliar with agency roles.

Where Do We Go From Here?

Although economic factors are certainly significant in the decision to adopt conservation practices, they fail to account for all adoption behavior. Sociological factors are also significant and, for some farmers and landowners, even outweigh economic considerations. Currently, we know a great deal about the characteristics of farmers and landowners who are most likely to adopt conservation practices. What we do not know very much about is how to motivate farmers who are not likely to use conservation practices without some kind of incentive. Sociological research tells us that this incentive is not always a monetary one.

We need to know more about the values and attitudes of the many different clienteles with whom we work, and the kinds of incentives that will motivate them to use conservation practices. When we have this information, we can develop implementation strategies and marketing techniques that will meet the needs of the target clientele as well as meeting agency goals for the application of soil and water conservation practices.

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Salinization Is Damaging Some Soils

Salinization is a problem in arid and semiarid areas where precipitation is insufficient to leach salts from the soils. If the soil moisture around plant roots contains too much salt, most crops cannot absorb the water and nutrients they need to germinate and grow well. Saline or sodic (excessive sodium) conditions are lowering productivity on 10 percent of the nation's cropland and pastureland, including nearly one-fourth of the irrigated cropland and pastureland. Six of the western water resources regions have salinity problems on one-third or more of their cropland and pastureland.

Irrigating with saline water or poor management of irrigation water can cause salinization of irrigated land. Some cropping practices on nonirrigated land can cause saline seeps where salt-bearing ground water emerges on the surface of a slope. Efforts to deal with salinization must be carefully planned to ensure that the problem is reduced, not just moved to another area. If return flow from irrigation carries excessive amounts of salt to the stream, the water may cause crop losses downstream, may be rendered unfit for people and animals to drink, and may cause high mortality of fish and other stream organisms.

Projections of future developments made for this appraisal did not consider the effects of salinity on cropland availability or productivity. The linear programming model used in the analysis calculates that, under intermediate levels of increase in demand and productivity, high percentages of cropland in the western half of the nation, both irrigated and dryland, would be removed from production. Reductions in acreage cropped can be assumed to reduce salinity problems also. Continued availability of sufficient land for special crops grown in areas with current or potential salinity problems was assumed but not analyzed in the model.

LAND AFFECTED BY SALINITY: More extensive than we thought

Saline soils and seeps have an excess of soluble salts in the root zone, which causes plant yields to decrease. Severe salinity may completely prevent crop growth. Saline seeps occur where salt-bearing groundwater, flowing over an impervious layer, emerges on the surface of a slope.

Sodic soils contain excessive amounts of adsorbed sodium. Because soil particles have negative electrical charges on their surfaces, they can adsorb and hold positively charged ions. A soil is sodic if 15 percent or more of its adsorptive capacity is taken up by sodium. Sodium saturation causes poor soil structure and severely limits water infiltration unless the soil is also saline.

In the 48 conterminous states, more than 57 million acres of cropland and pastureland are either sodic or affected by varying degrees of salinity. This estimate was obtained by cross-referencing information collected by the National Cooperative Soil Survey and the 1982 National Resources Inventory (NRI). The acreage is much larger than that in the 1982 NRI or any other previous sample inventory. Data collected by sample inventories alone, without reference to soil laboratory data, apparently recorded as sodic or saline-affected only those soils that are severely affected. Experiments have demonstrated that yields of some plants are reduced in soils that are only slightly affected. Some plants are highly sensitive to salt while others are quite tolerant (fig. 5-1).

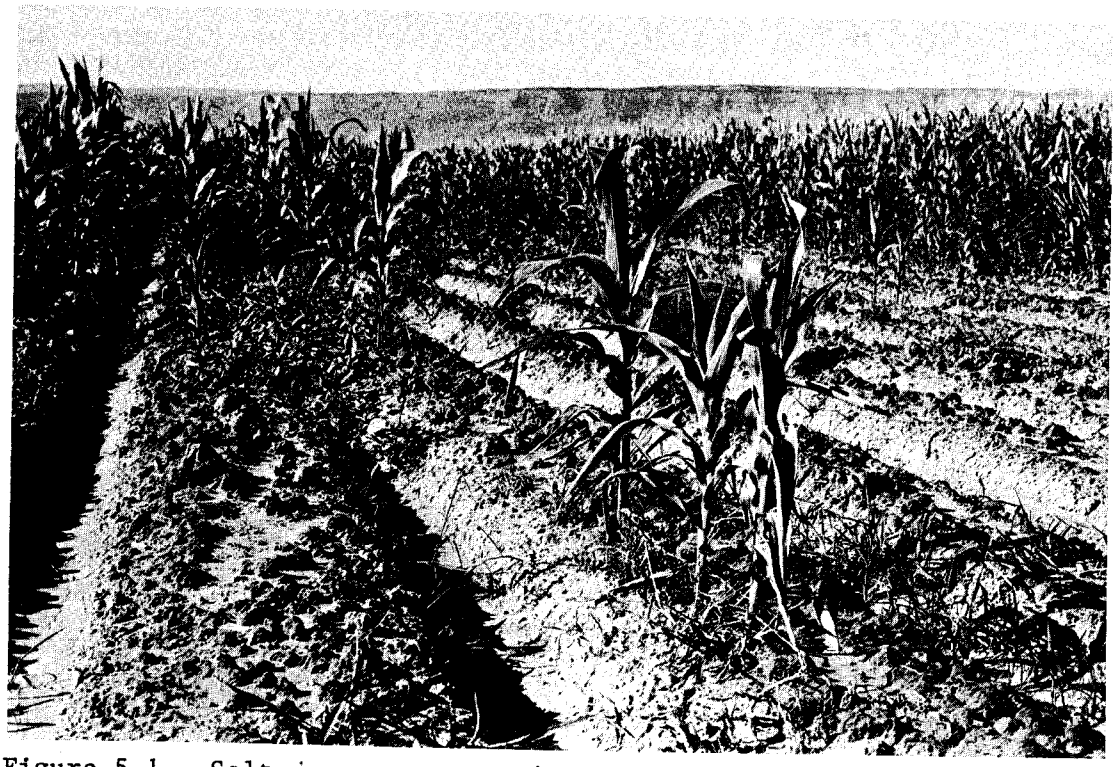


Figure 5-1.--Salt damage to corn in western Colorado.

Table 5-1 shows the approximate reductions in yield that specific levels of soil moisture salinity can be expected to induce in certain plants. The figures are based on average conditions in arid and semiarid regions where surface irrigation methods are used; a plant's tolerance may differ in a more humid environment or under sprinkler irrigation. 1/

Table 5-1.--Salt tolerance of selected crops

Crop	Salinity 1/ at the point where yield begins to decline	Yield decrease 2/ for each added unit increase in salinity	Salt tolerance rating 3/
Alfalfa	2.0	7.3	MS
Apricot	1.6	24.0	S
Barley (forage)	6.0	7.1	MT
Barley (grain)	8.0	5.0	T
Bermudagrass	6.9	6.4	T
Cabbage	1.8	9.7	MS
Clover	1.5	12.0	MS
Corn (forage)	1.8	7.4	MS
Corn (grain)	1.7	12.0	MS
Cotton	7.7	5.2	T
Grapefruit	1.8	16.0	S
Lettuce	1.3	13.0	MS
Onion	1.2	16.0	S
Orchardgrass	1.5	6.2	MS
Potato	1.7	12.0	MS
Rice	3.0	12.0	MS
Soybean	5.0	20.0	MT
Sugar beet	7.0	5.9	T
Tomato	2.5	9.9	MS
Wheat	6.0	7.1	MT
Wheatgrass, tall	7.5	4.2	T

1/ Salinity is expressed as electrical conductivity of the water in the soil in millimhos per centimeter at 25° C.
2/ Yield decreases are given as percentages of unaffected yields at sites where climate and soils are similar.
3/ S = sensitive; T = tolerant; M = moderately tolerant. Ratings for some tree crops are based on growth rates rather than yield responses because of limited data.
Source: Maas, E.V. and G.J. Hoffman, June 1977. Crop salt tolerance--current assessment, Journal of the Irrigation and Drainage Division, ASCE, Vol. 103, No. IR2, Proc. Paper 12993.

1/ For a detailed explanation of the relationship of salinity to plant physiology, see Salt water intrusion of ground water in the contiguous United States 1985. Ch. II, Vol. III, Part A. Environmental and Ground Water Institute, University of Oklahoma.

Table 5-2 shows the percentage of all cropland and pastureland affected by salinity and sodicity in major water resource regions or drainage areas (fig. 5-3). Soil salinity occurs mostly in the arid and semiarid areas of the West. Six of the western water resource regions have salinity problems on one-third or more of their cropland and pastureland.

In humid areas, rainfall long ago flushed much of the soluble salts and sodium from the soils and carried them to the ocean. In areas with limited rainfall, the salts have not been leached away. When land in these areas is irrigated, the leaching process begins. Well drained soils on higher parts of the landscape gradually become less saline when irrigated with good quality water, because irrigation water dissolves salts and transports them into groundwater, which may return to feed into surface supplies. This process adds salts to waters downstream. When these more saline waters are used for irrigation downstream, salts accumulate in low-lying, poorly drained areas (fig. 5-2).

Figure 5-2.--The white crust of accumulated salts indicates the cause of heavy crop losses in an irrigated field of cotton in California. Note that cotton is considered salt-tolerant (table 5-1).

Table 5-2.--Sodic and saline soils on cropland and pastureland, by region

Water resources regions	Sodic soils	Saline soils	Total affected soils	Total cropland/ pasture	Percent affected
	----------(thousands of acres)----------				
New England	0	0	0	4,131.4	0.0
Mid-Atlantic	0	0	0	18,212.1	0.0
South Atlantic-Gulf	1.3	33.5	34.8	42,616.2	0.1
Great Lakes	0	0	0	31,653.1	0.0
Ohio	30.2	0	30.2	48,295.3	0.1
Tennessee	0	0	0	8,470.5	0.0
Upper Mississippi	240.4	1,344.3	1,584.7	77,269.4	2.0
Lower Mississippi	645.5	93.7	739.2	28,635.6	2.6
Souris-Red-Rainy	518.8	6,959.2	7,478.0	22,740.9	32.9
Missouri	2,785.2	24,893.5	27,687.7	124,475.7	22.2
Arkansas-White-Red	554.2	2,239.1	2,793.3	60,380.4	4.6
Texas-Gulf	140.6	2,504.8	2,645.4	38,187.8	6.9
Rio Grande	118.5	2,897.1	3,015.6	3,714.7	81.2
Upper Colorado	31.7	881.9	913.6	2,482.6	36.8
Lower Colorado	26.5	915.5	942.0	1,484.9	63.4
Great Basin	149.2	1,683.0	1,832.2	3,551.3	51.6
Pacific Northwest	126.9	3,137.3	3,264.2	23,562.9	13.8
California	430.3	3,921.1	4,351.4	12,177.8	35.7
Hawaii	0	1.7	1.7	1,307.2	0.1
Caribbean	0	20.0	20.0	1,363.3	1.5
TOTAL	5,799.3	51,525.7	57,325.0	554,713.1	10.4

Source: 1982 NRI.

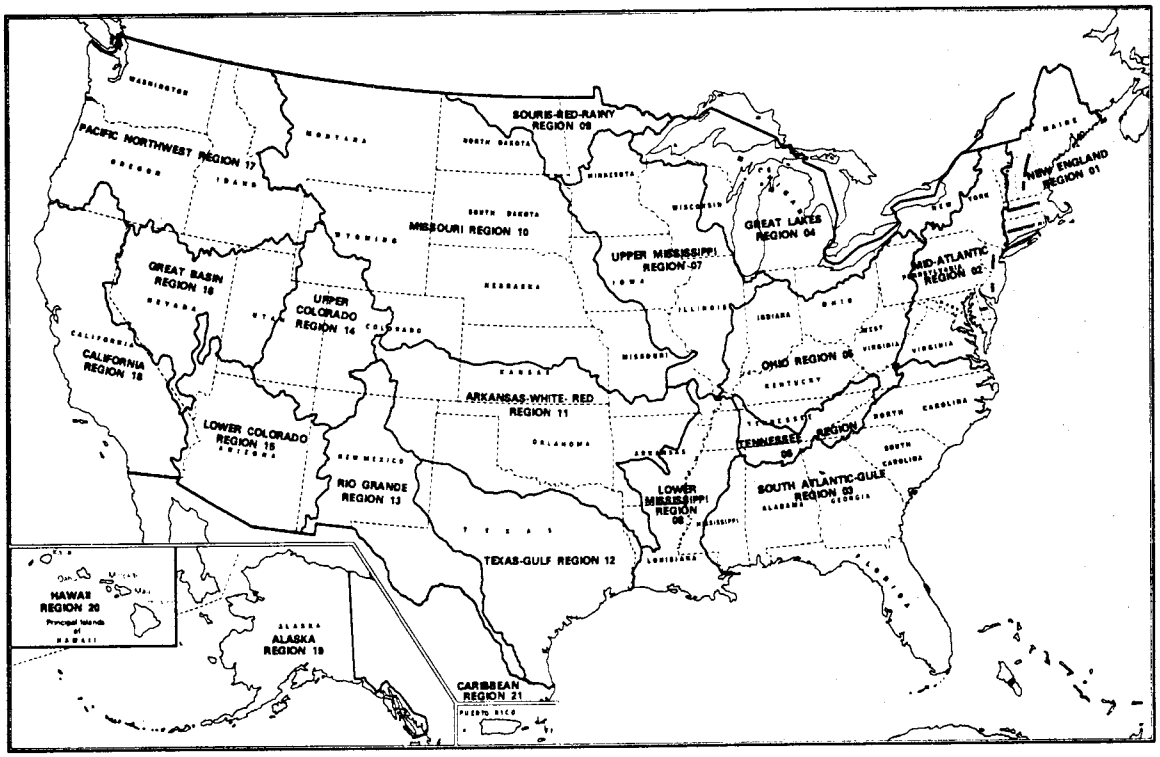


Figure 5-3.--Water resource regions of the United States.

Salinization occurs in both irrigated and nonirrigated areas (fig. 5-4 and 5-5). In 7 of the 12 western water resources regions, the percentage of affected cropland and pastureland is higher for the irrigated land than for the nonirrigated land. The exceptions are the Upper Mississippi, Souris-Red-Rainy, Missouri, Texas-Gulf, and Rio Grande regions.

In the 48 conterminous states, 14,870,000 acres (about 22.7 percent) of irrigated cropland and pastureland are affected by salinity or sodicity. Inefficient irrigation practices in either upstream or downstream areas can accelerate the rate of salinization. Acreages of salt-affected areas tend to increase as long as saline waters are applied without adequate drainage. Notable among locations where salinity is increasing because of irrigation practices are the area around the Salton Sea in southern California, parts of the lower Gila River basin in Arizona, and parts of the Rio Grande basin in southern New Mexico and western Texas. Increasing consumptive uses of water in the future will tend to increase salinity downstream.

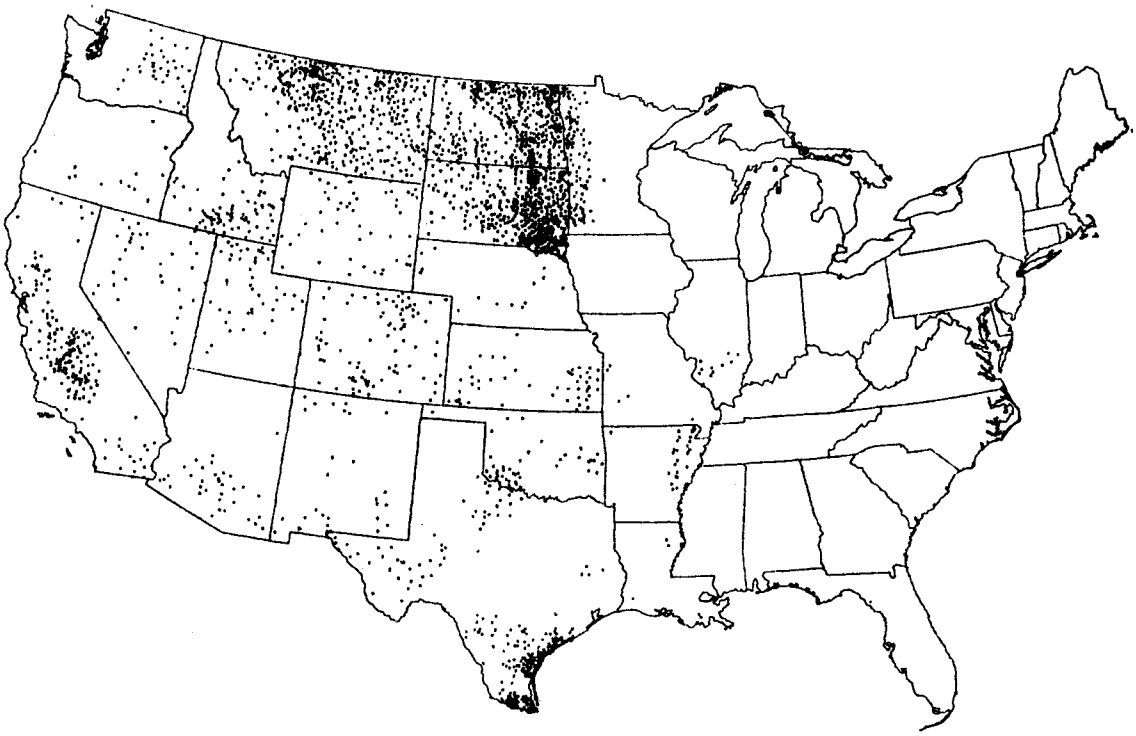


Figure 5-4.--Cropland and pastureland affected by sodicity and salinity. Each dot = 25,000 acres. See appendix table A5-1.
Source: 1982 NRI and National Cooperative Soil Survey.

On nonirrigated croplands in arid and semiarid areas, especially those of the High Plains, saline seeps are developing where crops are using less water than was used in the past by the natural vegetation. As the unused soil water percolates downward, it carries salts to the surface downslope. Where there is not enough water to carry these salts out to a flowing stream, salts and soil wetness build up.

Table 5-3 shows estimates of the acreage of saline seeps. These estimates may be low. Because slightly and moderately saline soils often cannot be detected visually, saline seep areas may be more extensive than has been believed.

The acreage affected by saline seep is increasing at an average of 10 percent per year in proportion to the first year of measurement (Thomas and Custer, 1976). It is not uncommon for seep areas to expand by 20 to 200 percent in wet years, but in dry years expansion may be very slight.

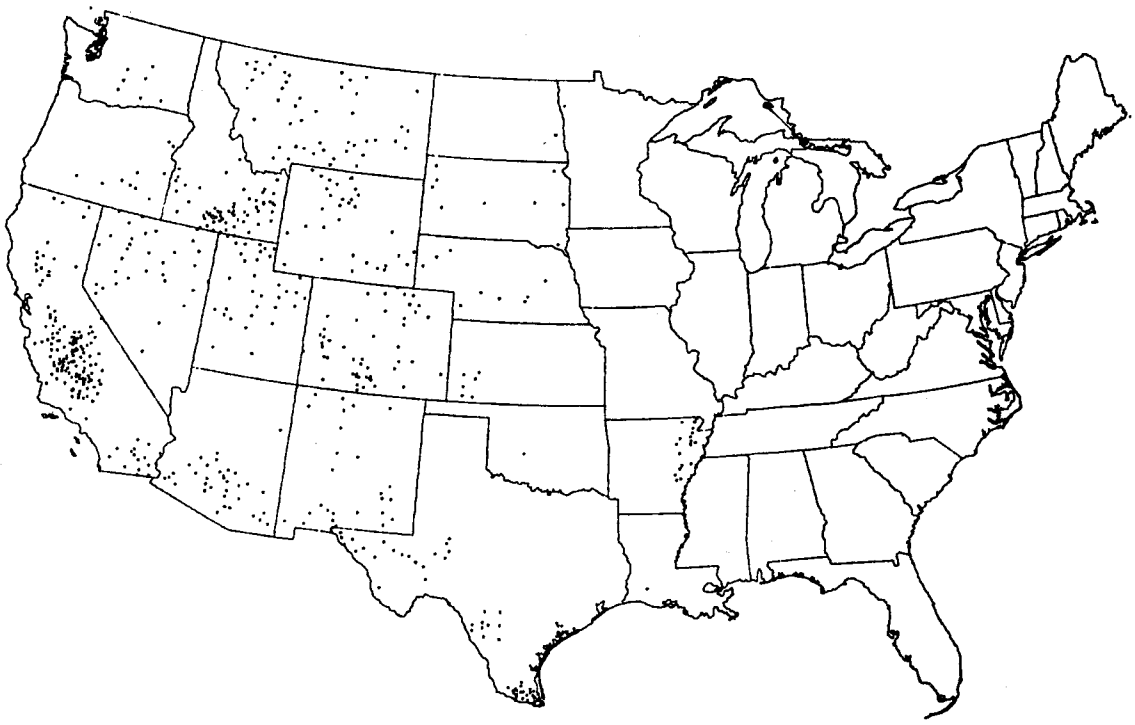


Figure 5-5.--Irrigated cropland and pastureland affected by sodicity and salinity. Each dot = 25,000 acres.
Source: (1982 NRI and National Cooperative Soil Survey.
See appendix table A5-2 for data for regions and aggregated subareas.

WHAT KINDS OF DAMAGE RESULT FROM SALINITY AND SODICITY?

Where soil has become saline or sodic, farm and ranch operators generally experience reduced yields and a reduction in net income. They may have to change their crop mix to more salt-tolerant crops.

Irrigation commonly leaches salts out of the soil, so the subsurface return flow contains more salts than the input water. Consequently, downstream irrigators may need more water to wash the salts out of their soils.

In addition to ruining thousands of acres of productive farmlands, water flowing from saline seeps has been observed to cause scours, staggers, and occasional blindness in livestock. Water from saline seeps commonly contains much higher concentrations of nitrates and trace elements than are found in water samples from nearby areas.

Salinity, or a high concentration of sodium, can make water unfit for human consumption. (See chapter 11.)

The inflow of saline waters or of waters containing high concentrations of trace elements can damage or destroy habitat for fish and wildlife, especially in wetlands. (See chapters 7 and 11.)

Table 5-3. Estimated areas of saline seeps in the Great Plains states

State	Acreage
Montana	200,000
North Dakota	133,600
South Dakota	10,000
Texas	68,000
Oklahoma	100,000
Wyoming	25,000
Total	536,600

Source: Report on saline seep problem in the Great Plains. Unpublished report by the Program Integration Staff, Planning and Evaluation, Soil Conservation Service, July 1981.

WHAT IS BEING DONE TO REDUCE SALINITY PROBLEMS?

In areas where salinity is related to irrigation and drainage, the Department of Agriculture is providing technical assistance to landowners who want to improve irrigation water management and provide adequate drainage. In the saline seep areas, technical assistance and computer software packages are provided to landowners who want to improve their management of soil moisture conditions through crop rotations, annual cropping, and drainage. Drainage assistance is not provided where it would lead to significant damage to wetlands.

In the Colorado River Basin, USDA's Soil Conservation Service and Agricultural Stabilization and Conservation Service are cooperating with the Bureau of Reclamation, state government agencies, conservation districts, local government agencies, and landowners to promote practices that reduce the flow of salts into downstream waters.

USDA also is conducting research in the use of alternative crops (such as Kochia) for treating seep areas and in methods for detecting and managing salinity problems.

In areas where saline seeps have developed, there are three basic approaches to treatment:

- planting deep-rooted crops, which reduce the amount of soil moisture entering the ground water;
- changing crop rotations to reduce the number of years in which cropland is left fallow;
- installing interceptor drains to collect and dispose of the excess groundwater.

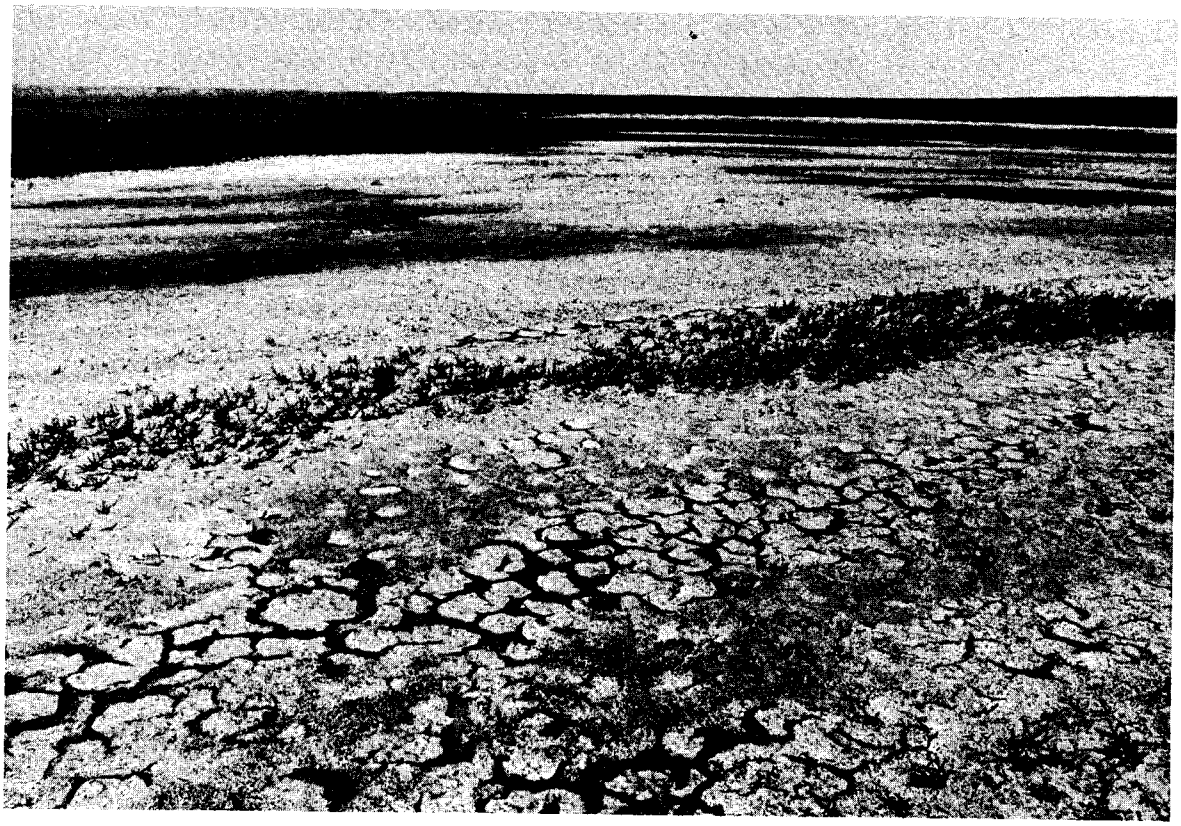


Figure 5-6.--This saline seep in north-central Montana has grown to cover nearly 60 acres. Saline seeps form when excess moisture travels through soil layers, absorbs salts, and resurfaces.

Range Resources Need Protection

Range vegetation is an important renewable resource that is an integral part of the resource base. The health of rangeland is measured by range condition. Much of our rangeland was severely abused by early settlers unfamiliar with the fragility of range ecosystems. Range scientists report that rangeland has generally been improving in condition since the 1930's. In spite of that trend, 61 percent of nonfederal rangeland remains in less than good condition. As a result, erosion and deterioration in the quality of plants continues in some areas.

Continued good management to maintain the improvement achieved so far is important because it is more costly to restore productivity and profitability than it is to maintain rangeland in good or excellent condition. Good management of rangeland increases forage for livestock, improves habitat for wildlife, and can increase the quality and quantity of the water supply that originates in rangeland watersheds.

Projections of future developments made for this appraisal include a livestock sector and a pasture/range sector. Assuming an intermediate rate of increase in demand and productivity, the linear programming model used in the analysis calculates that the least-cost method of meeting demands would entail greater use of pasture/range forage and reduction of the acreage of cropland required to feed livestock. Additional use of pasture/range is projected for dairy cattle, roughage-fed beef, and cow-calf operations.

Assuming intermediate conditions and full implementation of the conservation provisions of the Food Security Act of 1985, livestock are projected to consume 453 million tons of pasture/range forage in 2030. Assuming intermediate conditions in the absence of the conservation provisions, the model projects that livestock would consume 370 million tons of pasture/range forage and that some changes in the regional distibution of cow/calf operations would occur. Under either assumption, distribution of roughage-fed beef would differ from that in the 1982 base projection. The largest changes projected are an increase in the Southeast and a corresponding decrease in the Southern Plains. Assuming greater increases in demand and smaller increases in productivity, consumption of pasture/range forage is projected to increase slightly, to the full 460 million tons assumed available.

Erosion rates, potential for range degradation, and opportunities stemming from improved range management or conversion of cropland to pastureland were not considered in the analysis.

RANGE CONDITION: Judging the health of the resource

The major rangeland resource is vegetation -- principally grasses and grass-like plants, forbs, and shrubs. Many factors influence that vegetation, especially soil, climate, topography, fire, drought, and animal life. Soil, plants and indigenous animals develop concurrently. At first only annual, ephemeral, pioneer plants and primitive animal life are able to subsist on a site, but they make their organic contribution to soil development. Eventually, through a series of successional changes, a diverse and stable plant community evolves, self perpetuating and in dynamic equilibrium with the soil and other elements of the habitat. This climax vegetation, the product of the total environment, is the best suited to the soil, moisture, temperature, and other environmental conditions of that site. It is the most stable and productive natural plant community the site is capable of supporting. Thus, the plant species present, the percent composition, and plant vigor are the best indicators of range health. If the climax vegetation is destroyed, restoration is painfully slow. If the site is allowed to deteriorate, for example through soil erosion, restoration may be impossible.

Rangeland quality can best be judged by comparing the present vegetation of a site to the climax vegetation. The degree to which the kinds and proportions of plants in the existing plant community resemble those of the presumed climax vegetation for the site is called range condition. There are four range condition classes: excellent, good, fair, and poor. Excellent condition means that more than 75 percent of the present plant community is climax; good, 51 to 75 percent; fair, 26 to 50 percent; and poor, 25 percent or less. Range condition ratings are not assigned to the annual grasslands of California and areas elsewhere seeded to and dominated by introduced species.

Generally, the correlation between range condition and the quality of the range is high. As a rule, a site in good or excellent condition produces more forage and provides better habitat for native animals. Water infiltration is higher and runoff and erosion are lower. However, range condition indicates only the degree to which existing vegetation differs from the climax community. It is not a rating of the value of the vegetation for any specific use. Any of a number of causes may induce a departure from the climax community, and the resulting vegetation may be more or less valuable for a particular use than the species in the climax community.

Figure 6-1 shows the condition of nonfederal rangeland in 1982, the condition of state-owned rangeland as recorded in the 1982 NRI, and the condition of federal rangeland administered by the Bureau of Land Management. The figures show that 61 percent of all nonfederal rangeland, 60 percent of BLM-administered land, and 65 percent of state-owned rangeland are in poor or fair condition and, therefore, need improvement. Federal rangelands administered by the USDA Forest Service cannot be compared to nonfederal or BLM-administered lands because the Forest Service uses a slightly different system to classify land.

Of the more than 770 million acres of rangeland in the nation, 46 percent are nonfederal, 42 percent are federal lands administered by the Bureau of Land Management, 5 percent are federal lands adminstered by the USDA Forest Service, and 6 percent are federal lands administered by other federal agencies.

Range condition on nonfederal rangeland varies considerably by state. Figure 6-2 shows the percentages of nonfederal rangeland in excellent and good, fair, and poor condition for those states having rangeland.

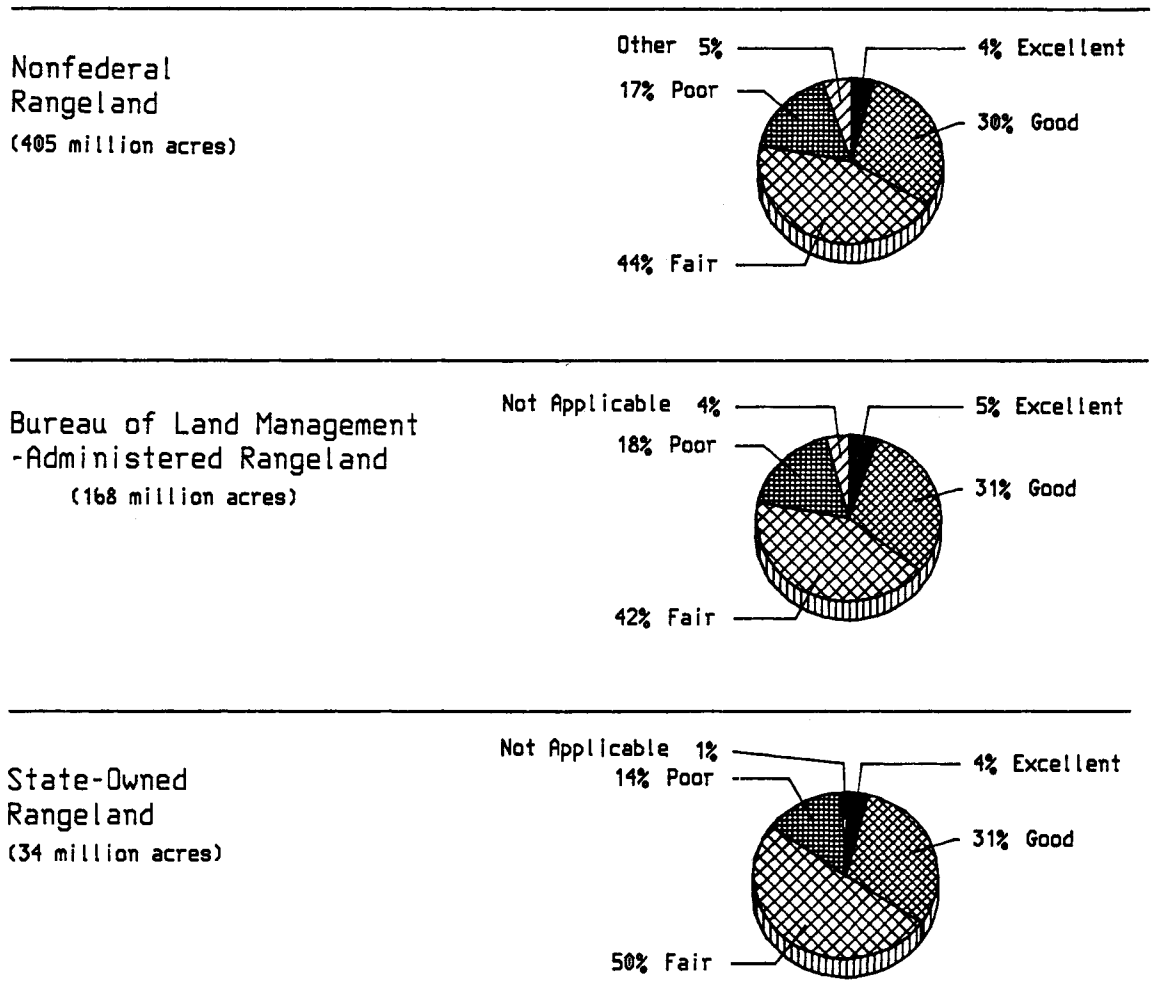


Figure 6-1.--Condition of all nonfederal rangeland, state-owned rangeland, and federal rangeland administered by the Bureau of Land Management. (Nonfederal and state-owned rangeland as recorded in 1982 NRI; BLM-administered land inventoried by BLM in 1984). See also appendix tables A6-1, A6-4, and A6-5.)

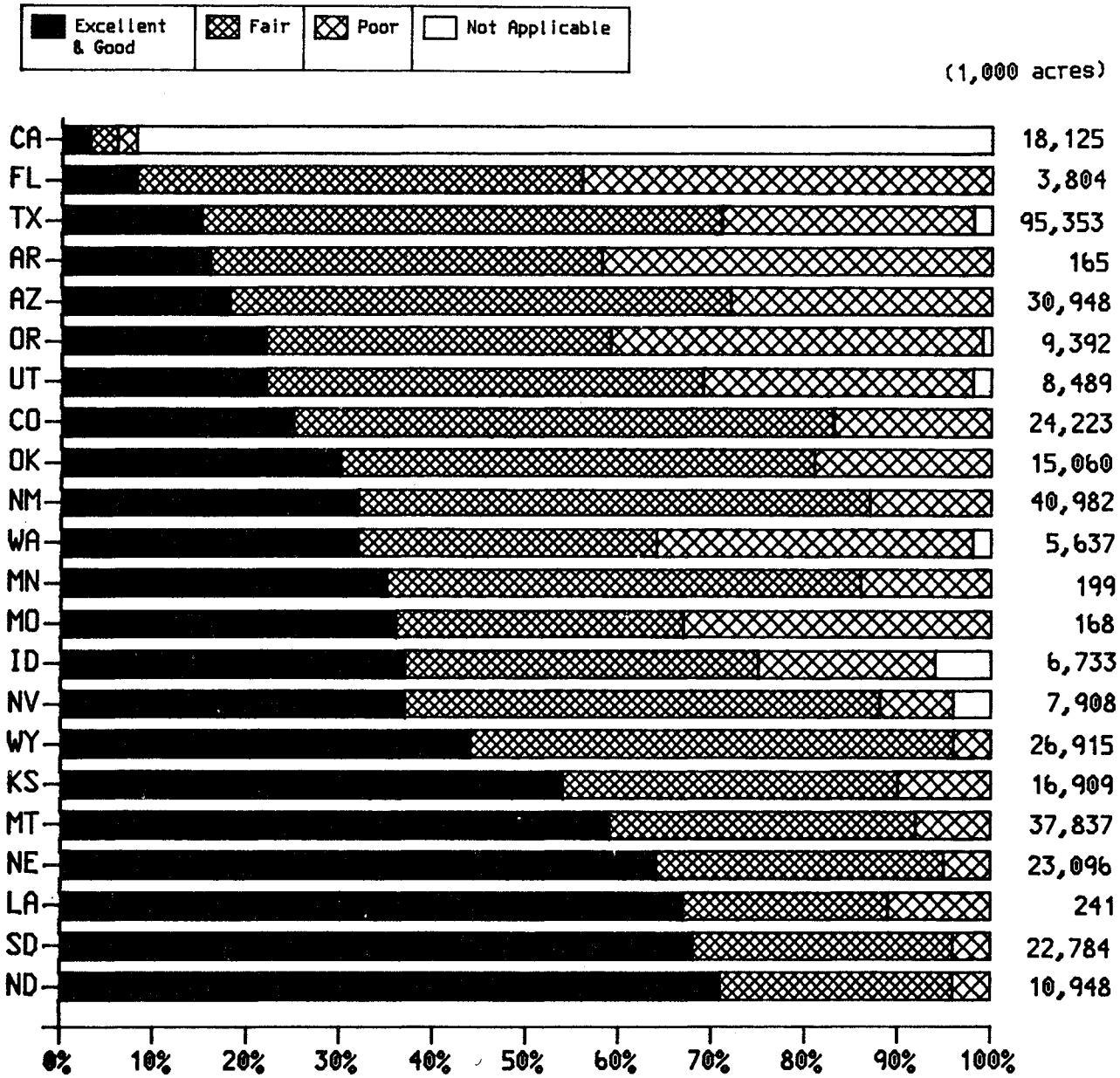


Figure 6-2.--Percentage of nonfederal rangeland in excellent and good, fair, and poor condition, by state (1982 NRI).
See also appendix table A6-1.

TREND: Is Range Condition Improving?

Trend in range condition is the direction a plant community is changing in relation to its potential. Because the fragile soils and harsh climate make proper range use essential, trend is the most important part of the range resource inventory. All conservation and management actions are based on whether or not the range is improving, deteriorating, or maintaining its current status.

Range scientists generally believe that range condition reached a low point in the 1930's and has been slowly improving since that time. SCS conducted range assessments in 1963, 1977, and 1982. Although methods differed considerably in the three assessments, they do show that range condition has improved since 1963. There is little difference in the condition of rangeland reported in the 1977 and 1982 NRI. This is not cause for concern in itself, because range condition generally improves slowly. In the 1982 NRI, range trend was documented as not changing on 69 percent of the land and changing on 31 percent of the land. The trend was up on 16 percent of the rangeland and down on 15 percent.

Over the past decades, range condition has improved because ranchers, aided by government programs providing technical and financial assistance, have worked to correct the problems. However, available data suggest that measures to improve the most severely damaged rangeland have been applied less intensively in the past few years. There are several reasons for this: the cost of most brush control methods has increased; constraints have been placed on use of herbicides to control brush; economic conditions have reduced livestock producers' investment capital; and reduced funding and limited priorities of federal programs have practically eliminated assistance available for range management.

The Conservation Reserve, other parts of the Food Security Act of 1985 and state initiatives, i.e. state range improvement programs such as those in Utah, Montana, California, and Texas may provide opportunities to reverse this trend.

WHAT CAN WE DO TO PROTECT AND ENHANCE RANGE RESOURCES?

Rangeland is not cultivated and, with few exceptions, is not routinely fertilized, overseeded, drained, irrigated, or mechanically harvested. Rangelands are natural ecosystems and are managed by varying the frequency and intensity of grazing and the season of use. Only on severely depleted rangeland do managers resort to more drastic reclamation measures such as brush management, mechanical soil treatment, range seeding, and erosion control practices. On rangeland, there is little or no distinction between "production" practices and "conservation" practices because the actions that increase forage production also protect the soil and conserve water.

Some rangeland is well-managed. About one-third of nonfederal rangeland (136 million acres) was identified in the 1982 NRI as adequately protected and thus needs only continued proper management. In this category are those acres where range condition, soil erosion, and other factors that influence sustained productive use of the resource are within acceptable limits. Figure 6-3 shows acreage of adequately protected rangeland in each state and the percentage of the state's rangeland that is adequately protected.

Improved grazing management would improve conditions on some rangeland. About one-third (134 million acres) of nonfederal rangeland needs improvement that can be achieved through refinements in grazing management. Figure 6-4 shows the acreage of rangeland in each state that could be improved by controlling the number of grazing animals and the season and duration of grazing. On rangeland that can be adequately improved and protected by better management, the desired vegetation is present, but the vigor or stand needs improving. The improvement can be accomplished by facilitating practices such as proper grazing use, deferred grazing, planned grazing systems, and fencing and water facilities for improved animal control and grazing distribution.

More intensive measures would be required to improve conditions of some rangeland. Protecting and enhancing most of the remaining one-third (117 million acres) would require more intensive treatment, such as brush management, range seeding, or erosion control. (Treatment is not feasible on 19 million acres.)

- Brush management. Invasion of brush is directly related to both deterioration of the plant community and soil erosion. Brush, as defined here, includes perennial woody plants that have encroached upon areas where they are not part of the climax plant community or that have thickened in density on sites where only small amounts were natural. Major problem plants include mesquite, juniper, sagebrush, several species of oak, sawpalmetto, creosote bush, chaparral shrubs, and cactus.

Brush reduces production of desirable forage species, adversely alters the hydrology of the site, interferes with the handling of livestock, and

renders the site more susceptible to erosion. On many sites, for example, where junipers have encroached, soil erosion is severe between shrubs and cannot be arrested through management or exclusion of livestock alone. Degradation of the soil and plant community is inevitable and irreversible until the juniper trees are controlled. Moisture use by deep-rooted brush species has caused springs to cease flowing and reduced formerly permanent streams to intermittent draws. Brush management methods include the use of herbicides, mechanical and biological measures, and controlled burning.

According to the 1982 NRI, 36 percent of all nonfederal rangeland had a woody canopy cover of more than 10 percent, and 16 percent had more than 25 percent cover (table 6-1). Brush management is the main conservation treatment that can benefit almost 81 million acres of rangeland. The vegetation on over 17 million acres of rangeland is so degraded that brush control must be accompanied by reestablishment of desirable forage plants. The need for brush management on rangeland is most severe in the southwestern United States (fig. 6-5).

- Reestablishment of vegetation. Over 28 million acres (7 percent) of nonfederal rangeland need range seeding to reestablish desirable vegetation. This acreage includes both abandoned cropland and severely depleted rangelands that cannot be expected to recover productive capacity in a reasonable time through management alone. Almost 11 million acres need seeding only; another 17 million need both seeding and brush control. Figure 6-6 shows the acres where reseeding is necessary.

- Erosion control. Properly managing the vegetation is the first line of defense against erosion on rangeland. On range in good or excellent condition, a vigorous stand of adapted native vegetation provides effective protection against severe winds and occasional torrential rainstorms. Erosion does not become visible on rangeland until the vegetation has been severely damaged, exposing bare soil.

Improving range condition reduces erosion. Table 6-2 shows the erosion reduction that could be achieved if all nonfederal rangeland were improved

Table 6-1.--Woody canopy cover on nonfederal rangeland, by canopy class

Canopy class (Percent cover)	1,000 acres	Percent
10	260,981.7	64
10-25	81,808.5	20
26-55	46,982.4	12
55	16,141.1	4

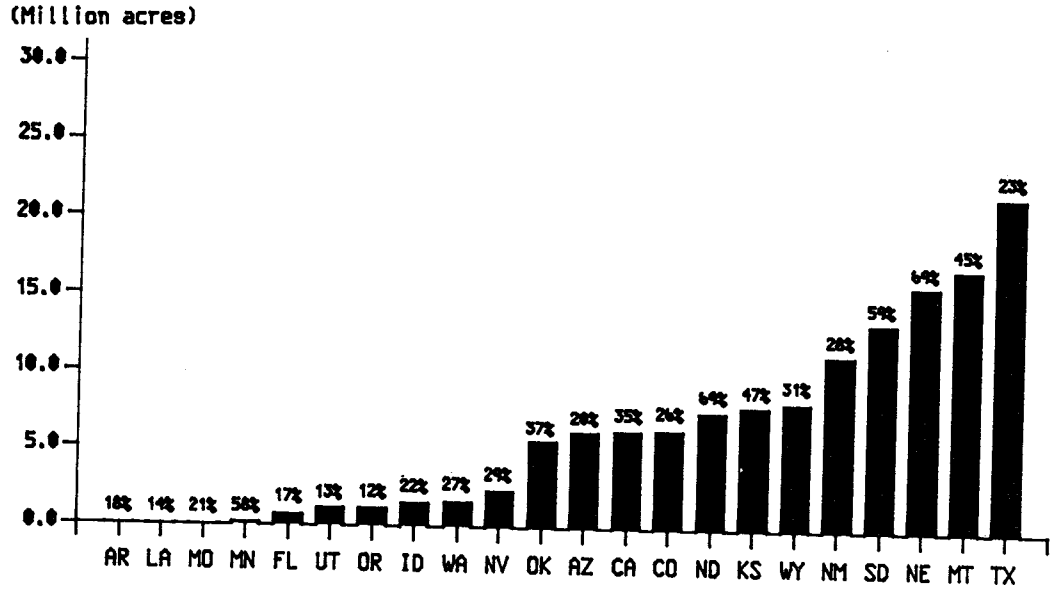


Figure 6-3.--Acres and percentage of nonfederal rangeland that was adequately managed in 1982, by state (1982 NRI).
See also appendix table A6-2.

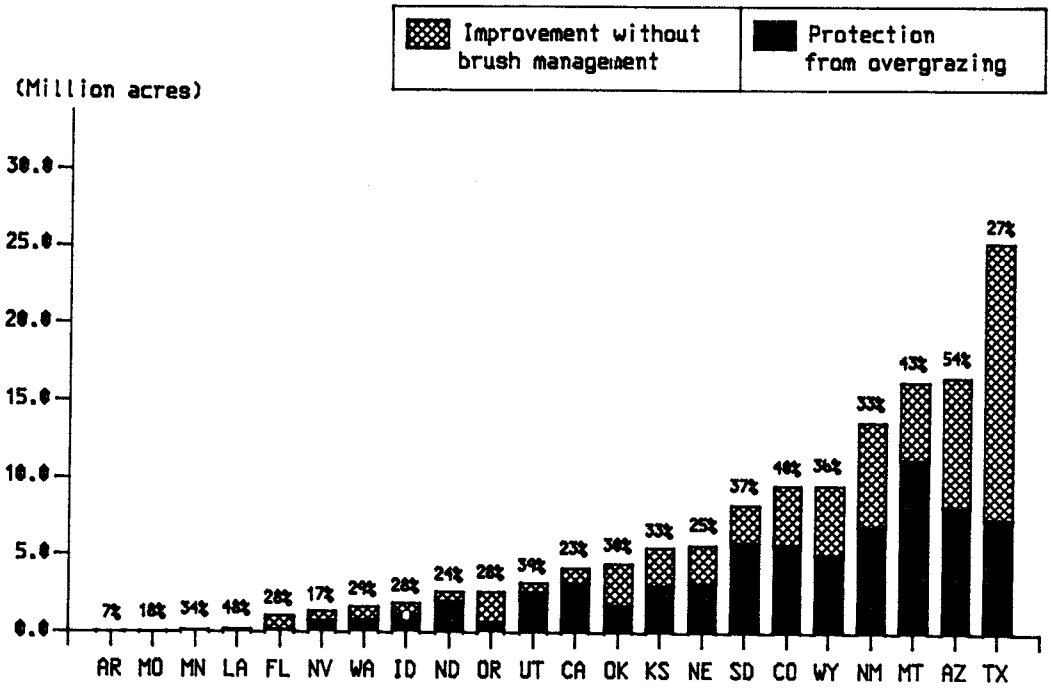


Figure 6-4.--Acres and percentage of nonfederal rangeland where improved grazing management would improve range condition, by state (1982 NRI).
See also appendix table A6-3.

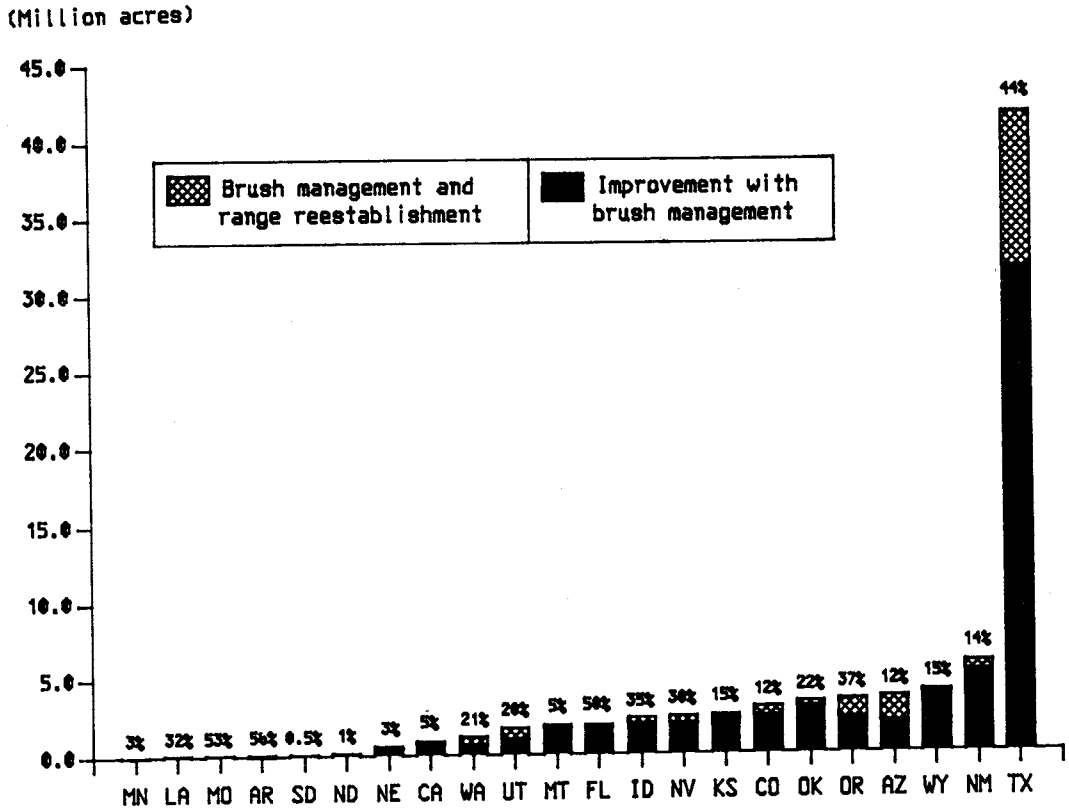


Figure 6-5.--Nonfederal rangeland where brush control is needed, by state (1982 NRI). See also appendix table A6-3.

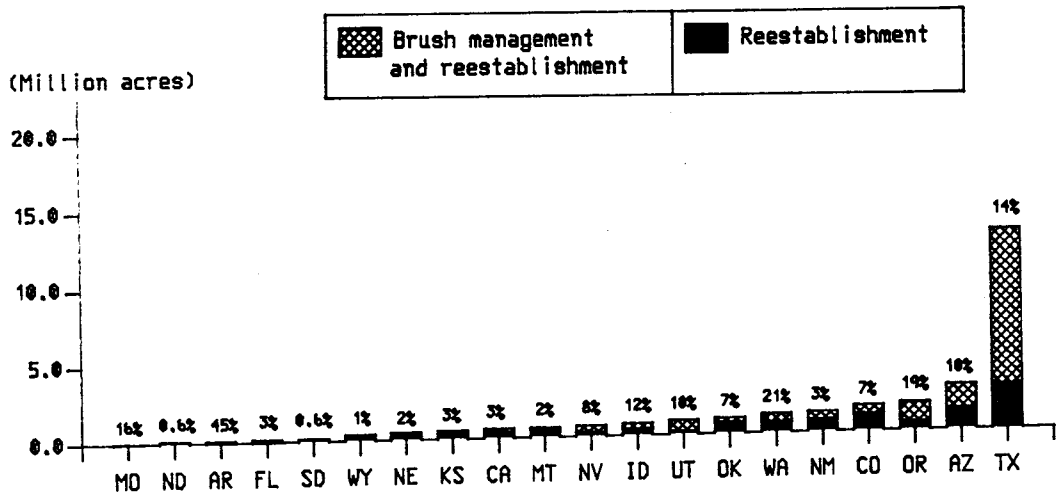
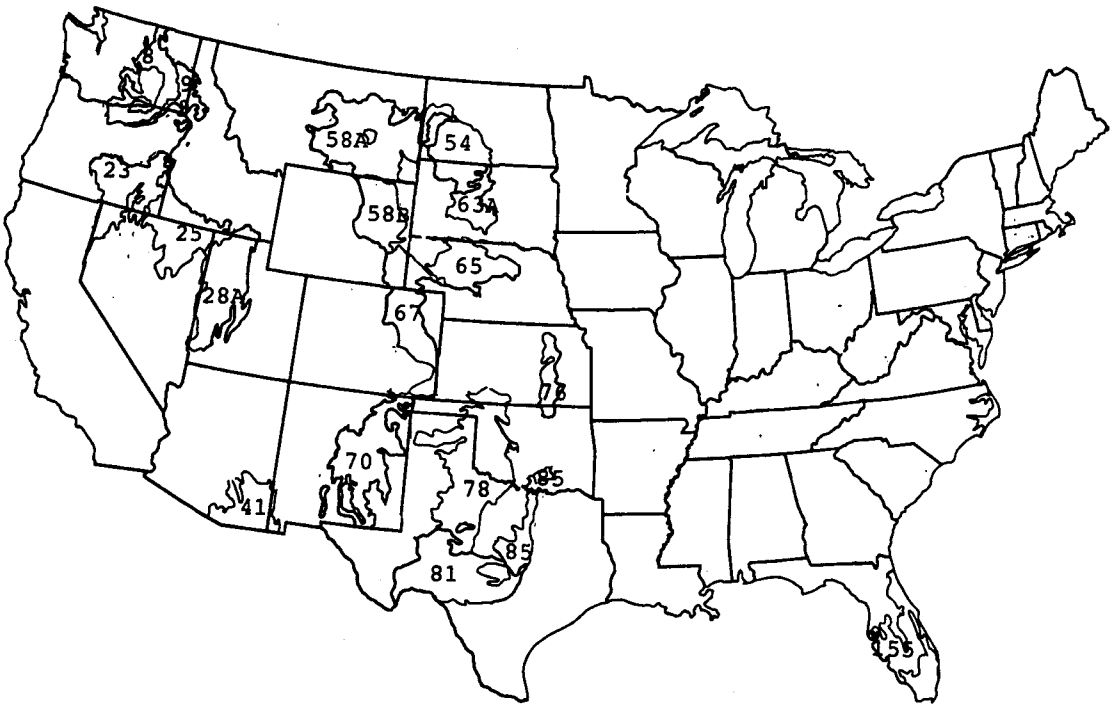


Figure 6-6.--Nonfederal rangeland where reestablishment of vegetation is needed to improve range condition, by state (1982 NRI). See also appendix table A6-3.

to good condition in several areas where range is an extensive land use. Twenty-eight percent of total sheet and rill and wind erosion in these areas could be eliminated by improving range condition. Potential improvement was estimated using the universal soil loss equation (USLE) and the wind erosion equation (WEQ). The reduction shown in the table is a conservative estimate of what could occur in reality.

Table 6-3 summarizes the erosion reduction that could be achieved by applying the specific practices needed to improve range condition in 18 selected major land resource areas. The percentages of erosion reduction shown in the table apply only to the acres needing the specific treatment and not to the entire area. For example, in Major Land Resource Area 78 (Central Rolling Red Plains), on the acres where the primary conservation need is erosion control, nearly 70 percent of the erosion could be prevented by applying erosion control measures. On the acres where the vegetation could be improved to satisfactory condition by improved management alone, applying grazing management would reduce the erosion by 65 percent. Applying brush management or vegetation reestablishment to the lands where those practices are the primary needs would reduce erosion on those acres by 71 percent and 80 percent respectively.



Major land resource areas (MLRA's) for which data are presented in tables 6-2 and 6-3. MLRA's are geographic areas having relatively homogeneous patterns of soil, climate, water resources, land use, and type of farming. There are 204 MLRA's in the nation.

Table 6-2.--Estimated percentage of erosion reduction achievable by improving all nonfederal rangeland in poor and fair condition to good condition, 18 selected major land resource areas

Major land resource area	Percentage reduction in Sheet and rill erosion 1/	Wind erosion 2/
8	9	65
9	20	0
23	0	100
25	18	20
28A	34	55
41	13	97
54	14	2
58A	7	100
58B	7	0
63A	15	100
65	16	62
67	18	82
70	12	68
76	36	0
78	34	24
81	53	16
85	53	47
155	0	0

1/ For sheet and rill erosion, it is assumed that if rangeland in fair condition were improved to good condition, the cover value (C factor of the USLE) would equal that of rangeland in good condition at that range site and major land resource area (MLRA). If the C factor recorded for good condition rangeland was lower than that for land in fair condition, the higher C value was used for the calculations because it is assumed that improving condition would not reduce the cover value.

2/ For wind erosion, it is assumed that improving the range condition class would result in the same rate of wind erosion as that estimated for other rangeland in the higher class in the area. Where erosion was not inversely related to condition class, however, it is also assumed that improving the condition would not result in more erosion but rather that the rate of erosion would remain unchanged.

Table 6-3.--Estimated percentage of erosion reduction achievable by applying primary conservation treatment needs on nonfederal rangeland, 18 selected MLRA's

MLRA	Primary conservation treatment need			
	Grazing management	Brush management	Vegetation reestablishment	Erosion control
	Percent erosion reduction			
8	73	74	83	89
9	68	0	56	58
23	40	46	56	50
25	15	17	58	87
28A	45	17	27	24
41	71	91	73	58
54	62	39	69	63
58A	70	50	90	78
58B	30	30	0	50
63A	68	68	90	61
65	73	90	94	85
67	39	60	93	55
70	53	71	83	71
76	50	54	81	47
78	64	71	80	70
81	70	74	81	81
85	75	79	83	77
155	0	8	58	84

The percent of erosion reduction indicated for each practice applies only to the acres needing that treatment and not to all rangeland in the major land resource area.

RANGE IMPROVEMENT: Does Conservation Pay?

Range management practices enhance the value of the range resource.--Range management practices protect range vegetation, prevent erosion, increase forage production, increase water yield and improve water quality, and improve wildlife habitat, esthetics, and recreation potential. The degree of improvement varies, depending on the characteristics of the site and its condition when the practice is applied. Some site-specific studies have attempted to quantify the multiple values resulting from improved range condition, conservation, and management. One study contracted by USDA has made an attempt to quantify the value of increased forage production across the western states.

Increased water yield.--The off-ranch benefits of conservation can be quite positive and dramatic, as in the case of the Rocky Creek watershed in western Texas. In the early 1960's, landowners on five ranches covering about one-half of the watershed began an extensive range improvement program. By 1970, springs dormant since the 1930's had begun flowing on all five ranches. The West Rocky Creek watershed, which makes up only 3 percent of the acreage, now supplies approximately 7 percent of the water supply of San Angelo, 20 miles away.

Besides brush control and range reseeding, the ranchers instituted a program of grazing management that would enhance the cover of grasses on the watershed. As a result, the range now is providing an estimated 2,000 to 2,500 pounds of forage per acre, mostly grasses. The grasses help to hold soil and water on the land, reducing sedimentation of downstream water supplies and allowing water to soak into the aquifer. Grasses also retard the re-invasion of brush, although the ranchers must also do periodic brush-control maintenance work.

All of the conservation work was done in a manner that would benefit whitetailed deer and turkey--both valuable for hunting.

Wildlife management.--Economic pressure is compelling many ranchers to seek ways of making their operations more profitable. Concurrently, outdoor recreation and tourism are rapidly becoming the largest growth industry in the Rocky Mountain states. In Colorado, one ranch in five has already diversified into tourism. Ranchers all over the West are realizing that wildlife and wildlife habitat can be an income-producing asset. The lease of hunting and fishing rights has been an established source of income in southwestern and south-central Texas since the 1930's. A recent study maintained that income from wildlife has been a major source of revenue on many Texas ranches during recent years. In 1984, gross income from hunting leases averaged over $4 per acre in the Rio Grande Plains and about $3.25 per acre in the Edwards Plateau. These areas are so attractive to deer and quail--and to hunters--that 12 percent of landowners found it worthwhile to provide supplementary feed for wildlife at a cost of $1,500 to $20,000 per year. The same study

made the point that in the Rocky Mountain states much of the land on lower slopes, valley floors, and foothills, which provides the necessary winter range for big game, is privately owned. These private lands are "critically important to wildlife populations and wildlife oriented recreation." 1/

Recreation.--A University of Wyoming research survey found that ranches and farms in Wyoming offered a remarkable variety of recreational pursuits to residents and out-of-state visitors. 2/ Besides hunting, fishing, and trapping, the farmers and ranchers responding to the survey mentioned swimming, horseback riding, hiking, camping, summer vacationing, cross-country skiing, snowmobiling, and special interests such as photography, hunting arrowheads and other artifacts, collecting rocks and fossils, and historical and geological tours. Ranchers' attitudes also varied widely. Hunting big game--deer, antelope, and elk--was the major activity for which fees were charged, but one-third of the ranchers allowed it without charge. Two-thirds made no charge for camping, fishing, or hunting waterfowl or upland game birds. Some ranchers, on the other hand, did not allow any hunting or access to their land. Those who charged the highest fees typically offered seasonal package plans to nonresidents, including lodging, meals, outfitting, and guides. Most ranchers said they would like various forms of educational assistance in setting up or improving their outdoor recreation enterprises.

Diversified land use.--On a ranch in western Nevada, proper management of the native vegetation produced a bonus by enhancing the beauty of the landscape. The scenic attraction of flourishing wildflowers, trees, and grass brought requests from city dwellers for vacation home tracts. Instead of selling land, the rancher chose to sell easements with certain stipulations that would not allow interference with the livestock operation. This arrangement has worked well for all concerned. The tenants have access to the entire ranch for outdoor activities and have been an asset to the rancher by providing volunteer help.

Range management practices that increase forage production can increase ranchers' profits.--USDA contracted a 17-state study that attempted to quantify the value of the relative effects of four conservation management systems on forage production. The four management systems are: (1) grazing management; (2) brush control and grazing management; (3) vegetative reestablishment and grazing management; and (4) brush control, vegetative reestablishment, and grazing management. On all ranch sizes, the analysis estimated that implementation of grazing management alone would yield the largest increase in net returns (fig. 6-7).

1/ Dwight E. Guynn and Don W. Steinbach, "Wildlife Values in Texas," Texas Agricultural Extension Service (1986), photocopy.
2/ Jeff Powell, Susan Bahr, and Kathy Green, "Wyoming Farm and Ranch Recreation Enterprises" (draft, 5 October 1986), photocopy.

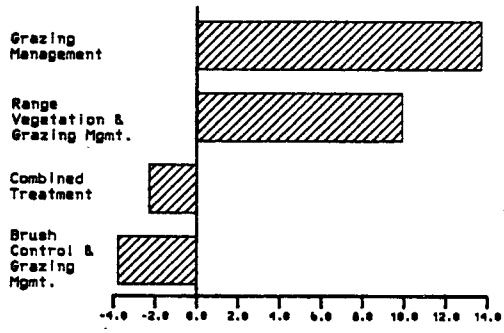
Although the analysis indicates conservation can increase profits, these increased gains in production and net income are not immediate. The same treatment has different production response times in different locations. For example, the response time for vegetative reestablishment (range reseeding) is 1 to 2 years in wetter sites and 2 to 3 years in drier sites. In some instances, the time required to recover application costs may take as many as 10 years.

Factors such as the rancher's management style, capital availability, and investment position influence the net returns that can be achieved by applying conservation practices. Because some geographical areas respond more quickly than others to improved management, the estimated increase in net return was larger where the dominant vegetation is tallgrass prairie (Kansas, Oklahoma, and Nebraska) than in areas that support mostly desert plant communities, such as Arizona, New Mexico, and western Texas.

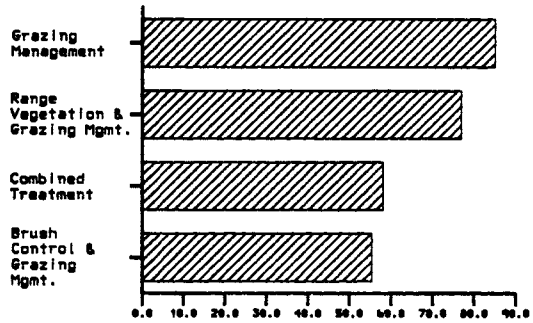
Rangeland conservation to improve forage can help a state's economy.--As part of the study of the effects of adoption of range management systems, the effects on the overall economies of each of the 17 western states were estimated. For each state, the economy was divided into 21 sectors, each related to ranching either directly or indirectly. In all states, grazing management was estimated to increase relative efficiency and production. The estimated degree of improvement varied from state to state; the average improvement achieved by adopting these improvements was about 14 percent.

This increase in efficiency suggests that adoption of grazing management by large numbers of ranchers would improve the economy of a state. However, individual ranchers would have to analyze their own situations to determine whether adoption of practices would be cost effective on their specific ranches.

Small ranches
(1 - 99 animals)



Medium ranches
(100 - 499 animals)



Large ranches
(More than 499 animals)

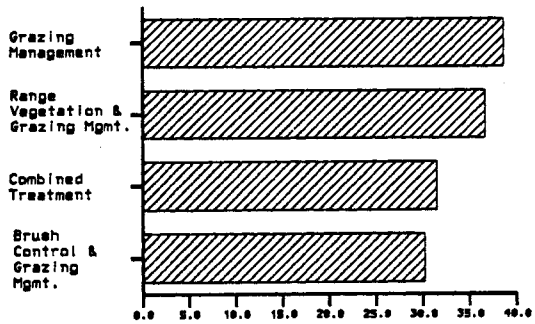


Figure 6-7. Estimated change in net return resulting from implementation of each of four conservation systems on small, medium, and large cattle ranches in western states.

The figure shows percent change in net returns from 1982 conditions. Results shown are averages based on typical ranch budgets developed to represent situations in each of the 17 western states. Ranch sizes are defined as: small, under 100 animals; medium, 100 - 499 animals; and large, more than 500 animals. The budget year represented is 1982, midway between the 1979-80 peak and the 1984-85 trough in cattle prices. The drop in land prices from the 1982 level is not fully reflected. The budgets include the ranch's livestock inventory, the organization and value of resources, cash and non-cash receipts, and costs. Net income was defined by returns to the operator for labor, management, and capital. A partial budgeting technique, which traces the effect of changing one factor, was used to analyze changes in costs and production that might result from implementing the management practices.

Water Management

In arid regions, crop production depends almost entirely on irrigation. Irrigated agriculture accounts for more than 40 percent of all freshwater withdrawals in the United States and consumes nearly three times as much water as all other uses combined. In subhumid and semiarid regions, agricultural production depends on water storage and distribution systems. Even in humid areas, droughts during the growing season are common and can significantly reduce yields.

Although localized or wide-scale water shortages of varying intensity and duration are occurring at times in most parts of the nation, most problems could be minimized with careful planning. Improved management of irrigation water, improved management of soil moisture, and increased storage to increase dependable supply can bring supply and demand into better balance. Some improvements are being implemented.

Farmers have increased their efficiency in using irrigation water; a national average of 47 percent of the water withdrawn from surface or ground sources for irrigation was consumed by the crop in 1985 as opposed to 41 percent in 1981.

On nonirrigated land, especially in areas of limited rainfall, farmers can make more water available for their crop by increasing infiltration and reducing runoff. Use of practices for soil conservation/soil moisture management can reduce erosion and increase net returns but must be monitored for possible effects on ground water quality.

Competition for water will intensify in the future if current trends continue. By 2030, four of the 18 water resources regions (Texas-Gulf, Rio Grande, Lower Colorado, and Great Basin) will not have sufficient water supplies, even in an average year, to meet nonagricultural needs and permit continued irrigation of the acreage currently developed for irrigation.

Projections of future developments conducted for this appraisal, however, suggest that, under all except the most extreme conditions, fewer acres will be irrigated and therefore less irrigation water will be needed in the future. Assuming "intermediate" rates of increase in demand and in crop yields and full implementation of the conservation provisions of the Food Security Act of 1985, slightly more than 30 million acres are projected to be irrigated in 2030, compared to 49 million in 1982. Assuming similar conditions in the absence of conservation efforts, fewer acres would be irrigated. Only at the highest levels of demand and slowest rates of increase in productivity studied are irrigated acres projected to increase. Under those assumptions 68 million acres would be irrigated.

WILL AGRICULTURE HAVE ENOUGH AFFORDABLE WATER?

Agriculture accounts for over 40 percent of all freshwater withdrawals in the United States (fig. 7-1). It consumptively uses 78 billion gallons per day--nearly three times as much as all other uses combined (fig. 7-2). Nevertheless, agriculture is the marginal offstream user of water resources. The net value of water used for irrigated agriculture is not high enough to compete with the values of water used for industrial or domestic purposes under free market conditions. Nonagricultural consumptive uses are expected to triple in the next 50 years. As these demands increase, water will be bid away from agriculture.

A comparison of water supply and water use data shows that water shortages of varying intensity and duration occur in many parts of the nation. Within the contiguous United States, 7.5 percent of the replenishable water supply is depleted. This percentage is expected to increase to 10.7 percent in the next 50 years, exclusive of any changes in agricultural water use. Depletion in humid regions is less than the national average, but in arid regions, the percentage is so high that it approaches the total replenishable supply. When U.S. Geological Survey personnel, in consultation with state and local officials, prepared state water-issue summaries in 1983, they found that the availability of surface water or ground water in adequate quantity is a concern in most states. Twenty-nine states cited temporary, drought-caused shortages of surface water supplies as a problem, and 17 states reported increasing competition for the developed supplies (those stored in reservoirs and administered via diversions and conveyance structures).

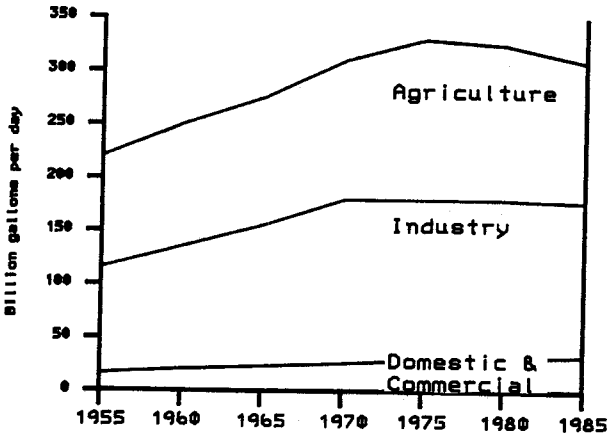


Figure 7-1.--Water withdrawals in the United States, by functional uses.

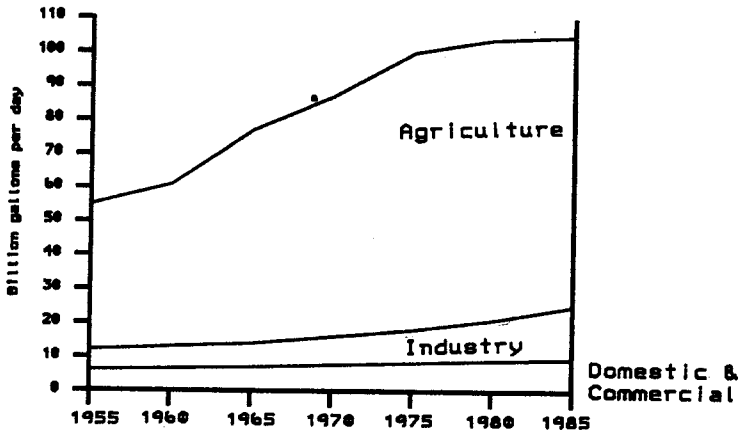


Figure 7-2.--Water consumption in the United States, by functional uses.

There is widespread concern that if developed supplies are not augmented by new reservoirs or conveyance structures, existing uses will be hampered by water shortages. Instream flow required for waste-load assimilation, fish and wildlife habitat, and navigation may not be available if predicted reductions in flow occur as a result of increased withdrawals. Appendix table A16-2 shows where streamflows fall short of requirements--that is, where problems exist and are likely to occur.

Figure 7-3 shows where water depletions are very large now or will be large before the turn of the century. Offstream uses deplete the Lower Colorado and Rio Grande so much that some forms of aquatic life once found in these regions have disappeared. In the Great Basin, some forms of aquatic life are dying out. Projected offstream uses in the Texas-Gulf cannot be met without continued rapid ground water overdraft, dewatered streams, or curtailed offstream water use activity. Flows diverted for offstream uses deplete streamflows by more than 70 percent in 16 of the 99 subregions in the contiguous United States.

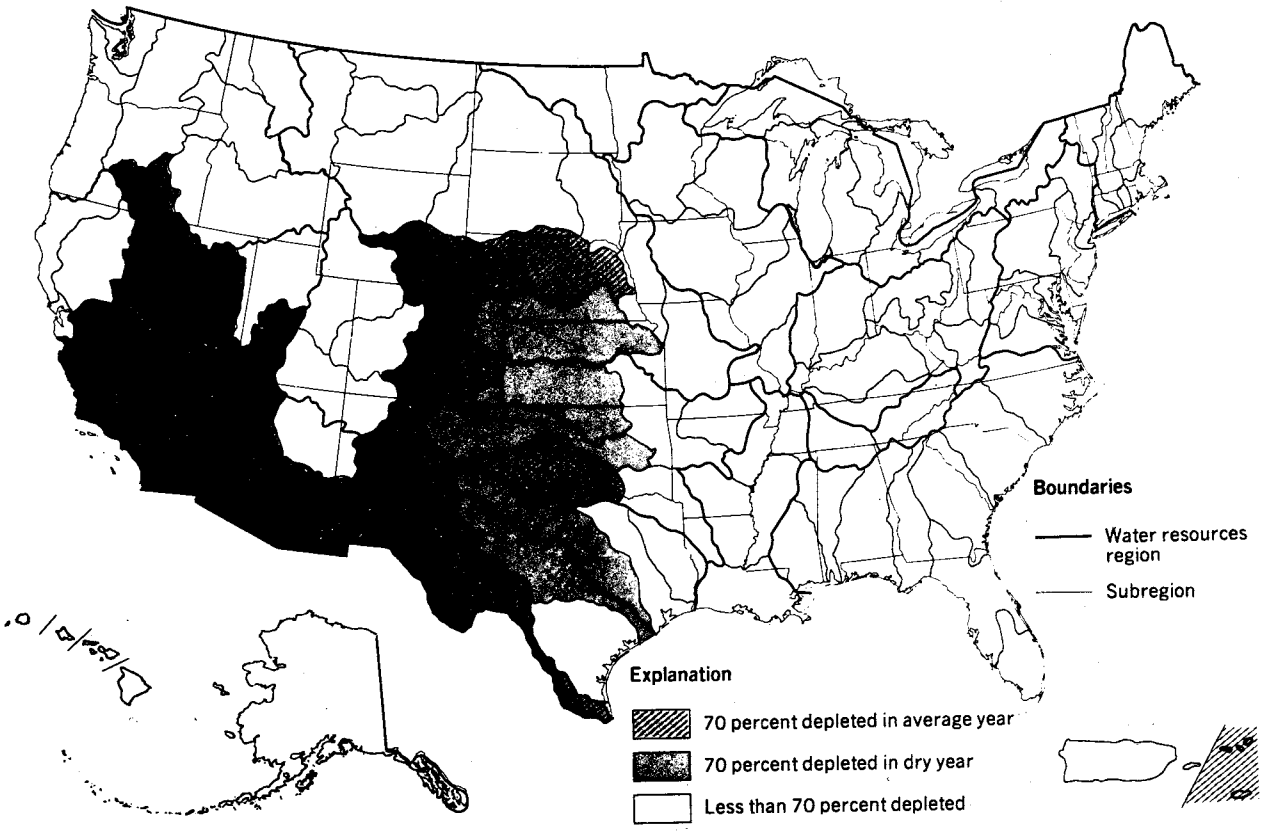


Figure 7-3.--Water depletion areas in the United States.

Many states are relying on ground water to meet most of their projected increases in water use, but ground water availability is an issue in 47 states. The most common problems of ground water availability are water-level declines caused by intensive pumping (35 states) or increasing competition for available ground water supplies (26 states). The ground water level inevitably falls in the vicinity of a well that is being pumped, but this drawdown does not necessarily mean that ground water supplies are being significantly depleted. The state water-issue summaries cited only those declines that are progressive or are extensive in area, that cause significant decreases in streamflow, or that are in conflict with state regulations (fig. 7-4).

Major areas of ground water decline are concentrated in the irrigation-dependent Southwest. Some declines have interstate ramifications because pumpage in one state can cause water-level declines in an adjacent state. Ground water mining--withdrawal at a rate that exceeds long-term natural recharge--and the resulting lowered water tables increase pumping lifts and costs and may contribute to land subsidence, diminished streamflows, and salt water intrusion into fresh water aquifers.

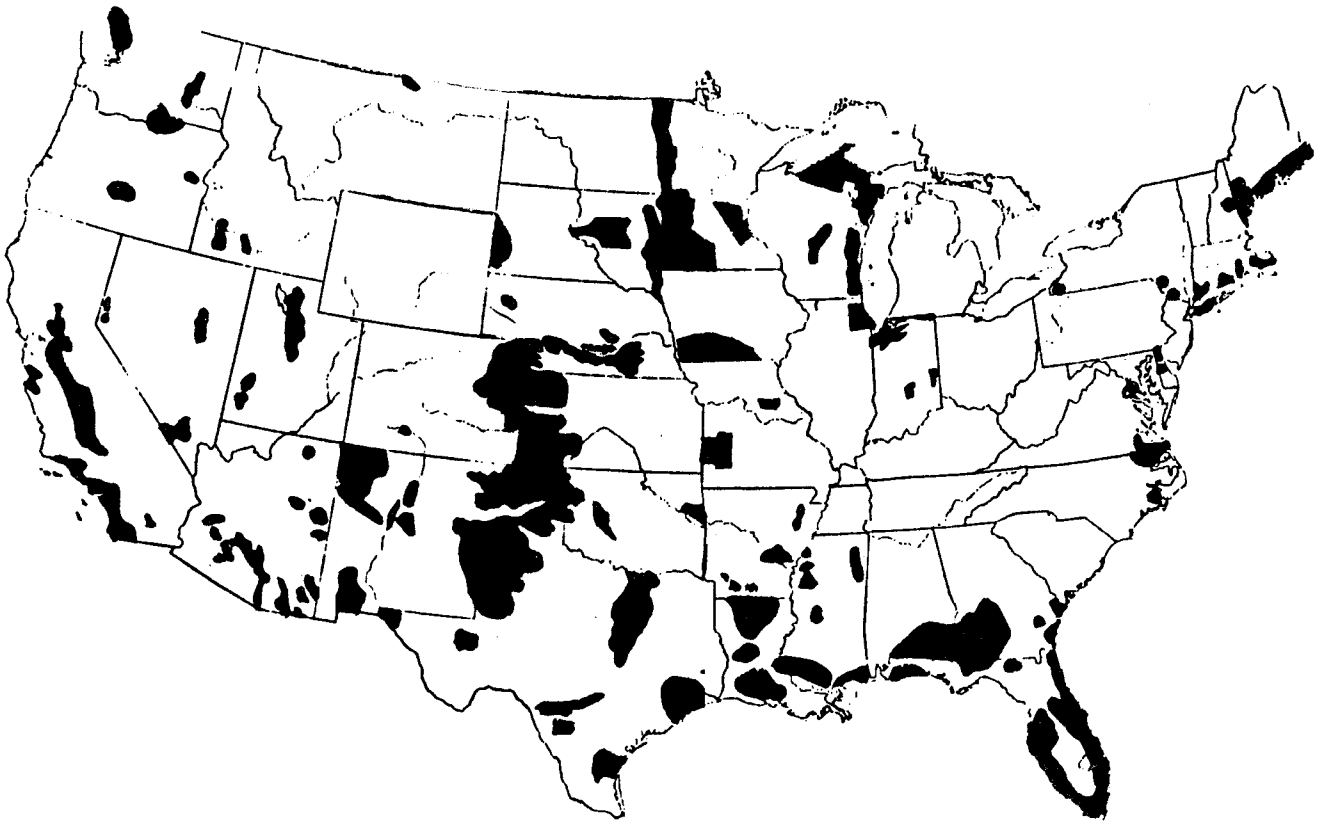


Figure 7-4.--Areas where ground water decline is of state or local concern.

What Causes Water Shortages?

Shortages are most likely to occur where water supplies are chronically scarce, precipitation is erratic, streamflows fluctuate widely, water requirements have sharp peaks or seasonal variations, and demands at current prices are equal to a large part of the supply. More than one of these conditions can and frequently does occur in the same area. These shortages result in inadequate water supplies for irrigation and other offstream uses, diminished streamflows for aquatic life and hydropower generation, and overdrafts of ground water.

Shortages resulting from scarce supplies are likely to be prevalent in areas that are underlain by aquifers yielding less than 50 gallons per minute per well and that have less than 1 inch of annual runoff (fig. 16-2). Generally, areas receiving less than 20 inches of precipitation a year have less than 1 inch of runoff (fig. 16-3).

Shortages resulting from wide fluctuations in supplies occur where precipitation varies during the year and from one year to the next. Fluctuations in supply also result from the normal distribution of monthly flows and the size of high and low monthly flows. Periods of abnormally low rainfall may last several weeks or longer in humid areas; long droughts may extend well beyond a growing season in arid and semiarid areas. Droughts exhaust the available soil moisture, empty reservoirs, deplete lakes and streams, and fail to recharge aquifers.

Shortages can result from fluctuations in demand. Each water use has its own water demand--the amount of water of acceptable quality needed at a particular location for use at a given time and a given price. Water demands can fluctuate widely. For example, livestock use and domestic use vary markedly during the day. Domestic use is lowest during the night and peaks at 8 a.m. Peak use for livestock operations occurs during feeding and cleanup periods and when animals come in from the field. Irrigation water is usually applied only immediately prior to and during the growing season, peaking in summer, which generally is the season of low streamflow. Demands for water and competition for limited supplies increase with population and economic growth.

Nearly two-thirds of the fresh water withdrawn from surface sources and subsurface aquifers returns to the water supply and is available for downstream use. The rest is consumed--lost to the atmosphere through evapotranspiration or incorporated into plant or animal tissue or manufactured products. Competition for water is the keenest where consumptive use is highest in proportion to the renewable supply. Table 7-1 shows an average ratio of 37.4 for the nine western water resources regions. In contrast, consumptive use in the nine eastern regions averages only 2.8 percent of the renewable supply.

A comparison of two water resources regions, Texas-Gulf and Tennessee (fig. 7-5), can help to clarify the range and complexity of the problems. Tennessee's average outflow is about 41 billion gallons per day in a normal water year, 36 in a dry year. Texas-Gulf's average outflow--for an area several times that of the Tennessee region--is 36 billion gallons per day in a normal year and only 19 in a dry year. As the charts show, the Texas-Gulf region's annual streamflow is far more erratic. However, the warm-temperate to subtropical climate not only accommodates many more kinds of crops than the cool-temperate Tennessee region, but allows farmers to harvest two or more crops a year from the same land. Crops (and livestock) use more water in warmer and less humid climates. For these reasons, agriculture in the Texas-Gulf region depends heavily on ground water to meet its year-round needs (as in California and Florida, despite the latter's generally abundant annual rainfall). As of 1982, resulting overdrafts and increased costs had led to a sharp drop in Texas' use of irrigation (table 7-3), even though streamflow in 1982 was above normal for both Texas-Gulf and Tennessee. Farther west, the water year was one of extraordinary abundance, especially in the Great Basin and California regions (see fig. 16-5). States in those areas reported only slight to moderate declines in irrigated acreage. The hydropower-producing Tennessee region makes little use of ground water, but it has the highest instream flow requirement in the East: 94 percent of average annual streamflow.

Table 7-1.--Average consumptive use and renewable water supply in western regions, 1985

Water resources region 1/	Total consumption 2/	Renewable supply	Ratio of consumption to renewable supply
	(million gallons per day)		(percent)
Missouri	21.3	61.5	34.6
Arkansas-White-Red	9.8	67.7	14.5
Texas-Gulf	10.4	35.6	29.2
Rio Grande	3.8	5.3	71.7
Upper Colorado	3.5	13.9	25.2
Lower Colorado	5.0	9.4	53.2
Great Basin	4.1	6.0	68.3
Pacific Northwest	15.6	268.5	5.8
California	23.0	68.1	33.8

1/ Shown in figure 16-2.
2/ Includes net evaporative losses.

HOW CAN WATER SUPPLIES BE USED MORE EFFECTIVELY?

There are two approaches for increasing the capabilities of our water supplies to meet demands:

- o Demand management--lowering water requirements,
- o Supply management--changing the quantity of water available.

Table 7-2 summarizes potential ways to conserve and supply water. Demand management (through improved irrigation water management and limited irrigation) and supply management (through ground water storage and soil moisture management) are discussed in detail in the following pages. New ideas and technologies are being developed in both fields.

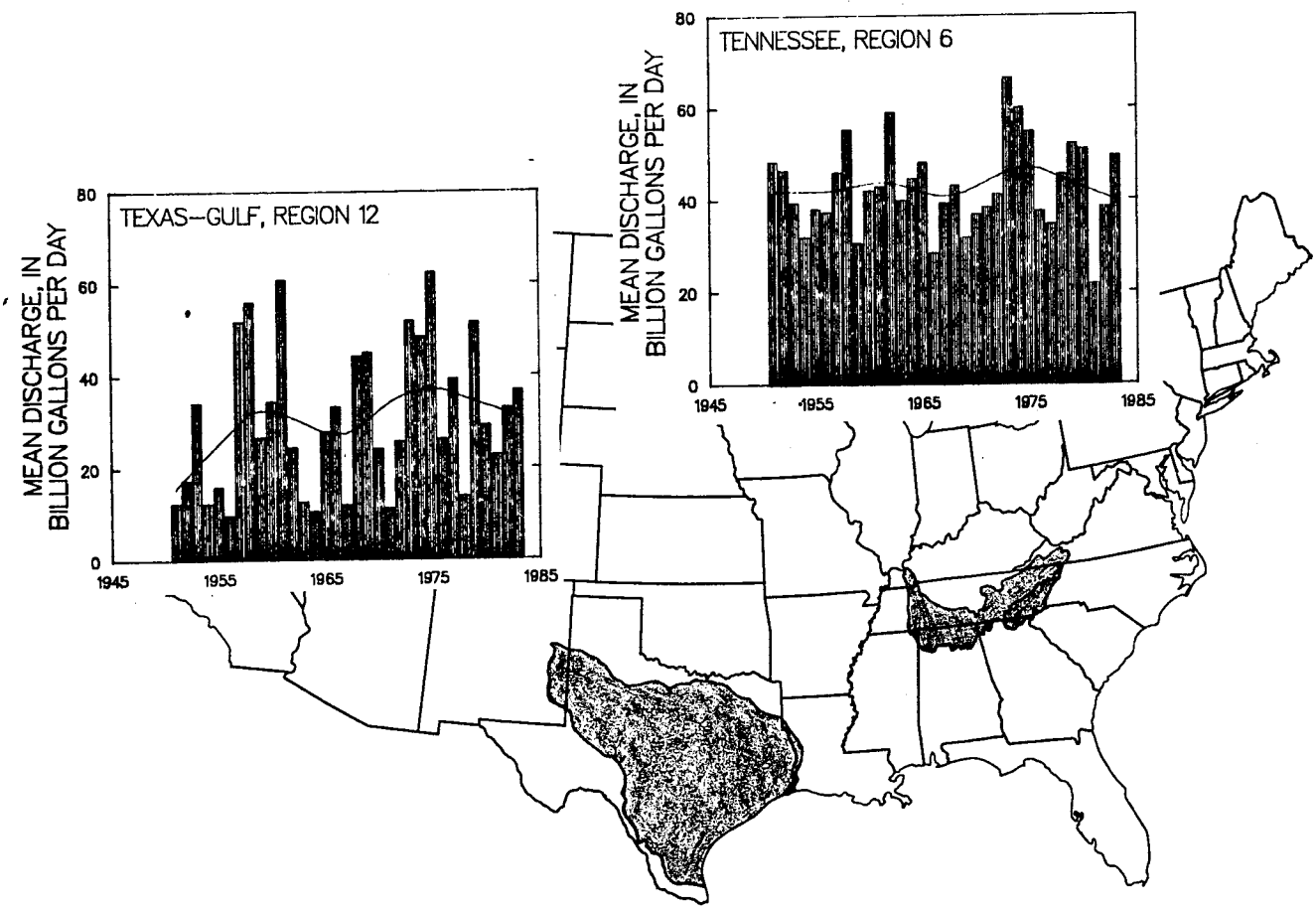


Figure 7-5.--Yearly streamflows, 1950-82, in the Texas-Gulf and Tennessee water resource regions (U.S. Geological Survey).

Table 7-2.--Potential ways to deal with water shortages

	DEMAND MANAGEMENT
Reduce Non-Beneficial Evapotranspiration	o Irrigation Water Management (IWM): Provide information on when, how much, and how to apply irrigation water. o Measures to Increase Irrigation Efficiencies: Install physical measures such as canal lining, piping, land leveling, control structures, improved and automated irrigation systems, etc. o Reservoir Evaporation Suppression: Use chemical films to impede escape of water molecules from the liquid to air. o Measures to Reduce Water Use by Phreatophytes and Other Non-Economic Vegetation: Clearing, thinning, etc.
Reduce Crop Water Requirements	o Limiting Acreage of Irrigated Crops: Convert irrigated cropland in water-short areas to dryland. o Decision-making Information and Models: Use data on water availability and other factors to recommend location, acreage, and type of plantings. o Crop Stress: Provide less than optimum water requirements (limited irrigation--alternate rows, etc.). o Crop Variety Selection: Select drought resistant strains that can withstand dry periods.
	SUPPLY MANAGEMENT
Store Runoff Water	o Surface Water-Ponds and Reservoirs: Catch and retain floodwater for release during droughts. o Groundwater Recharge: Convey or confine surplus runoff to recharge areas, to increase supply that can later be withdrawn.
Increase Water Yield	o Water Harvest: Construct impermeable surface to reduce infiltration and store runoff. o Vegetative Management: Manipulate vegetative cover to increase runoff.
Capture and Retain Precipitation	o Snow Management: Snow fences, selective cutting, etc., in high mountain areas and tall-grass strips, etc., on cropland to collect snow and retard snowmelt. o Soil Moisture Management: Cultural (conservation tillage) and mechanical (level terraces) practices to decrease evaporation and thereby increase moisture available in soil profile for plant growth. o Increase crop rooting depths to expand their reservoirs: by breaking hardpans, liming acid soils, and selecting crop species and varieties that root more deeply.
Add to Available Water Supply	o Inter- and Intrabasin Transfers: Divert water from areas with surplus water to water-short areas. o Use of moderately saline drainage water on soils suited to long-term use. o Renovation of wastewater effluents for agricultural production. o Transfer water from lower valued to higher valued crops or uses.

Manage Irrigation Water Efficiently

One of six objectives for USDA's National Soil and Water Conservation Program is to increase irrigation efficiencies. Irrigation efficiency is defined as the volume of applied water in the root zone used by the crop, expressed as a percentage of the volume of water pumped from the ground or diverted from a stream or other water source. The national average, which was estimated to be 41 percent in 1975, was estimated to be 47 percent in 1982--much higher than the figure projected in the 1980 RCA Appraisal.

According to the 1982 National Resources Inventory, an irrigation water management system is needed on 19 million acres--about 29 percent of all irrigable farmland--to control erosion, reduce water losses, synchronize water applications with crop needs, or correct excessive saline or alkali soil conditions.

In 1982, 14 percent of U.S. cropland was irrigated. Some irrigation is practiced in every region (fig. 7-6). Over 90 percent of the water consumed by irrigation is used in the chronically dry regions of the West (fig. 7-7).

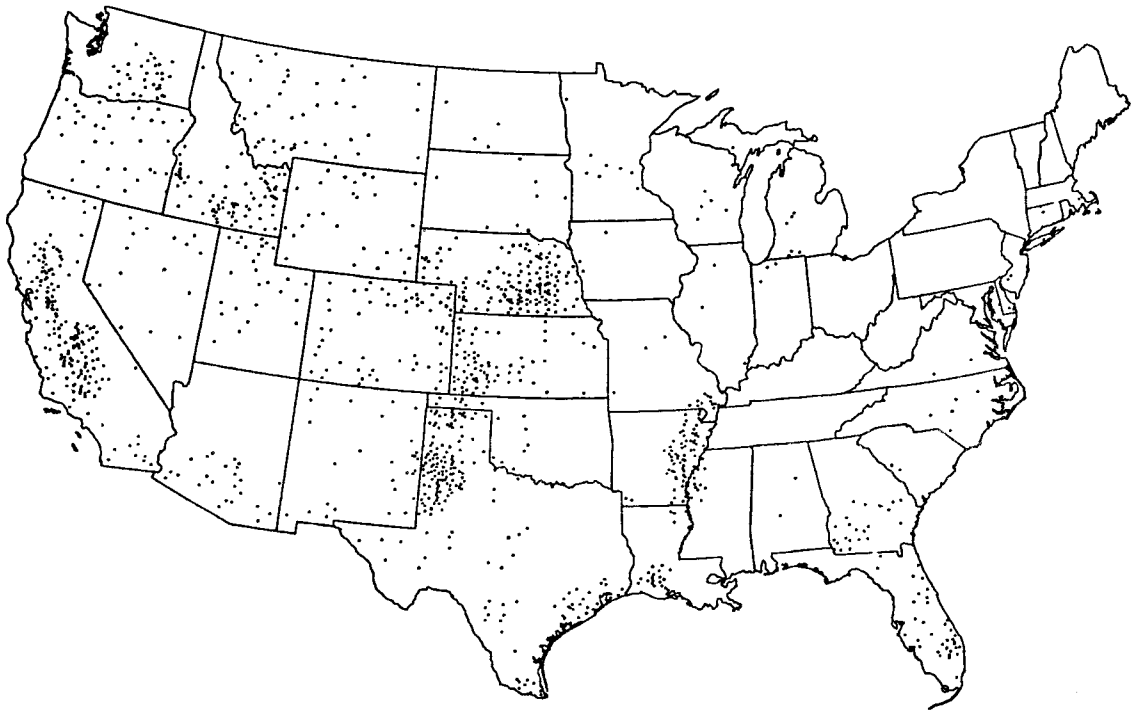


Figure 7-6.--Irrigated cropland (1982 NRI).
Each dot = 50,000 acres.

The rapid expansion of irrigated land and increase in irrigation water use has slowed during the last few years (fig. 7-8). In 1982, the Census of Agriculture reported a decline in acres irrigated for the first time. Fewer acres were irrigated because lowered water tables and higher energy costs have markedly increased the cost of pumping water and because lower commodity prices have made irrigation less profitable.

The three inventories in figure 7-8 give different figures on irrigated acreage because they use different definitions and survey methods. The Natural Resources Inventory uses SCS personnel to record information for statistically selected sample points. The information includes the number of acres irrigated during the survey year or any 2 of the previous 4 years. Thus the NRI indicates how much land has irrigation systems in place. The Census of Agriculture uses a questionnaire to ask farmers how many acres they irrigated during the census year. The Irrigation Journal's data are estimates made annually by state irrigation and water quantity specialists. Both the Census and the Journal inventory attempt to record the land actually irrigated rather than the acreage prepared for irrigation.

In 1978 and again in 1982, 14 states had over a million acres irrigated. Of these, Nebraska and Arkansas irrigated more acres in 1982 than in 1978; the other 12 states irrigated fewer (table 7-3).

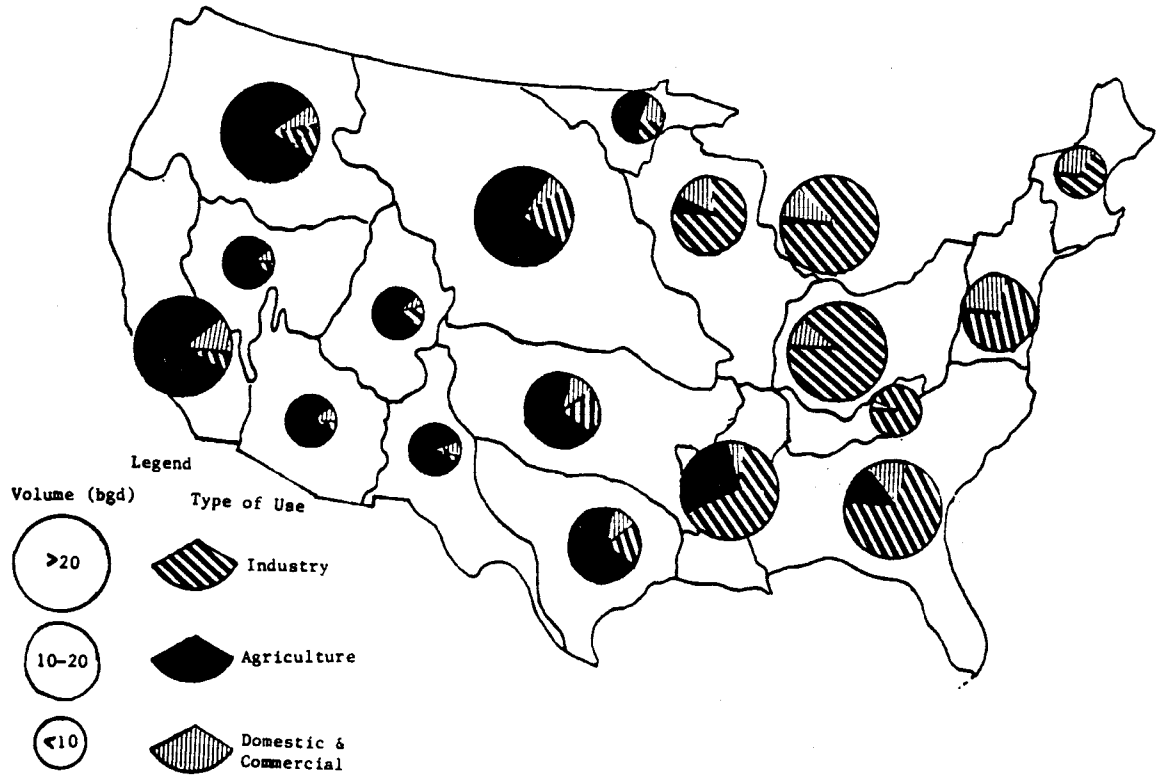


Figure 7-7.--Regional water withdrawals, by functional use.

Table 7-3.--Top 14 states (1982) and the number of acres irrigated, selected years from 1944 to 1982

State	Irrigated area					
	1944	1954	1964	1974	1978	1982
	1,000 acres					
California	4,952	7,048	7,599	7,749	8,505	8,461
Nebraska	632	1,171	2,169	3,967	5,683	6,038
Texas	1,320	4,707	6,385	6,594	6,947	5,573
Idaho	2,026	2,325	2,802	2,859	3,475	3,451
Colorado	2,699	2,263	2,690	2,874	3,431	3,193
Kansas	69	332	1,004	2,010	2,685	2,675
Arkansas	289	858	974	949	1,683	2,034
Montana	1,555	1,891	1,893	1,759	2,069	2,023
Oregon	1,129	1,490	1,608	1,561	1,880	1,809
Washington	520	778	1,150	1,309	1,639	1,638
Florida	222	428	1,217	1,559	1,980	1,584
Wyoming	1,354	1,263	1,571	1,460	1,661	1,565
Arizona	726	1,177	1,125	1,153	1,196	1,099
Utah	1,124	1,073	1,092	970	1,168	1,083
All other states	1,885	2,748	3,777	4,467	6,348	6,776
50 states, total	20,539	29,552	37,056	41,243	50,350	49,002

Source: 1978 and 1982 Census of Agriculture.

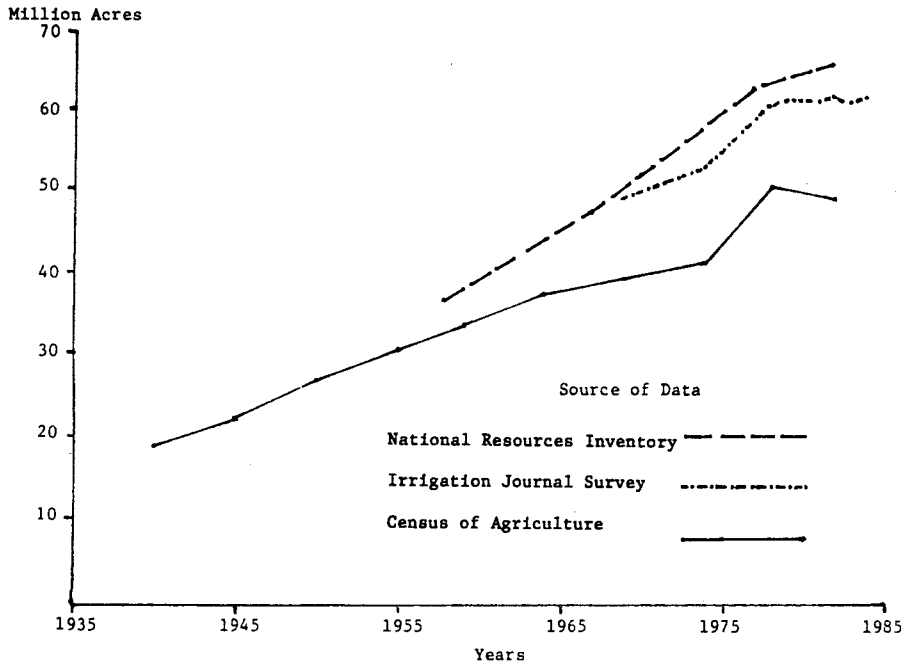


Figure 7-8.--Amount of irrigated land, 1935-1982.

Irrigation is increasing in the East. A half century ago, nearly all irrigated acreage was in the 17 western states. By 1969, 4.3 of 39.1 million acres irrigated (11 percent) were in the eastern states. In 1982, 7.7 of 49 million acres irrigated (15.8 percent) were in the eastern states. Arkansas and Florida together accounted for over 3.6 million acres--almost half of the eastern total. The Pacific Region had the greatest increase relative to total cropland--9.3 percent during the 13-year period (fig. 7-9).

The rate of change in acres irrigated has been greatest in the Lake States and Corn Belt, where three to four times more land is irrigated now than in 1969. Acres irrigated have decreased in the Southern Plains.

At the turn of the century, more than 90 percent of irrigation water came from project facilities. Emphasis on project development began to weaken in the late 1930's. Interest was rekindled in the mid-1950's to 1960's, but the acceleration has declined in recent years. Now, only about 40 percent of the irrigated farmland receives water from project facilities. Federal entities, primarily the Bureau of Reclamation, constructed about half of these projects. The federal share of all irrigation investment has dropped from 40 percent in the 1950's to less than 20 percent in the 1970's (table 7-4).

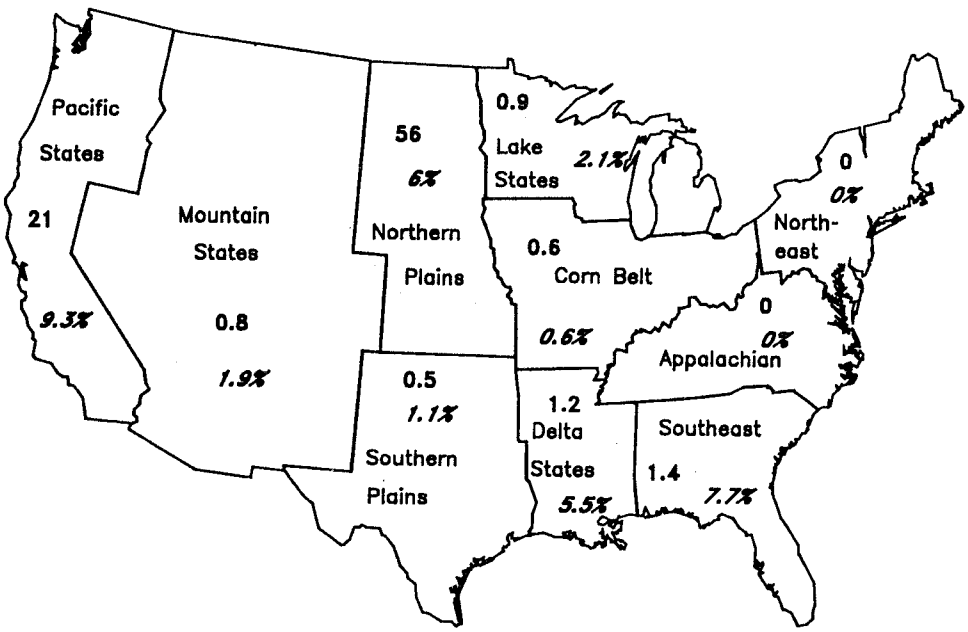


Figure 7-9.--Changes in irrigated land relative to cropland, 1969-1982, by farming region (millions of acres and percentage of increase).

In recent years, the tight farm economy and higher pumping costs have checked the increase of irrigated acreage in water-short areas and reinforced the incentive to improve irrigation efficiencies.

Although farmers irrigated nearly 20 percent more land in 1982 than in 1975, they used only about the same amount of water. Irrigation water use per acre was lower in 1982 because:

- Irrigated farming has shifted in part from arid to more humid regions, where precipitation fills much of the crops' water requirements.
- Conveyance losses have been reduced by increased use of lined canals and onfarm water sources.
- Onfarm distribution and application systems have been improved or new ones introduced--for example, laser-beam field leveling, surge-pulse irrigation, and drip systems.
- Irrigation water management is more sophisticated, making use of computer-aided scheduling, risk acceptance, and cost-reduction objectives.

The main components of irrigation efficiency are:

- off-farm conveyance--from the water diversion point to the farm,
- on-farm distribution--from the farm headgate or farm irrigation well to the application facility (sprinkler line, border strip, or group of furrows),
- application--from the application facility to uptake by the crop and to soil storage in the root zone, and
- management--the human element that affects the operation and use of the irrigation system.

Off-farm conveyance efficiency is defined as the volume of water delivered to the farm, expressed as a percentage of the volume of water pumped from the ground or diverted from a stream or other water source. Irrigation districts and other suppliers of irrigation water have increased the

Table 7-4.--Gross annual irrigation investment, 1951-80

Period	Nonfederal facilities		Federal investment	Total investment
	On-farm	Project		
	(Million 1977 dollars)			
1951-1955	353	53	258	664
1956-1960	350	39	268	657
1961-1965	394	101	313	808
1966-1970	559	110	254	923
1971-1975	688	26	238	952
1976-1980	1,240	21	148	1,409

Source: Pavelis.

average conveyance system efficiency from 78 percent in 1975 to an estimated 81 percent in 1982, in part by coordinating the amount and timing of water deliveries with onfarm irrigation needs and by flow measurements, record keeping, etc.

Onfarm distribution and application efficiency is defined as the volume of applied water in the root zone that is used by the crop, expressed as a percentage of the volume of water delivered to the farm. Irrigators have improved onfarm efficiencies from 53 percent in 1975 to 59 percent in 1982 by adjusting to limiting physical factors and by effective water management. Water measurement devices, ditch maintenance, location and alignment of ditches, and lining of ditches affect onfarm delivery efficiencies (fig. 7-10). Land shaping and the selection and design of an application method suitable for the soils and slopes improve application efficiencies.

Table 7-5 shows irrigation efficiencies for the acreage irrigated in the nation in 1982, by water source and application method. Table 7-6 lists potential efficiencies of specific application methods. Appendix table A16-3 lists, for each water resource region, the acres irrigated, irrigation efficiencies, and water use in 1982.

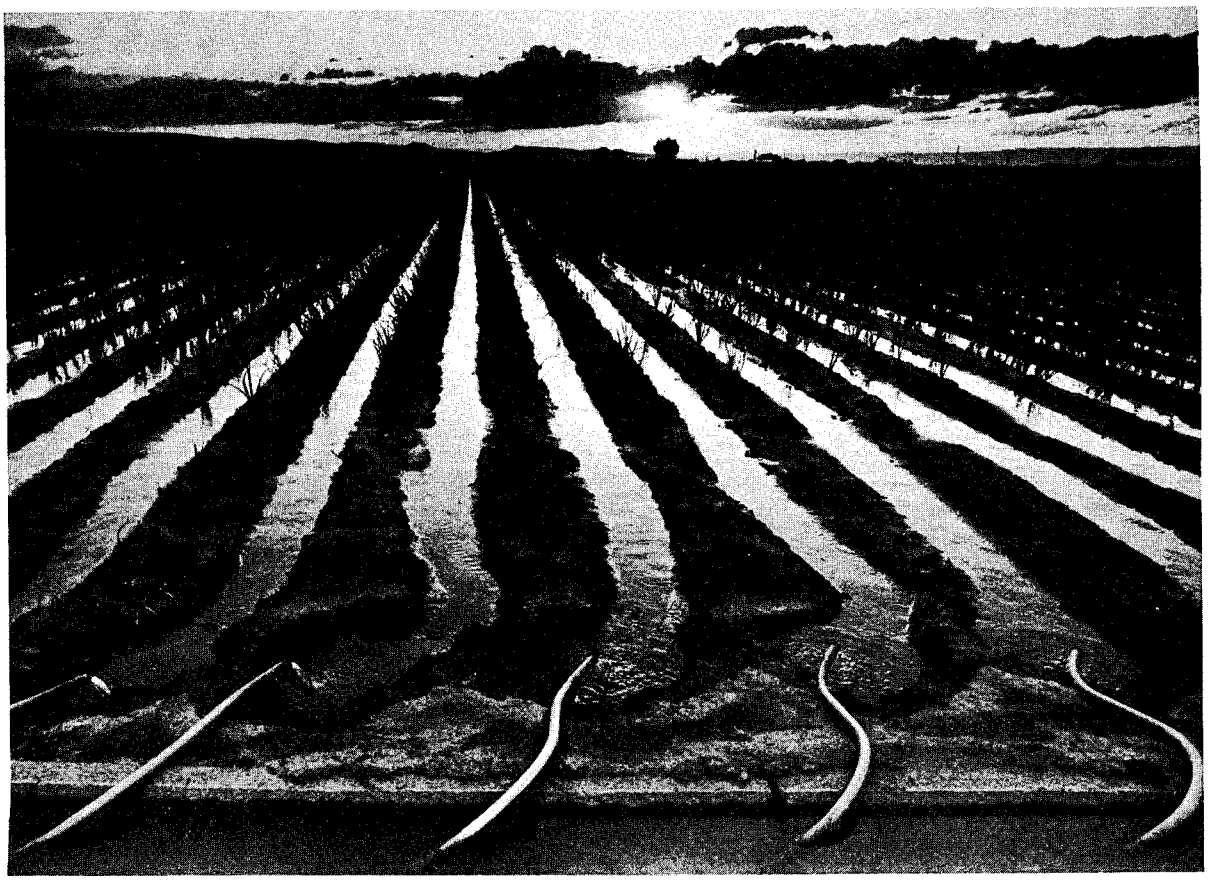


Figure 7-10.--Siphon irrigation from a concrete-lined ditch, on a field of onions in Colorado's Grand Valley.

Table 7-5.--Irrigated cropland (1982) and estimated efficiencies

Irrigation water source	Acreage irrigated by		Total	Efficiencies		
				Conveyance	Application	
	Pressure	Gravity			Pressure	Gravity
	(million acres)			(percent)		
Ground water	15.1	13.5	28.6 1/	89	59	58
Surface water	6.5	13.9	20.4 2/	73		

1/ Includes 4.6 million acres irrigated from off-farm irrigation wells.
2/ Includes 6 million acres irrigated from onfarm surface sources.

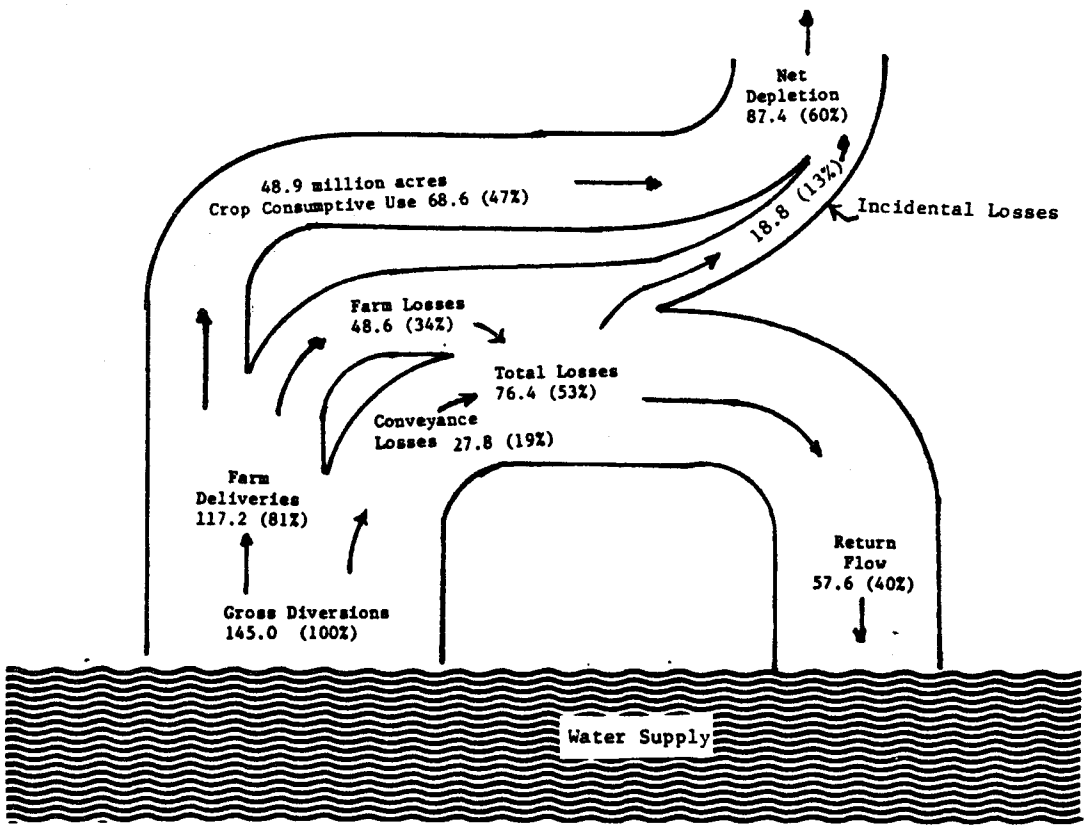
Table 7-6.--Potential efficiencies and reported use (by acreage) of application methods

Gravity methods	Potential efficiency 1/	Acres 2/	Pressure methods	Potential efficiency	Acres 2/
	(percent)	(million)		(percent)	(million)
Flood		9.0	Sprinkle		20.6
Level Border	90		Center Pivot	82	9.4
Graded	80		Solid Set	77	9.4
Guide Border	70		Wheel/Handline	73	6.3
Contour Ditch	60		Other: gun, etc.	65	3.7
Contour Levee	70				
Flood	60				
Furrow		18.0	Drip Trickle		1.0
(water delivered via gated pipe and open-ditch siphon tubes)			Continuous Tape	90	1.0
			Point Source Emitters	90	
Graded Furrow	75		Spray Emitters	85	
Corrugations	80				
Subsurface	75	0.4			

1/ Based on USDA, SCS, 1-85, Water Conservation Effects of Land Treatment and Irrigation, unpublished.
2/ Based on US Department of Commerce, Bureau of Census, 12-85, 1984, Farm and Ranch Irrigation Survey preliminary reports; and USDA, SCS, 1982 National Resources Inventory.

The human element affects both off-farm and onfarm irrigation efficiencies. Irrigators can improve efficiencies by scheduling use of water, timing the applications, and applying correct amounts of water. Irrigation scheduling services and other technical assistance can aid in making the best use of irrigation water supplies. Irrigators may not achieve potential efficiencies because of physical factors--for example, soil intake rates and water-holding capacities may vary within a field, or the field slope-length relationship may be unfavorable--or because irrigation is used for leaching and other purposes unrelated to crop water requirements. Water conservation may be affected by institutional and social factors including water laws or court decrees, water prices, environmental conflicts, financial capabilities, and social attitudes toward land use.

Not all water "lost" because of inefficient conveyance and distribution is really lost. Most of the diverted water not used by the intended crops is returned to the stream system to become available somewhere downstream. Some of the return is overland; the remainder returns through underground flow.



(million acre-feet--percent of diversions)

Figure 7-11.--Irrigation water budget for the United States and Caribbean--1985 average year.

The portion of the water taken for irrigation that neither produces the intended crops nor returns to the river basin water system is called "incidental loss". Nationally, the average incidental loss of irrigation water is about 13 percent of the diverted flow. As a practical matter, very little of the incidental losses can be prevented within existing physical and economic limitations.

Practice Limited Irrigation

Limited irrigation refers to a moisture management strategy that integrates irrigation water with moisture from rainfall. The strategy is to apply limited amounts of irrigation water to achieve the greatest return per unit of water. The strategy includes using crops that transpire less water, changing the cropping system to match periods of high crop use with expected rainfall and carryover soil moisture, and letting the soil dry to near the wilting point before applying irrigation water. This last technique allows more capillary water to rise into the root zone and more rainwater to soak into the ground. Some farmers are changing their farm operations and adopting new conservation practices so that they can take full advantage of rainfall and use less irrigation water. Limiting irrigation water may, however, result in below-maximum yields.

Irrigation water can be conserved by planting drought-tolerant crops and cultivars that have the ability to recover from stress, and by adding the irrigation water only when it is needed. Technologies include selecting crops whose critical growth periods coincide with patterns of highest rainfall, using different plant populations and spacings (such as super-thick sorghum), retaining cover crops to use available moisture in the soil profile, using no-till or conservation tillage, leveling land, and placing small dikes in irrigation furrows to capture and hold rainfall.

Irrigation and soil salinization.--Irrigation tends to increase salinity in three ways as water moves downward through a river basin, by:

- accelerating the leaching of salts through irrigated soils, subsoils, and geologic formations in upstream parts of watersheds and river basins;
- inducing the erosion and transport of salty sediments (this problem is much more significant for natural runoff from non-irrigated lands than for tailwater runoff from irrigated areas--clear surface water running off a moderately saline soil picks up very little salt); and
- concentrating salts in surface water and ground water when part of the irrigation water is used by plants or evaporates from wet soils or water surfaces.

In many places, improved control of irrigation water can reduce downstream water salinity by reducing the rate at which the salts are transported. Options include canal and ditch lining to reduce seepage through salty formations, limiting irrigation application rates, and reducing irrigation-related erosion from salty soils. Because such practices reduce the rate at which salts are leached from the upstream soils or formations through which the water passes, they can prolong, or even increase, the salinity of the soils.

Most irrigated soils in arid and semiarid areas are probably less saline now than they were when irrigation was initiated. However, salts tend to accumulate where drainage is limited. This happens either where insufficient water is available to move the salts through the root zone or where the soil becomes overwet because water cannot flow out as rapidly as it flows into a site. Applying additional irrigation water where the first condition exists may reduce soil salinity (in the ground, at seeps, or in surface waters downstream). Applying irrigation water in the second case usually just adds to the salt loading and increases both soil and water salinity at or near the site.

Usually the most effective treatment for excessive soil salinity is to improve drainage so that effective leaching can occur. Case examples can help to illustrate the various soil salinity conditions.

The available water of the Rio Grande River in western Texas is so completely appropriated that there is almost no natural outflow except in the wettest years. This river basin has the highest proportion--81 percent--of its cropland and pastureland affected by salinity or high sodium ion concentrations (sodicity). As water uses in the basin have increased, soil salinity has become more concentrated in those areas having limited soil leaching or drainage restrictions and the total available streamflow to the lower basin has decreased. A salt balance study of the basin reveals that considerably less salt is being transported past Fort Quitman than flows into the lower basin past El Paso. Salinity problems are aggravated by salt water intrusions from deep saline aquifers that have been penetrated by wells drilled for oil and gas development. An increase in groundwater pumping for irrigation in recent years also

may be affecting salt concentrations in the basin. Local landowners may deal with salinity in this area by concentrating more water on less land to improve soil leaching, improving drainage of waterlogged soils, planting salt-tolerant crops, and other practices. These do not represent long-term solutions; salinization of soils and water in this basin will tend to increase over time.

In Kings County, California, (USDA SCS, 1984) irrigation water is being applied in an area where drainage outflow is restricted. The situation is somewhat unique because the drainage limitation is as much an institutional as a physical problem. State law restricts the discharge of saline drainage waters and a drain that was planned to discharge from this area into the San Francisco Bay has never been built. Selenium concentrations are so high in the county's Kesterson Reservoir area (a terminal pond into which agricultural drainage has been discharged) that the U.S. Department of the Interior has forced the closing of discharges into the site. The lack of drainage outlets so limits drainage that pumping water into evaporation ponds seems to be the only feasible, though temporary, solution. Improving irrigation water management in this area without the proper drainage is only a temporary solution for some farmers. If drainage to the sea is not allowed, a major part of Kings County could be forced out of production within the next decade.

The Imperial and Coachella Valleys in southern California (Kaddah et al., 1976; Bower et al., 1969) provide an interesting example of soil salinity and the effects of drainage. Irrigation was started in the Imperial Valley in 1901 by importing water from the Colorado River. By 1975 the irrigated area was about 440,000 acres. Soil salinity was increasing until major drains were installed in the 1960's. Drainage has been installed on about 88 percent of the irrigated area. Continued irrigation is decreasing the salinity in most soils in spite of the high salt content of the Colorado River water. Downstream, however, the Salton Sea is becoming more saline.

Most of the water used in the Wellton-Mohawk basin of southwestern Arizona also comes from the Colorado River (Wellton-Mohawk et al, 1982). Soil salinity in this basin was increasing until pump drains were installed. The discharge of these drains has been the subject of international controversy. A treaty now limits the amount of salts that are to be delivered to Mexico. A desalinization plant is proposed to reduce the salinity of water delivered to Mexico. In recent years, there has been a concentrated effort to improve irrigation water management. This effort has been very successful in reducing the amount of water delivered to the drains as well as the total salt load. However, an examination of the trend lines in salinity indicates that this approach has now accomplished about all that can be done to reduce downstream salinity without allowing salts to build up in the basin's soils and underground formations or without reducing the irrigated area.

Use Productive Wet Soils

Excess water is the dominant hazard or limitation on 309.3 million acres of nonfederal land in the United States. Of this, 233 million acres are used for agriculture. These soils, which are affected by poor soil drainage, wetness, seasonally high water tables, or overflow, are classified as "w" subclass (table A5-11). Only one-third of the "w" soils are identified as wetlands. Wetlands are discussed in more detail in the wildlife habitat chapter.

About 46 percent (107 million acres) of the "w" soils used for agriculture are cropped. Wet soils make good cropland when drained because they are generally highly fertile, can be cropped continuously, and are level.

The USDA Economic Research Service (ERS) estimates that about 150 million acres have been drained at least once since 1855 and that 100 million acres of wet soils had adequate drainage in 1985. About 65 percent of the land is drained by surface features only and 35 percent by a combination of subsurface and surface measures. About 65 percent of the farm area drained is served by outlets or other disposal facilities installed by drainage districts or other multipurpose organizations.

In the 1982 National Resources Inventory, USDA identified about 24 million acres of nonirrigated cropland and 2.6 million acres of irrigated cropland where drainage is the main action that could be taken to enhance productivity. In addition, there are 2.3 million acres where wetness is a secondary problem.

Aging drainage systems need repair.--The estimates of cropland area needing drainage include some areas where drainage systems were installed many years ago but are no longer effective. The average life of an open ditch system is probably less than 20 years and of an underground system, less than 30 years. To maintain drainage systems on acreage already drained, an average of 4 to 5 percent of the existing systems will need to be replaced each year.

Nearly 60 percent of the present area drained has been drained since 1945. Nearly 40 percent has been drained since 1960. The replacement rate has been much less than 4 or 5 percent. For the next 10 or 20 years, replacements may have to be much higher than 5 percent annually for the presently drained area to remain productive. ERS estimates that as of 1985, 55 percent of all expenditures by drainage organizations had been for maintenance and replacement. ERS did not estimate maintenance expenditures by individual landowners.

Environmental effects of draining cropland vary.--The environmental effects of draining cropland vary widely and depend greatly on the design of the drainage systems. Further, the short-term effects may be adverse but the long-term effects favorable. Such could be the case when dealing with associated salinity problems at a site.

It is often possible to design features in drainage systems that provide nesting, resting, and feeding areas along the beds and banks of open drains. Improved crop yields can enhance the possibilities of leaving crop residue for wildlife use. Flows from underground drains can supply cool water for instream flows during dry periods or improved flows of relatively warm water during the winter.

However, adverse effects are just as possible. Replacing open drains with subsurface drains can eliminate areas of wildlife habitat. Drains can be stopped or pumped back during dry seasons to provide subsurface irrigation. Draining small wetland areas to reduce farm operating expenses reduces the quality and quantity of nesting and resting areas for upland wildlife.

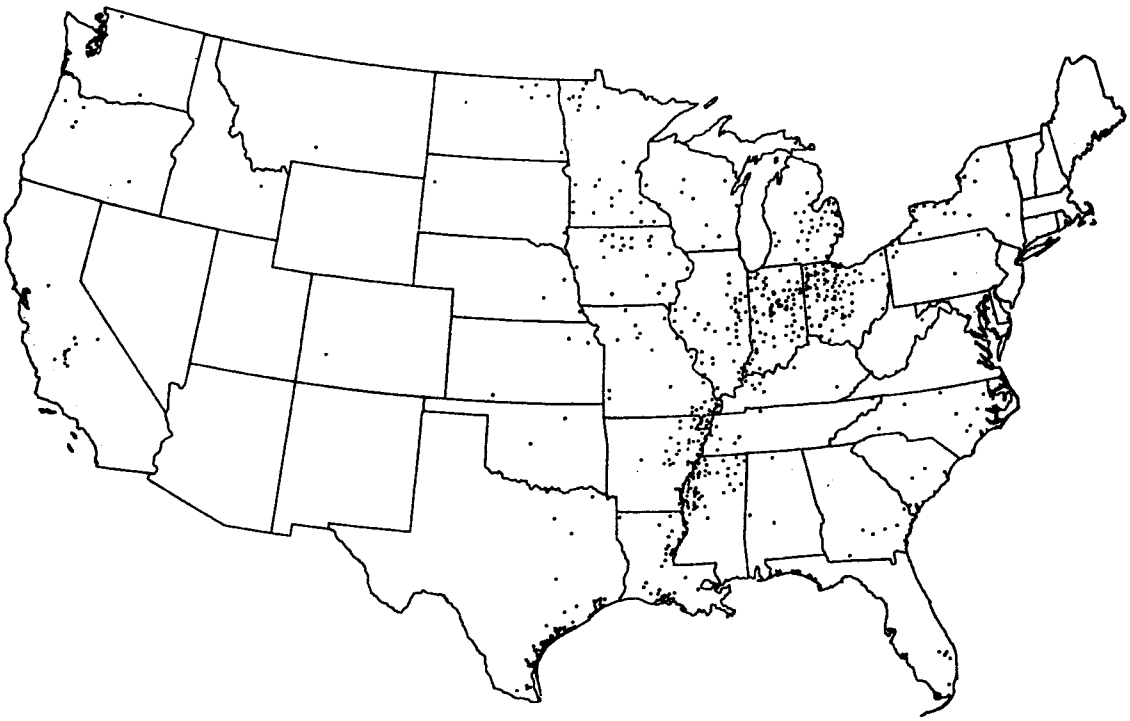


Figure 7-13.--Cropland where drainage is the major management improvement needed to enhance productivity (1982 NRI).
Each dot = 50,000 acres.
See appendix table A7-1 for data on cropland and pastureland needing drainage, by state.

Landowners should consider the effect on wildlife as well as on crop productivity when evaluating alternative drainage options. Favorable economics in draining wet soils on croplands should not be an argument for converting wetlands to agricultural uses. The preservation of wetlands with their wildlife and other environmental values has been a national and USDA policy since the 1950's. The swampbuster provision of the Food Security Act of 1985 reinforces that policy. Under the swampbuster provision, farmers can lose eligibility for most USDA support programs if wetland areas are drained and converted to cropland. (The provision does not apply to wetland areas drained prior to passage of the law.)

Problems can develop from uncontrolled drainage, as experience shows in North Carolina. Uncontrolled drainage is being blamed for a number of problems: a lowered natural water table, reduced ability of many soils to produce crops and forest, and saltwater intrusion into farmland and forestland adjacent to estuaries and sounds. Furthermore, agricultural and silvicultural runoff is being blamed for degradation of water quality in rivers, sounds, and primary saline nursery areas.

Recently, farmers in eastern North Carolina have begun to correct these problems with water conservation practices. For example, conservation practices can reduce some of the freshwater runoff blamed for degradation of primary saline nursery areas. Water-control structures in major ditches and canals can determine the quality and quantity of water entering these areas during critical periods. They also can be used to increase the amount of fresh water available, and some research suggests they can be used to increase the rate of recharge to aquifers. Water historically drained from a watershed can be conserved and stored in a surficial aquifer for use as irrigation water.

Increase Dependable Supplies

Dependable water supplies are quantities of water that users can rely on with a stated frequency of chance of shortage. Dependable supplies can be increased by storing high flows and runoff in reservoirs or aquifers.

Increase surface storage.--The unregulated flow of many rivers varies from year to year or season to season. The rate of flow is many times greater during floods than during low flow periods, and some streams cease flowing during droughts. Even where the rate at which water withdrawn from a river is small compared to the average flow, there may be periods during which the desired supply of water is unavailable. Therefore, dependence on surface water as a source of supply usually requires an impoundment to store water for release during dry periods. Table 7-7 shows how much additional storage would be required to obtain the potential dependable supply of surface water in each water resources region.

Table 7-7.--Storage required to obtain potential available dependable supply

	Water resources region	Dependable annual streamflow		Storage required to meet potential		
		Current 1/	Potential 2/	Additional volume	Surface area	Initial cost
		(billion gallons per day)		(million acre-feet)	(thousand acres)	(billion 1984 dollars)
1.	New England	62.7	63.3	17.5	635	13.6
2.	Mid-Atlantic	70.4	73.5	23.0	547	25.8
3.	South Atlantic-Gulf	164.1	182.5	10.6	3,589	55.4
4.	Great Lakes	57.3	57.3	34.2	1,342	33.4
5.	Ohio	257.8	263.2	65.9	3,224	70.8
6.	Tennessee	55.2	55.3	18.3	787	13.7
7.	Upper Mississippi	198.4	210.5(-.2)	48.0	2,345	35.9
8.	Lower Mississippi	761.0	932.0	48.0	3,000	23.0
9.	Souris-Red-Rainy	3.4	4.8	5.4	90	2.4
10.	Missouri	99.2	107.2(-2.0)	31.5	1,591	23.5
11.	Arkansas-White-Red	42.5	58.3(-2.1)	44.3	2,179	28.1
12.	Texas Gulf	12.3	22.6(-1.5)	25.3	1,034	12.5
13.	Rio Grande	.9	2.1(-.2)	1.3	43	.8
14.	Upper Colorado	13.1	14.7(-.4)	4.8	138	4.4
15.	Lower Colorado	1.6	1.6(-.1)	.3	11	.4
16.	Great Basin	6.7	8.5(-.6)	5.6	220	12.4
17.	Pacific Northwest	371.4	372.1(-2.3)	105.2	2,317	55.7
18.	California	30.4	38.6(-.3)	34.7	787	47.0
	Conterminous U.S./all	2,208.4	2,468.0(-9.7)	523.9	23,879	458.8
19.	Alaska	795.0	795.0	202.8	3,379	607.5
20.	Hawaii	4.9	5.4	4.5	90	13.5
21.	Caribbean	3.3	3.9	3.3	82	4.9
	United States and Caribbean	3,011.6	3,272.3(-9.7)	734.6	27,430	1,084.7

1/ Current annual streamflows are sums of "dry year" outflows (discharges with an 80 percent chance of being exceeded) of the aggregated subregions, as reported in the 1975 Second National Water Assessment (NWA).

2/ Potential streamflows are 80 percent of the sums of mean annual yields (outflows) of the aggregated subregions as reported in the NWA. Numbers in parentheses are the decrease in flows expected as a result of net evaporative losses.

Increase Ground Water Storage.--Ground water is withdrawn at an average annual rate of 86 million acre-feet per year. In 1985 ground water constituted 31 percent of all fresh water withdrawals--up from 24 percent in 1975. Ground water supplies accounted for 47 million of the 87 million acre-feet consumed by irrigation.

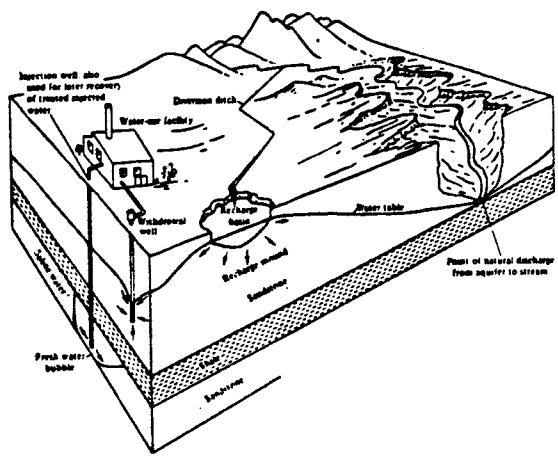
Aquifers can be managed so that water in storage is reduced during peak consumption and replenished by recharge during periods of surplus water. Any technique that increases natural recharge to or decreases natural discharge from an aquifer will increase the stored ground water that can be withdrawn by pumping wells. Production wells can be located according to aquifer properties and boundaries and pumped according to calculated time schedules. The withdrawals induce changes in ground water movement, control the distribution of ground water in storage, and affect the nearby streamflow. The resulting changes in ground water and surface water can increase the supply that is available at the desired time and location.

Recharge beyond what would naturally occur is practiced in some areas to take advantage of the ground water storage. Artificial recharge is the process of replenishing ground water through human activities. It consists of manipulating input to the ground water reservoirs in addition to regulating pumping withdrawals. In the broadest sense, artificial recharge includes not only planned replenishment but also additions to the ground water that are incidental to other activities; it includes not only good quality water but also any waste water that is added. Disposal of some nonconsumptively used water in septic tanks, pits and sumps, and seepage ponds also may replenish ground water supplies.

Artificial recharge may be used either to replace ground water where water levels have been drawn down or to temporarily increase local ground water storage for later recovery. Artificial recharge also can help to even out streamflow--that is, aquifers can be used to absorb flood runoff and release the water back to the stream as runoff subsides. During a drought or any period in which water demand increases, water supplies can be obtained by pumping wells and overdrafting ground water from storage. Artificial recharge also may be used to reduce salt water encroachment, to prevent subsidence from worsening, and to improve water quality by filtering the water through natural sand and gravel.

Artificial recharge may be accomplished by direct and indirect methods. Direct methods of recharge include water spreading by means of ponds, check dams, pits, furrows, or ditches to increase the amount of water infiltrating from the surface into the ground water reservoir. Impounded surface water can infiltrate a permeable part of the aquifer that is exposed at the land surface. Water can be injected directly into the aquifer through wells or shafts (fig. 7-14). Indirect methods of recharge include inducing movement of water from streams or lakes into underground formations and preventing the natural flow of ground water to the land surface by lowering ground water levels.

Ground water is replenished in many places by irrigation on permeable soils in natural recharge areas, and in some places by flooding to leach soluble salts from saline or alkaline soils. Even where water supplies are adequate, however, applying enough water to leach salts from soils can create new problems. For example, the reservoir in the Kesterson Wildlife Refuge in California collects excessive levels of selenium, as described earlier in this chapter.



Source: Todd, 1983

Figure 7-14.--How artificial recharge can increase the ground water supply. Source: Todd, 1983. Cited in Environmental Ground Water Institute, 1985, vol. I.

Aquifers have cogent advantages over surface impoundments as reservoirs for cyclic storage of water:

- they are relatively permanent.
- they do not lose storage capacity through sedimentation.
- they do not lose water by evaporation.
- they are less vulnerable to destruction or contamination.
- they pose no flood threat to downstream communities (Kazmann, 1967).
- their capacities are greater.
- they can be used as a distribution system.

However, when ground water supplies do become contaminated (see chapter 10), decontamination is far more prolonged and difficult than it is for surface waters. Aquifers that underlie rapidly permeable soils are most exposed to the risk of contamination.

Most ground water recharge occurs on privately owned rural lands. Identification of areas underlain by significant aquifers, implementation of measures to improve percolation, delineation of recharge areas, and management of the ground water resource can lead to wider use of ground water storage.

Improve Management of Soil Moisture

On nonirrigated land, especially in areas of limited rainfall, farmers can make more water available for their crop by increasing infiltration and reducing runoff. USDA has estimated the reduction in runoff that results from application of conservation practices and has used the Erosion/Productivity Impact Calculator (EPIC) and the Interactive Conservation Evaluation System (ICE) to estimate the effects that reducing runoff by specified increments would have on crop yields, erosion, and net returns to capital and management.

The analysis shows that soil moisture management can provide highly desirable results in terms of crop yields, erosion control, and net profit. However, it also shows that it is quite easy to have negative effects on yield and easier yet to have negative effects on profits. A fairly sophisticated site-specific analysis will generally be required to determine which practices provide the most cost effective results.

Increasing infiltration can increase crop yields.--The effects of specific soil moisture management practices are difficult to study in field experiments because the effects of the various management actions and physical processes involved in agricultural production are interrelated. Soil moisture management practices affect soil moisture in various ways--through effects on runoff, infiltration, permeability, and evaporation. Those practices that increase infiltration may have potential for increasing ground water recharge as well.

For this appraisal, USDA has analyzed the increases in yield and decreases in erosion that might be associated with one specific result of these practices--their effect on runoff. The analysts used the Erosion/ Productivity Impact Calculator (EPIC) and varied the runoff curve numbers in the model to reflect the effects of measures that reduce runoff. The EPIC model simulates interactions of the soil-climate-plant-management factors of agricultural production. The runoff curve number is a widely used method for estimating the volume of runoff from storms. Runoff curve numbers have been estimated for specific soils, land uses, and hydrologic conditions.

Table 7-8 shows the changes in yield that EPIC estimates would result from lowering the runoff curve number by specified amounts. The results shown in the table are based on representative soils in the five major land resource regions shown in figure 7-15. They summarize average results for each crop wherever it may be grown in the region. Results are based on average management conditions for an average soil in an average weather year. The benefits or potential hazards of changing soil infiltration rates at any specific site could differ from these averages and average results might differ in a wet or dry year.

The model showed potential changes in the yields of winter wheat from -1.94 to +3.92 bushels per acre, changes in corn yields from +1.95 to +8.93 bushels per acre, and changes in soybean yields from +1.66 to +3.57 bushels per acre. The negative yields for winter wheat in regions J and M indicate that these regions commonly have more soil moisture than is needed for optimum growth of this early maturing crop. These changes are important and can have a significant impact on economic returns to farmers.

Soil moisture management practices reduce erosion.--Farmers can reduce runoff from fields by applying soil conservation/soil moisture management practices. Table 7-9 shows the average reduction in runoff curve numbers associated with some conservation measures designed to reduce runoff.

Conservation measures allow less rainfall to leave a site as surface runoff. Reduced runoff means that more water infiltrates the soil, so the available moisture supply is greater. Reduced runoff also means reduced erosion. Erosion reduces the thickness of the soil; therefore, preventing erosion maintains the soil's water-holding capacity.

Table 7-10 shows the reductions in sheet and rill erosion that the ICE model estimates would occur if erosion control/soil moisture management practices were applied in land resource region M. Sheet and rill erosion is a serious problem in only a few areas in the other land resource regions studied; ICE does not estimate wind erosion, which is severe on some cropland in these regions.

Table 7-8.--Estimated changes in yield resulting from reduction in runoff, in selected land resource regions

Crop	Region	Runoff curve number reduced by 3	4	5	9
		(Bushels per acre)			
Winter wheat	B	2.14	2.85	3.07	3.92
	F	.68	.90	.99	1.34
	H	.23	.30	.38	.68
	J	-.56	-.75	-.98	-1.88
	M	-.85	-1.14	-1.30	-1.94
Corn	J	1.95	2.60	2.67	2.92
	M	4.06	5.41	6.11	8.93
Soybeans	M	1.66	2.21	2.48	3.57

Source: Erosion/Productivity Impact Calculator (EPIC).

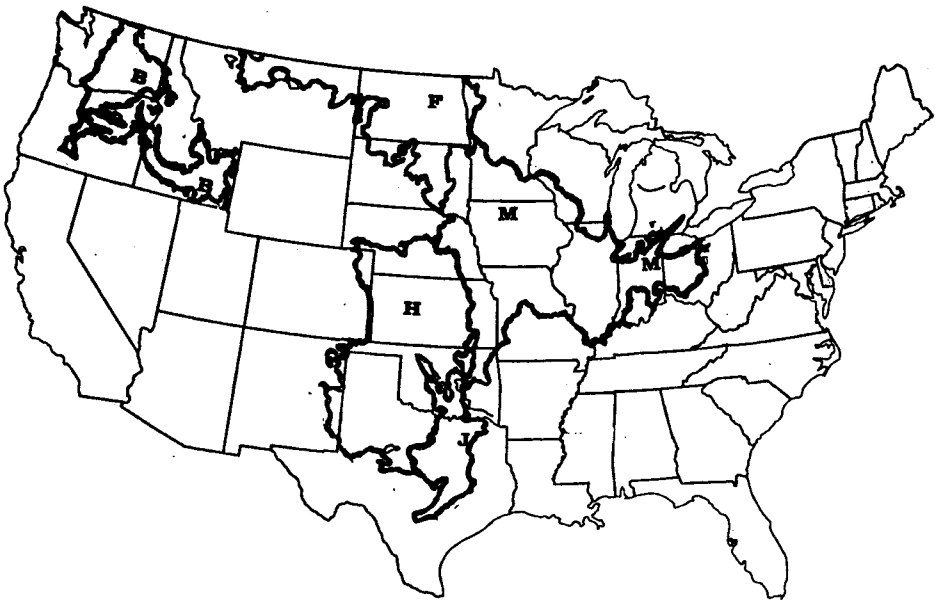


Figure 7-15.--Selected land resource regions.

Table 7-9.--Reduction in runoff curve number resulting from selected conservation practices

Practice	Change in watershed runoff curve number	Practice	Change in watershed runoff curve number
Cropland		Rangeland	
Terraces	-9	Mechanical range treatment	-7
Conservation tillage	-5	Deferred grazing	-3
Mulching	-5	Brush management	-1
Residue use	-5	Fencing	small
Grasses and legumes	-5		
Diversion	-4		
Contour stripcropping	-4		
Contouring	-4		
Chiseling and subsoiling	-3		
Filter strip	-3		
Stripcropping	-2		
Stubble mulching	-2		
Hedgerow planting	small		
Grassed waterway	small		
Lined waterway	small		
Surface drain	small		
Subsurface drain	small		

Table 7-10.--Estimated sheet and rill erosion on cropland, Land Resource Region M

Conservation practice	Crop		
	Soybeans	Corn	Wheat
	(tons/acre/year)		
No treatment	25.7	24.2	5.0
Terraces	23.5	22.1	4.6
Conservation tillage	11.6	11.1	3.0
No-till	8.1	9.6	2.5
Contouring	12.9	12.1	2.5
Diversion	18.4	18.4	3.8
Contour stripcrop	10.7	10.2	1.4
Chisel and subsoil	11.6	11.6	3.0

Source: Interactive Conservation Evaluation System (ICE).

Soil moisture management can change net returns.--Table 7-11 shows the estimated changes in net return to capital and management resulting from application of various measures. In most cases the ICE analysis indicates that some form of reduced tillage (conservation tillage, no-till or chiseling) would give a farmer the highest net return.

Because these tillage methods cost significantly less than conventional methods, they result in increased net returns even in regions J and M where they cause yields of winter wheat to decrease.

Soil moisture management on noncropland.--As important as soil moisture management practices are on cropland, they may be even more vital on nonirrigated pastureland and rangeland. For example, when overgrazing reduces the production of shallow-rooted grasses, deep-rooted brush species invade. Soil moisture can be reduced to the point that grasses will not recover without brush suppression. This consideration deserves more attention.

Table 7-11.--Estimated changes in net return resulting from application of selected soil protection practices

	Winter wheat					Corn		Soybeans
Practices	B	F	H	J	M	J	M	M
	(dollars per acre)							
Net return:								
(no treatment)	140.06	64.12	28.21	29.96	94.16	125.28	231.04	76.33
Change resulting from:								
Terraces	11.68	3.75	1.03	-2.01	-5.16	2.90	17.77	11.74
Conservation till.	9.65	11.85	36.64	.57	.64	6.19	22.35	31.01
No-till	.64	7.22	29.08	6.52	9.50	12.43	7.27	53.86
Contouring	8.49	2.52	.08	-.80	-3.03	-3.59	10.76	7.27
Diversion	8.49	2.52	.08	-.80	-3.03	-3.59	10.76	7.27
Contour stripcrop	8.49	2.52	.08	-.80	-3.03	-3.59	10.76	7.27
Chisel and subsoil	.47	8.84	35.86	1.68	4.25	.41	9.70	20.65

Source: Interactive Conservation Evaluation System (ICE).

Related effects of nutrient management.--Improved management and adequate fertilization, which increase yields, also improve water-use efficiency. The nation's average yields for corn, soybeans, wheat, and alfalfa have increased 15 to 18 percent in the past 10 years with little increase in water use. Using fertilizer to improve crop yields is a water management practice as well as a production practice. Adequate fertilizer helps a crop use water more efficiently because it increases the vigor of the crop. The crop therefore:

- Develops an earlier and fuller crop canopy, which reduces evaporation from the soil surface.
- Provides more cover during the growing period and provides more residue after harvest, which reduces runoff and increases infiltration.
- Produces more organic matter, which improves tilth and increases infiltration.
- Has greater resistance to disease and nematodes.
- Develops a larger root volume.
- Provides a more favorable habitat for soil microorganisms.

The effect on root volume is most important in dry years. The greater root volume allows the plant to extract water more completely and to a greater depth. When soil moisture is low, adding phosphorus and potassium increases the concentration gradient and speeds movement of water into the roots. Several studies have documented this effect.

Increasing soil moisture is not desirable in some cases.--Enduring practices that increase soil moisture infiltration in dry years also will do so in years when excess soil wetness is a serious problem. While this may have some benefits to ground water recharge, it also can decrease yields and net returns. Soluble nutrients or pesticides in the soil may move with the excess water through the root zone into ground water. This may pose a hazard to wells in the vicinity. Cropping practices that increase soil moisture beyond the needs of the crop in some soils can result in saline seeps (chapter 5). Because of the wide range of possible effects, including serious negative effects at some sites, expert advice should be sought for planning and implementing soil moisture management practices.

DO EXISTING INSTITUTIONS, POLICIES, AND LAWS ENCOURAGE OR HINDER WATER CONSERVATION?

In a broad sense, most institutions, laws, and policies tend to protect vested interests more than they tend to foster changes. In this sense, existing water institutions do tend to inhibit alterations in water uses, to protect the existing patterns of water use, and to restrain new water developments. To some extent this restraint prolongs some inefficient water use practices, even where water is most in demand. Examples of limited ability to use the power of existing laws and institutions to promote water conservation can be found in states where a riparian doctrine of water law prevails as well as those where the appropriation doctrine governs.1/

Some interstate and federal institutions, by affecting the transferability of water or its prices, may affect attitudes about water conservation. Interstate compacts, in the interests of comity, set more or less permanent apportionments of water supplies between states. Reclamation Project water service contracts provide subsidized water for irrigation over a long period of time and set up irrigation district organizations that tend to resist water transfers to other uses. Water reservations for Indian tribes tend to be uncertain in terms of quantity and thus create uncertainty in the water market until the amounts are established through negotiation, adjudication, or legislation. When such rights are quantified, they also tend to become permanent.

Some changes in laws, institutions, and policies that affect water use are inevitable. As long as demands for water for nonagricultural uses increase and the nation's agricultural production continues to outpace domestic demands, we can expect amplification of those laws, institutions, and policies that discourage the development of new consumptive uses by agriculture and encourage reductions in existing agricultural water uses. More restrictions will be placed on agricultural activities that adversely affect water quality.

There may be a few local cases where special changes in law or policy are needed to encourage water conservation. For example, because return flows from irrigation and other uses usually are of reduced quality, institutions or arrangements may be created to reduce irrigation diversions. From a national point of view, however, conditions do not indicate any

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1/ Riparian water law and the appropriative doctrine are the two systems of water allocation that apply to flowing streams, lakes, and other surface sources. In the riparian system, the water is not owned by anyone, but the rights to use the water arise out of ownership of lands that touch the stream or lake. In the system called prior appropriation, the landowner who can make beneficial use of water can obtain a permit from the State to use a given amount of water at a given time and place. The beneficial use of the water and the antiquity of the permits rather than ownership of land determine the right.

pressing need for federal intervention to accelerate such changes. On the contrary, there are numerous examples to indicate that water use patterns are changing fairly rapidly as the value of water increases, as new users compete for a share of the available water, as the costs of using water increase, and as the constraints on water pollution become more stringent.

This trend is particularly evident in the western states where the appropriation doctrine prevails and where competition for water is most keen. This may seem to be a paradox since the appropriation doctrine is frequently viewed as giving more protection to existing water rights and established water uses than does the riparian doctrine. However, because water allocations are more clearly defined when flow, use, and storage rights are established, the effects of making changes in water use patterns can be more easily determined. This allows market forces to operate more freely than where such factors are unknown or undefinable.

Before any major changes are proposed in the prevailing patterns of water use or in existing water institutions, policies, or laws, a detailed analysis should be made of the physical, economic, and hydrologic characteristics of the river basin in which the changes are proposed. A careful analysis of individual basins may reveal that:

- Many of the changes desired can be achieved without modifying existing laws, institutions, and policies. USDA agency personnel and local water organizations have been able to inspire significant changes in the management and use of water within existing federal, state, and local laws, institutions, and policies. In western Wyoming, the pooling of individual water rights is endorsed where groups of water users have organized districts to develop and maintain SCS-designed sprinkler irrigation systems to distribute the available water supply more evenly and increase irrigation efficiencies. In Colorado, Kansas, Oklahoma, and Texas, technical assistance is being provided to help increase the efficiency of water pumped from the Ogallala aquifer. Examples such as these can be found throughout irrigated regions of the nation.

- Existing water uses may not be as wasteful as generally perceived. It is very important to study the effect of the proposed changes on the unconsumed portion of the water returned to the stream as well as to examine changes in diversions and water use patterns. For many municipal and industrial uses, the amount of water actually consumed is a small part of the water withdrawn from the stream or aquifer. Even where irrigation is a common practice in a river basin, most of the diverted water not used by the intended crops is returned to the stream system to become available somewhere downstream.

- Altering the institutional, legal, or policy situation may not accomplish the changes desired. Most western state water laws are designed to encourage water salvage by awarding at least a part of

the savings to the person who accomplished it. However, such provisions may be of little effect where it is not physically or economically practical for the persons presently using the water to capture much of the water that they save.

When water is salvaged, it is usually to supply additional consumptive uses, and these increased uses will reduce the water available for existing uses downstream. For example, a study of the present uses of water in the Columbia River Basin system has revealed that an increase of 1 acre-foot of water consumptively used in July or August by agriculture in southern Idaho could mean a loss of up to $150 in hydropower revenues in Idaho, Washington, and Oregon. There would be additional losses from reduced recreation and fishery values and indirect environmental costs associated with the increased generation of electric power from other energy sources.

There is a tendency to view opportunities for new water developments on the basis of average or even wet-year conditions. In most streams, the water available in a prolonged dry period may be a small fraction of that available in average conditions. Many streams may have no water at all for a part of the year. Increasing the commitment or allocation of water based on averge conditions tends to decrease the ability to meet minimum demands for hydropower and other uses in times of drought. There may be some insurance value in allowing inefficient uses of water in average years if it will reduce problems in dry years.

- Institutions, laws, and policies may not be as restrictive as generally perceived. Having no free water is left for development does not necessarily mean that an institutional problem exists. Even in states like Wyoming, where irrigation water rights are tied to the land area on which the water is to be applied, nonagricultural water users find it quite possible to purchase agricultural water rights and convert them to other uses. One of the most significant examples of water conservation being encouraged by market conditions within existing institutions is the ongoing negotiation for water to be salvaged by the Imperial Irrigation District for sale to the metropolitian water districts of California's southern coastal areas.

Agricultural water users can expect to be deeply involved as changes in water uses accelerate. Individual farmers have ambivalent views on the issues. Many will be concerned about the loss of water for agriculture; yet, especially in the appropriation doctrine states, the ability to transfer water rights can represent a considerable portion of an owner's net worth.

To protect the long-term productivity of agriculture, farmers will need technical assistance in accommodating changes with a minimum of disruption. The need continues for research and development of methods to reduce water use for crop production and for technical and financial assistance to reduce nonproductive water losses.

Flood Damages Are Increasing

Upstream flood damages, apart from deaths and other social consequences, average more than $5 billion a year. By the year 2030, damages are projected to reach $9 billion or more. Damages in upstream watersheds account for half of all flood damages, and 80 percent of upstream damages occur in rural areas.

Projections of future developments made for this appraisal suggest that the acreage of cropland might decrease significantly in the future. The reduction in flood-prone cropland likely would not be great, however, because a considerable portion of the reductions are projected for areas where not much of the cropland is flood-prone. Agricultural damages are expected to increase in the future because cropland is being cropped more intensively, requiring larger investments.

Flood-prone lands will likely remain in agricultural use, both because of their high productive capacity and because costs of capital improvements, insurance, and related factors will discourage their conversion to other uses. Damages to cropland and pasture, however, will not increase as rapidly as damages in urban areas and damages to land in other rural uses.

Flood-prone areas include alluvial fans, plains, or other lands adjoining water that in the past have been covered intermittently by floodwater or have a 1-percent chance of being flooded in any given year. All states have flood-prone rural land (fig. 8-1). The Federal Emergency Management Agency (FEMA) has determined that about 20,000 out of 34,000 communities in the United States have some flood hazard areas (FEMA, 1986). Two-thirds of the Nation's flood damage occurs in rural areas. Flooding in upstream watersheds accounts for half of the flood damage, and over 80 percent of upstream damage occurs in rural areas (table 8-1) (U.S. Water Resources Council, 1978). Sixty million acres (14.4 percent) of the nation's cropland are in flood-prone areas (USDA SCS, in press) and about 31 percent of all flood-prone land is used as cropland.

How serious is the damage?

Floods are among the most significant natural disasters in the United States in terms of loss of life and property. Between 1960 and 1982, flooding caused an average of 151 fatalities annually (fig. 8-2).

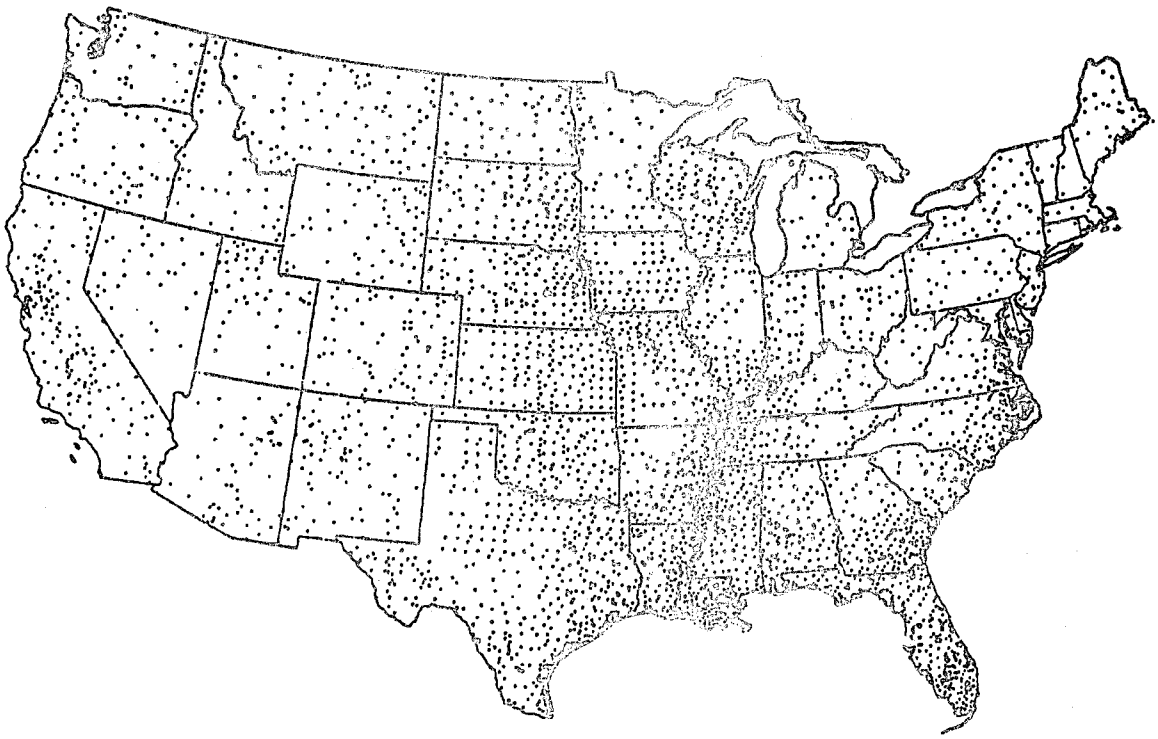

Figure 8-1.--Flood-prone rural land (1982 NRI).
Each dot = 50,000 acres.
For state data, see appendix table 8-1.

Property damage in flood-prone areas is increasing. Nationwide, 195 million acres, or 13 percent of the nonfederal inventoried land area, are flood-prone (1982 NRI). In 1975 flood-prone lands were estimated to contain at least 6.4 million structures. A study by Hoyt and Langbein in 1955 estimated that 10 million people lived in flood-risk areas and projected that the number would double by 1985.

No unified data base exists for recording flood damage information, and data sources vary widely in their estimates, primarily because different organizations use different criteria to define property damages. The Water Resources Council Second National Water Assessment estimated damages for "1975" at $5 billion (updated to 1980 dollars). 1/ The Council also predicted that the damages would reach $7 billion by the year 2000.

Table 8-1.--Flood damages in "1975" 1/ normalized water year

	Upstream	Downstream	Total	
	(millions of 1980 dollars)			%
Urban and built-up land	434	1,218	1,652	33
Agricultural land	1,632	807	2,439	49
Other (rural utilities, roads, railways, homesteads, forests, grasslands, refuges, parks, etc.)	441	485	926	18
Total	2,507	2,510	5,017	100

SOURCE: Second National Water Assessment.

1/ "1975" represents a normalized year based on average water use in 1975. Data do not represent actual water use in that year.

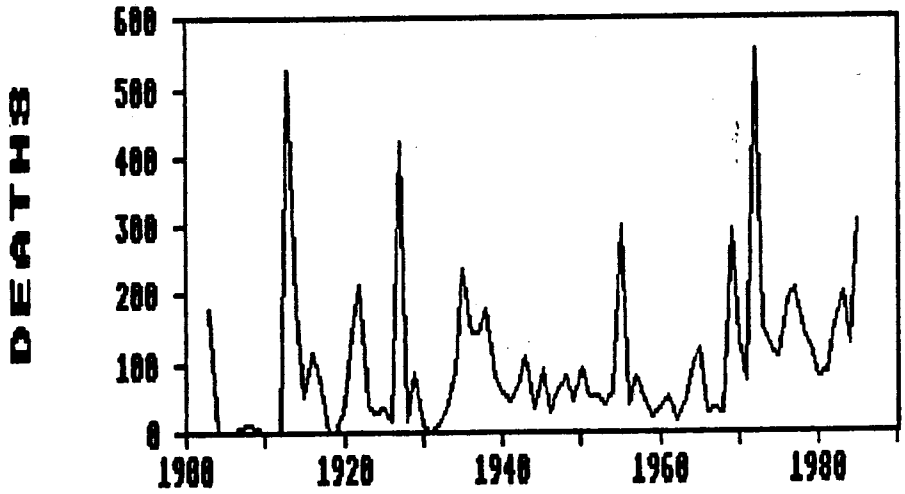

Figure 8-2.--Flood related deaths annually, 1903-84 (NOAA/NWS).

The National Oceanographic and Atmospheric Administration/National Weather Service (NOAA/NWS) estimates average annual flood damage between 1940 and 1984 to be $1.5 billion. This estimate and the Water Resources Council's estimate are in 1980 dollars. The lower figure given by the NOAA/NWS probably does not include many of the agricultural damages caused by minor storms, which usually account for 70 percent of agricultural damages. A regression analysis of trends showed that damages are rising by $30.3 million per year. Storm events and subsequent flood damages vary widely from year to year, but all available data and costs show a steady upward trend unrelated to changes in dollar value (fig. 8-3).

The National Flood Plain Management Program has been successful in limiting construction in flood plains. Rural flood damages, however, are expected to increase because existing cropland is being cropped more intensively, requiring greater investments. Flood-prone lands are the most productive, supplying as much as 20 percent of the nation's crop production. These lands are expected to stay in production because of their high productivity, and more flood-prone areas are likely to be farmed as some of the highly erodible soils are put into the conservation reserve. Figure 8-4 shows the location and percent of cropland subject to flooding, and figure 8-5 shows the location and percent of flood-prone land used for crops. Both figures show data for aggregated subareas--small drainage areas within the major water resource regions, adjusted to county or related political boundaries.

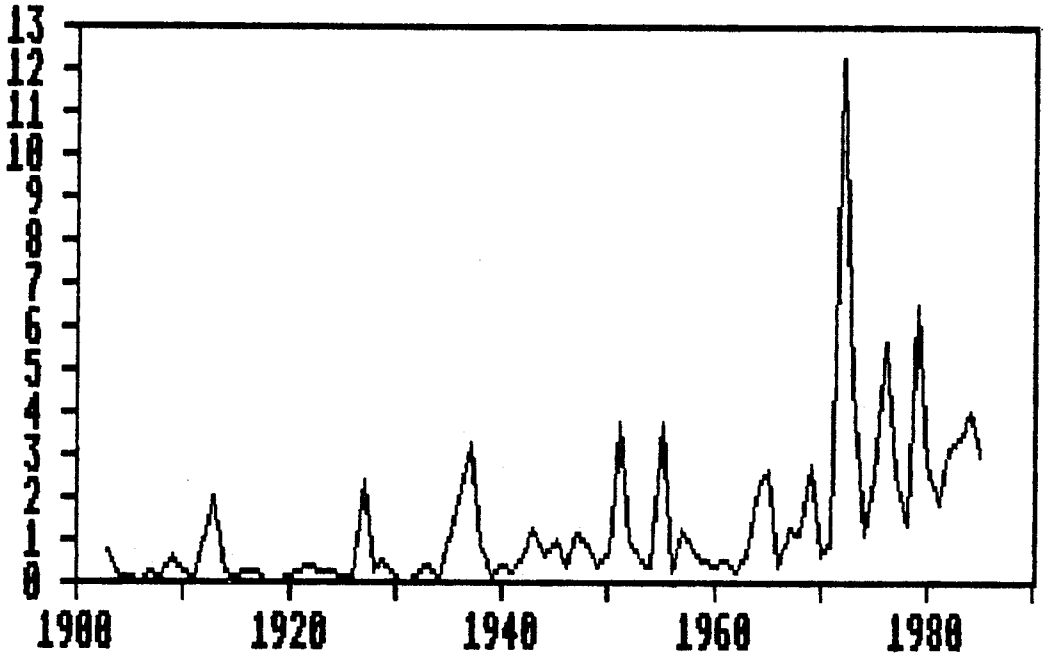

Figure 8-3.--Annual flood damage, 1903-84, billions of 1984 dollars (NOAA/NWS).

LIMITING FLOOD DAMAGES: What Can Be Done?

There are three general approaches to relieving flood damages. None of the three is sufficient alone; flood-plain management that combines at least two of them generally provides the greatest net benefit (USDA SCS, 1981).

The first approach is mainly palliative. It eases suffering and hardship and provides economic relief by means of flood emergency measures, post-flood recovery measures, flood insurance, and tax adjustments. The second approach seeks to protect life and property. It includes information programs to make the public aware of flood hazards; flood plain regulations and development policies, disaster preparedness, and response planning; flood proofing, and flood forecasting and warning systems. The third approach seeks to contain or redirect floodwaters before they overflow. It comprises structural measures--such as dams, dikes, levees, floodwalls, channel alterations, high flow diversions and spillways, and onsite detention measures--and also land treatment measures designed to increase infiltration and reduce runoff.

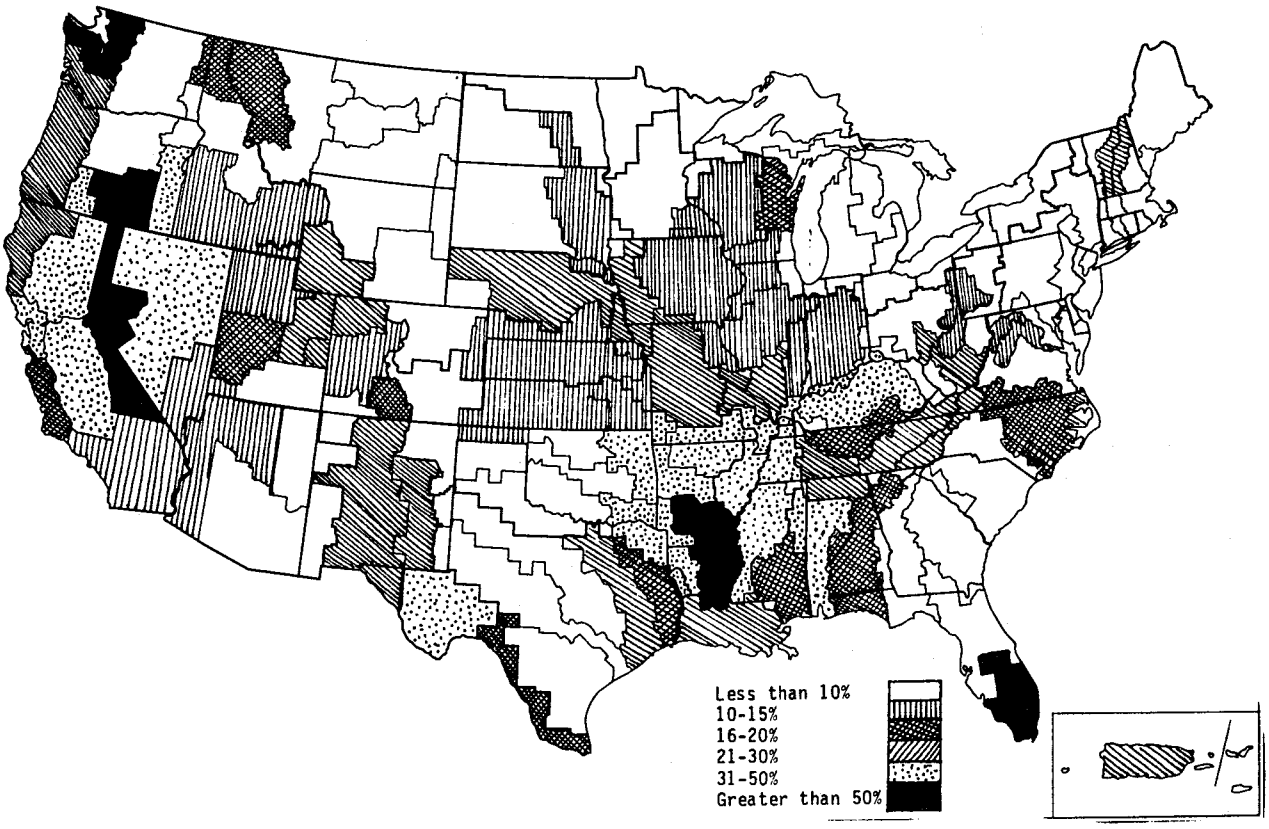

Figure 8-4.--Percent of cropland subject to flooding, by aggregated subarea (1982 NRI).

REDUCING FLOOD DAMAGE: What is USDA's role?

The Flood Control Act of 1944 and the Watershed Protection and Flood Prevention Act (Public Law 83-566, Stat. 666) authorize USDA to work with local people and organizations in solving flood problems. The programs developed under the Watershed Protection Act are unique among federal water programs in being federally assisted, not federally directed. All actions pertaining to them must be initiated by local people, and decisions as to the scope of any project are made locally. The federal government's commitment to cooperate on any proposed project is based on current policy, approved guidelines, and Congressional constraints.

More than $76 million in benefits is accruing annually in the completed projects, based on estimates made in the project plans (table 8-2). The cumulative total cost of these projects was $727 million; thus the $76.3 million average annual benefits are equivalent to 10.5 percent interest.

The economic benefits and effects of the watershed program, which has existed for 30 years, are documented in an evaluation required by the Resources Conservation Act. The evaluation assesses actual benefits and compares them with the benefits projected when the projects were planned. About one-third of the projects had economic benefits accruing in 1985 that were within 25 percent of the planned benefits in constant dollars. Over three-fourths of the projects had 1984 benefits within 50 percent of the planned benefits. In a 58-project sample, actual benefits exceeded planned benefits by 34 percent. Benefits to rural communities exceeded planned benefits by nearly 200 percent, and sediment damage reduction was more than 300 percent greater than planned (table 8-3). Only in the categories of erosion damage reduction and "other agricultural benefits" were benefits less than planned.

The benefit-cost ratio for 1984 is an estimate at a given time. The benefits estimated in another year could be more or less than those estimated in 1984. Given that the parity ratio for farm prices received versus prices paid was lower in 1984 than it was at the time the the

Table 8-2.--Reduction of flood damages in watershed projects

Project status	Number of projects	Damages without project	Damages with project	Average annual benefits
			(1980 dollars)	
Preconstruction	293	22,936,487	12,704,830	10,231,657
Under construction	417	96,927,356	25,608,309	71,319,047
Construction completed	649	129,075,231	52,756,799	76,318,432

Source: SCS, 1985.

projects were planned, and that they were lower than in any year from 1957 to 1981, it is likely that the estimated agricultural benefits in 1984 are conservative.

The planning estimate of benefit-cost ratio for all 486 completed projects averaged about 2 to 1. The implied actual ratio of benefit to cost in 1984, based on the sampled projects, was about 2.2 to 1.

Considering the distribution of benefits accruing in 1984 relative to planned benefits, it can be deduced that about 90 percent of the completed projects have benefits accruing that are equal to or greater than the annualized costs.

The shifts from planned benefits were primarily away from the agricultural sector and toward urban areas. In this context, "urban" indicates that benefits accrue to owners of homes and businesses in rural communities rather than to farm owners. Only direct dollar benefits were summarized. There is considerable evidence that secondary benefits are accruing to these projects; however, most are regional in nature and appear as tradeoffs in the national economic account. As such, they are not identified separately.

Table 8-3.--Comparison of planned and actual (1984) benefits for 58 sample projects

Benefit category	Number of projects	Planned benefits		Actual benefits	
		Annual return 1/	Percent of total	Percent of total	Percent 3/ of planned
Cropland and pasture	55	$2,049,369	74	57	101
Other agricultural	31	98,121	4	2	76
Urban	19	317,530	12	26	298
Transportation	30	61,518	2	5	323
Nonagricultural	18	90,361	3	3	121
Erosion	21	79,788	3	1	63
Sediment	19	49,140	2	6	431
Total	58	$2,745,8272 2/	100%	100%	134%

1/ These dollar amounts are accumulated from the project plans and are not adjusted to a base year.
2/ This total does not include some minor benefits ($3,979), which do not fall into a listed category and could not be evaluated in 1984 for lack of data.
3/ Benefits measured in 1984 were adjusted for price and technology changes to put the 1984 estimates on the same basis as the original plan estimates for this comparison.

Projects completed under Public Law 566 also provide a wide range of social benefits; that is, benefits that enhance the quality of people's lives. Many of these benefits generally are not included in the calculation of monetary effects, primarily because of the difficulty of assigning monetary values. Yet social impacts cannot be ignored simply because quantification is difficult.

By reducing upstream flooding, small watershed projects help overcome the following risks to society:

- Threat of loss of life.
- Health hazards, such as insect breeding pools, sewage overflows, and chronic wet conditions that are particularly hazardous to the elderly and to children;
- Significant risk and inconvenience associated with damage to roads and bridges;
- Disruption of necessary services such as police and fire protection and use of emergency equipment;
- Pollution of drinking water;
- Interruption of utilities.

Employment opportunity is a social benefit of project activities. This is particularly true if the employment is made available to individuals who are at a disadvantage in the labor market because of lack of skills or minority status or if the project is in an area of high unemployment.

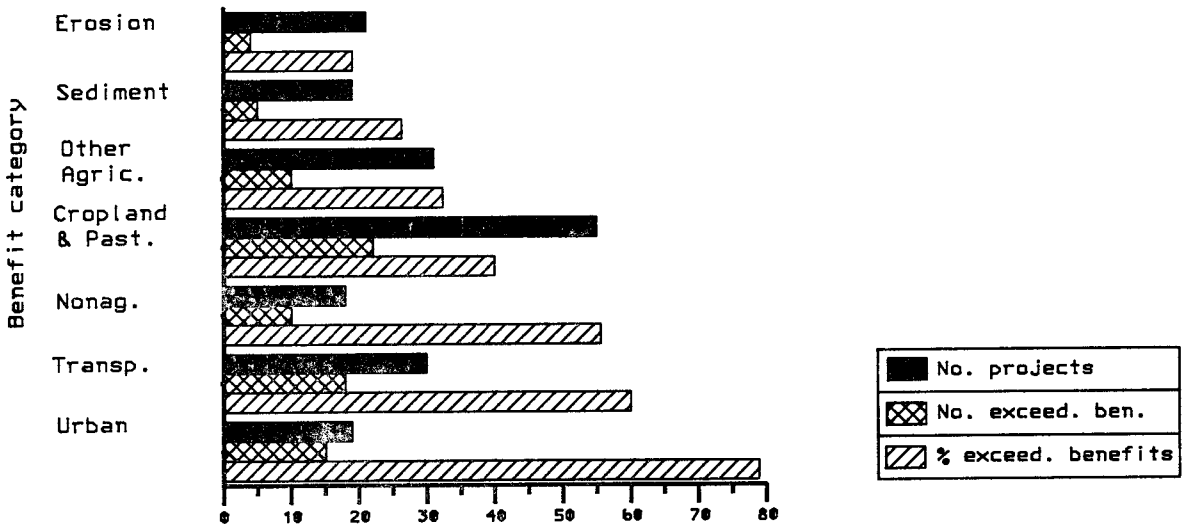

Figure 8-5.--Comparison of planned and estimated 1984 benefits accruing from 58 watershed projects (SCS 1985).

For the projects sampled, employment opportunities averaged 15.8 staff years per project during construction and 20.3 after construction. Minority workers filled about 15 percent of the jobs created during construction and about 10 percent of the jobs available after construction.

The 60 sample projects completed by 1978 were analyzed in both the preproject (project plan) and post-project (1984) stages for the number of buildings that would be susceptible to flood damage with and without project measures in the event of a 100-year frequency flood. A "100 year frequency flood" has one chance in 100 of being equalled or exceeded in any one-year period. The preproject and post-project estimates indicate that Public Law 566 projects reduced by 95 percent the number of buildings susceptible to flood damage. But data for fiscal year 1984 show an increase in the number of buildings susceptible to flooding with and without project measures. The greatest increase was for residences.

Trends

The Water Resources Council projected an increase in flood damages from $5.5 billion in 1975 to $7 billion by the year 2000 and $9 billion by 2030 (U.S. Water Resources Council. 1978b). The corresponding figures for the NOAA/NWS are $3.5 billion in 2000 and $4.7 billion in 2030 (NOAA/NWS). All figures are in 1980 dollars.

The Council analysis projects that upstream damages will increase from 47 percent of the total in "1975" to 50 percent in 2000. Rural damages are projected to increase more slowly than urban damages, but they still will make up the majority of total damages: 63 percent by the year 2000 versus 66 percent in "1975" (U.S. Water Resources Council, 1977).

Upstream flood damages will continue to increase as the real values of property in flood plain areas increase. Even though many communities have voiced concern over the development of flood-prone lands and the number of regulations governing the use of flood plains has grown, large investments will continue to be made in flood hazard areas. Agricultural damages are expected to continue to increase because of the large acreage of flood-prone land used as cropland. Shifts in crop production to flood-prone lands will add to this upward trend.

The 1980 RCA Appraisal estimated that flood losses could be reduced by 20 percent if economically feasible flood control structures were built (USDA SCS, 1981). Current economic conditions have reduced the number of projects funded, casting doubt on the long-term future of upstream flood damage control. At present, the federal investment in water resources projects is less than 0.3 percent of the total federal budget. This figure is projected to drop to 0.2 percent. The SCS watershed operations program, the primary federal program addressing upstream

flood damages, receives less than 10 percent of the total amount devoted to water resource projects.

Future commitments for authorized projects are currently at about 1.5 billion dollars. At the current rate of funding, an unfunded commitment of half that size can be sustained based on the historical rate of installing these projects (USDA, SCS, 1987).

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Atmospheric Deposition

Studies have demonstrated that plants are injured and crop yields are reduced by the presence of above-normal levels of ozone in the surrounding air. Tests have not demonstrated damage to annual crops by "acid rain." There is a growing popular concern that atmospheric pollution and the resulting deposition may be damaging aquatic ecosystems and injuring forests in the United States. Water bodies and soils in some areas are more acidic because of acid rain.

The Department of Agriculture is a leading participant in several programs designed to identify and monitor the effects of this atmospheric deposition on crops, forests, soils, and surface waters.

Projections of future conditions made for this appraisal do not consider the possible effects of increases or decreases in ozone or other atmospheric pollutants on yields and therefore on the land needed to meet future demands for food and fiber.

The term "atmospheric pollution" means the release into the earth's atmosphere of gaseous pollutants (ozone, sulfur dioxide, and oxides of nitrogen), atmospheric particulates (dust, smoke), and acidifying chemicals. Many of these particles and gases eventually are deposited on the earth's surface in either wet precipitates (rainfall, aerosols, fog) or dry deposition.

Many chemicals, released into the atmosphere, affect sensitive biotic species in the vicinity of the source. The various components of atmospheric deposition directly affect terrestrial ecosystems, and the components themselves can change as they cycle through the ecosystem. Deposited chemicals may be taken directly into plants by the foliage, altered by passing through plant canopies, taken up by plant roots from the soil solution, utilized or modified by soil organisms, altered by soil chemical reactions, and discharged into lakes and streams. They can cause changes in plant health and vigor, changes in soil productivity, and acidification or other chemical changes in surface waters. On the other hand, they may contain nutrients that can enhance plant growth. Many terrestrial ecosystems can buffer, or neutralize, acid deposition.

There is concern in the United States that acidic deposition, or acid rain, may have substantial adverse impacts on plant growth (crop and forest production) and on water quality. There is also a more general concern that deposition of atmospheric pollutants--including photooxidants such as ozone, oxides of nitrogen and sulfur, other gases, and metals--is "bad for the environment." Unexplained growth reductions are occurring in some U.S. forests, and acidification of some streams and lakes has been documented. Although the changes in forest condition could be due to factors other than air pollution, the widespread forest decline in central Europe, generally regarded as caused by atmospheric pollutants, has helped focus attention on the potential for a similar problem in the United States. Research to date has shown little effect of acidic rain on crops, but the adverse effects of photooxidants and acidifying gases on crops are well documented.

Atmospheric deposition data are being collected to provide information on time-trends and geographic patterns. Data collected before 1950 are of relatively little value for time-trend comparison. Some data of the 1950's can be qualitatively compared with data for 1978 to the present collected under the National Atmospheric Deposition Program (NADP). However, this comparison, which seems to show an increase in acidity, has been debated at length. Experts who examined trends for all the ions found that ions with soil sources (e.g. calcium and magnesium) decreased dramatically over the period; thus the apparent decrease in pH did not result from the presence of more acidic pollution but from the decrease in basic particles. The higher calcium and magnesium concentrations in the precipitation of the 1950's probably were due to one or both of two factors: the drought of the 1950's, and inadequate sampling methods.

Current levels of precipitation acidity, the geographic pattern of sulfur deposited in precipitation, and the pattern of ammonium-nitrogen and nitrate-nitrogen in precipitation are shown in figures 9-1 through 9-3. The highest concentrations of deposited acidic pollutants center on the eastern Great Lakes region and the Ohio River valley. Areas of particular concern are those in which surface waters (fig. 9-4) and soils (fig. 9-5) are sensitive to acidic deposition.

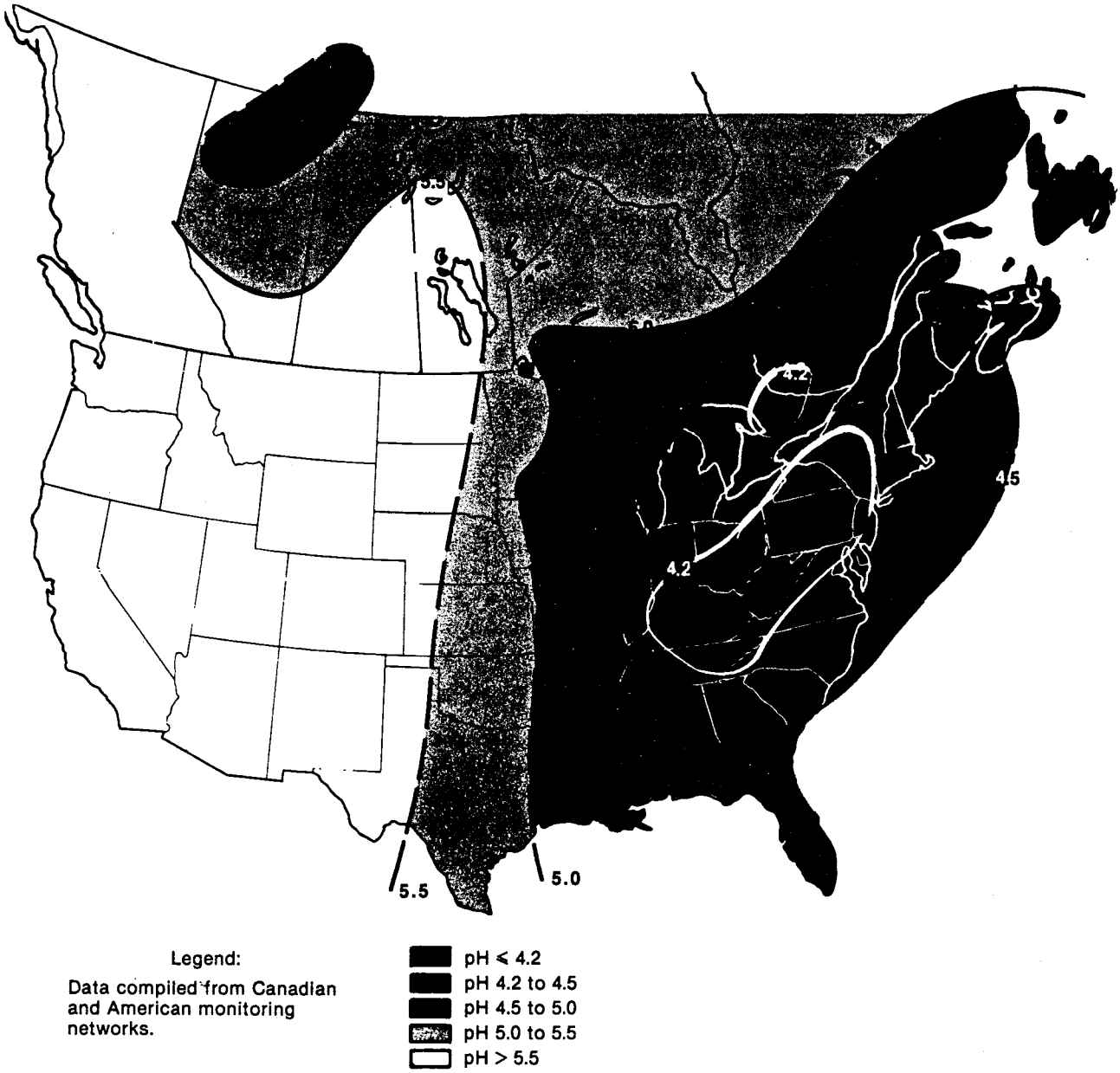

Figure 9-1.--Precipitation acidity--annual average pH for 1980.

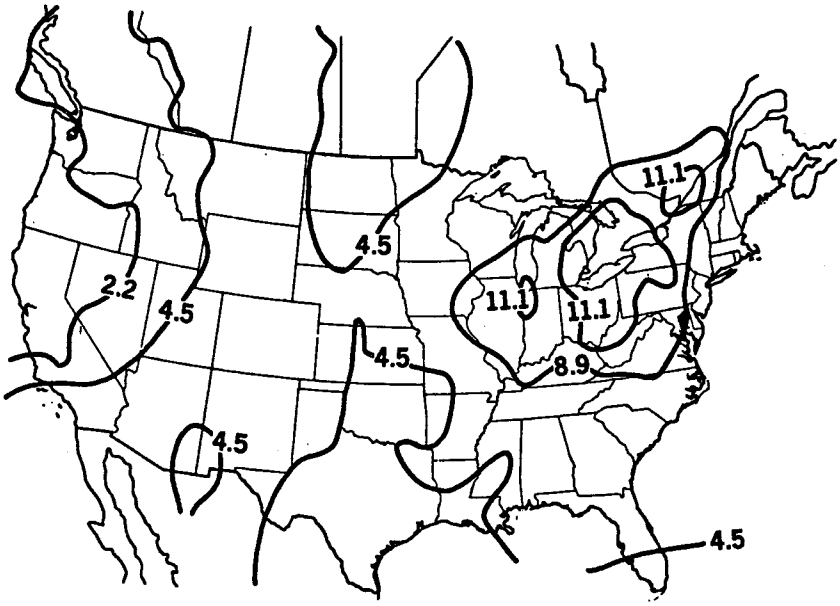

Figure 9-2.--Deposition of sulfur in precipitation in 1981. Numerical values are pounds of sulfur per acre.

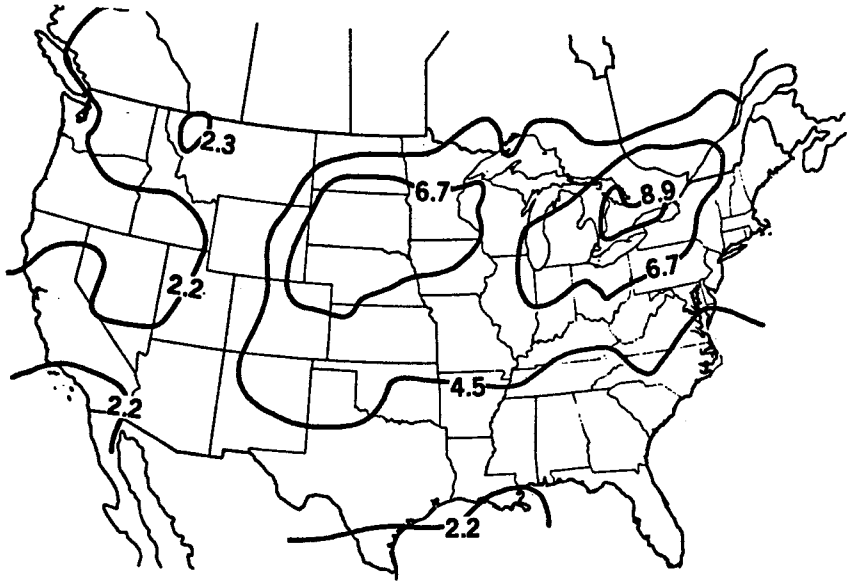

Figure 9-3.--Deposition of ammonium-nitrogen and nitrate-nitrogen in precipitation in 1981. Numerical values are pounds of nitrogen per acre.

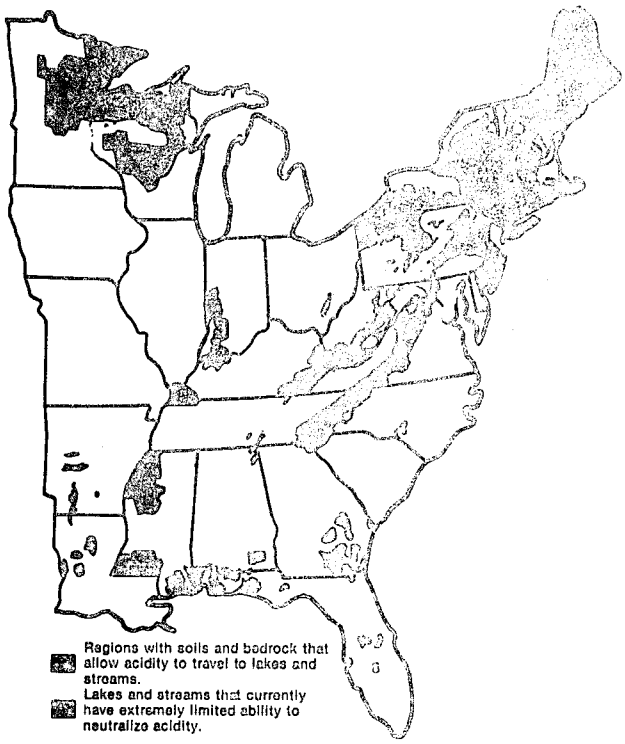

Figure 9-4.--Regions where surface waters are sensitive to acidic deposition (Office of Technology Assessment).

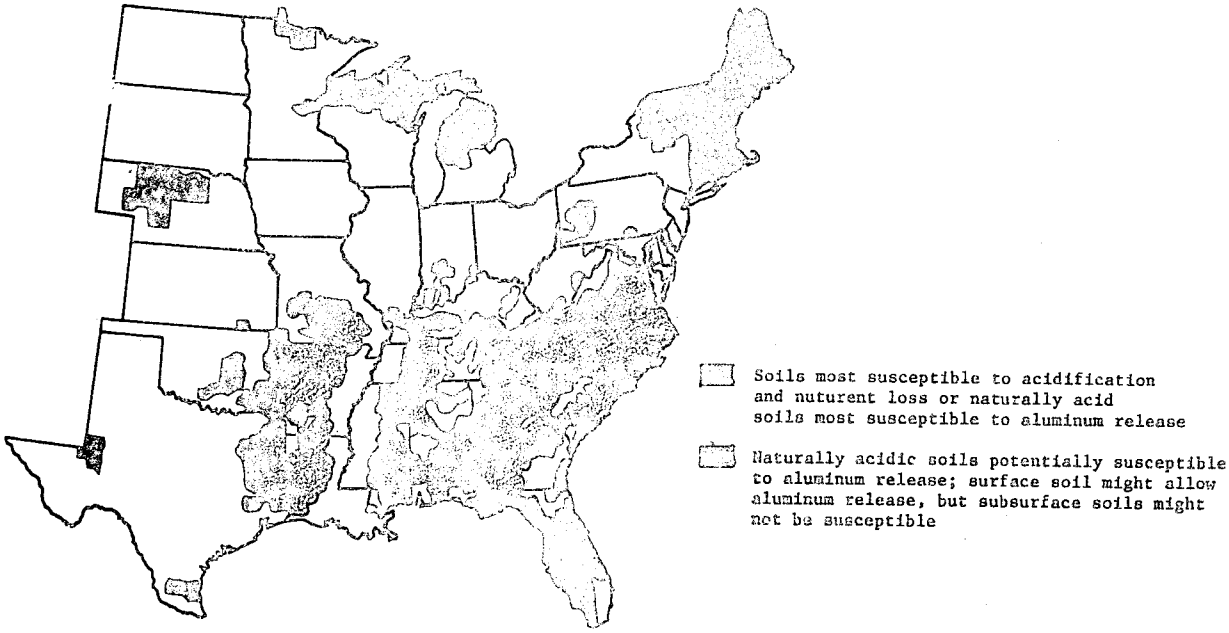

Figure 9-5.--Regions where soils (in forested and range areas) are sensitive to acidic deposition (Oak Ridge National Laboratory, 1983).

Average daytime concentrations of ozone vary considerably throughout the conterminous United States during the growing season. The amounts were charted nationally for 1982 (fig. 9-6).

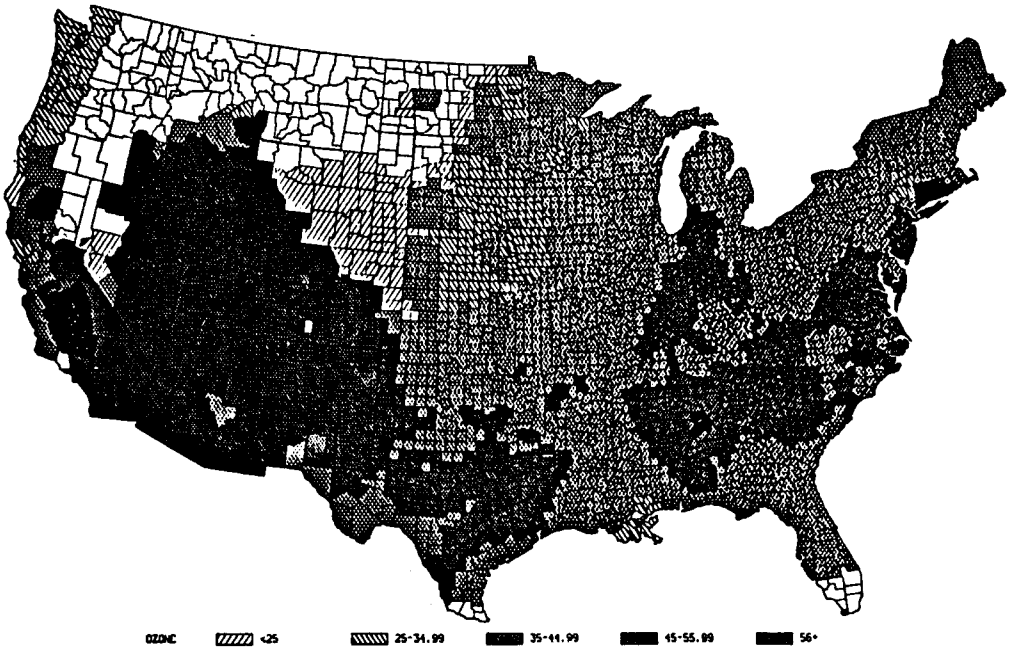

Figure 9-6.--Ozone concentrations, 7-hour daytime average (0900-1600), April through September (1982). Local peak concentrations caused by urban influence are not shown.

WHAT ARE THE KNOWN EFFECTS OF OZONE AND ACIDIC DEPOSITION ON CROPS, FORESTS, SOILS, AND SURFACE WATERS?

Crops

Ozone accumulations in the lower atmosphere are known to reduce yields of many crops and other plants. Vegetation damage from constituents of photochemical air pollution (ozone and associated oxidants) was first proved in the mid-1940's by agricultural scientists in the Los Angeles basin (Middleton et al., 1950). Ozone, however, has not been demonstrated to have harmful effects on soil or water resources.

Crop productivity is significantly affected by ozone on a broad regional basis and--especially in the vicinity of point sources--by sulfur dioxide (SO_2). The National Crop Loss Assessment Network (NCLAN), an Environmental Protection Agency (EPA) program, has studied the effects of ozone on selected crop species. NCLAN experiments estimated yield losses, for crops exposed to ozone at concentrations of about 50 parts per billion (ppb) in ambient air, as follows: soybeans, 9 to 18 percent yield loss compared to yields in clean air (natural background ozone of about 25 ppb); corn, less than 1 to 3 percent yield loss; wheat, 6 to 16 percent; cotton, 3 to 20 percent; peanuts, 13 percent; lettuce, 22 percent; and kidney beans, 3 percent. When ozone concentrations around those crops are artificially increased above 50 ppb, yield losses are generally greater.

Data from NCLAN field experiments were used to develop dose-response functions that express the changes in yield of corn, soybeans, wheat, cotton, grain sorghum, barley, and hay resulting from changes in ozone. These functions were used in a large-scale model of the U.S. agricultural sector to evaluate the effects of hypothetical reduction or increase in ozone levels over crop-growing regions (Adams, Hamilton, and McCarl, 1984). The model also calculates changes in the livestock economy as the effects of changes in crop prices caused by ozone work their way through the agricultural system. An EPA study concludes that reducing ozone levels 25 percent would result in a benefit to society of $1.6 to $1.9 billion, with both farmers and consumers sharing in the benefit. Conversely, a 25-percent increase in ozone levels would result in a cost or loss to society of $1.9 to $2.3 billion, with both farmers and consumers sharing in this loss. Comparable studies by other economists reach generally similar conclusions.

Experiments with simulated acid rain conducted for the National Acid Precipitation Assessment Program (NAPAP) and the National Atmospheric Deposition Program (NADP) have shown little or no resulting reduction in crop yields. Test plots showed no yield reductions for corn and wheat; yield was reduced for only one soybean variety. Controlled experiments are still under way on clover, timothy, tomatoes, potatoes, cotton, tobacco, alfalfa, and peanuts. Preliminary results show no significant reduction in yield of these crops resulting from simulated acid rain. Possible effects on other crops are under investigation.

Forests

Ozone is causing injury to ponderosa and Jeffrey pine in California and to some eastern white pine in the East. There is evidence that this problem is increasing. Unexplained growth loss is occurring in red spruce in New England. The same condition afflicts spruce along the Appalachians, pitch pine in New Jersey, and some commercial pine in the Piedmont region of the Southeast. Other symptoms of decline have been documented, such as early mortality and loss of foliage. There is currently no conclusive scientific evidence linking acidic deposition to these problems. Circumstantial evidence suggests that acidic deposition plays a role in the spruce decline, because deposition rates are greater at the high elevations where the problem is more pronounced.

In numerous laboratory and greenhouse studies, tree seedlings have been exposed to simulated acid rain, alone or in combination with other air pollutants. The results so far are variable and difficult to interpret. Pitch pine seedlings grew better with more acidic treatments. The effect of simulated acid rain on loblolly and shortleaf pine was to limit root length; ozone exposure reduced shoot growth in those two species. Red spruce growth was stimulated by combinations of simulated acid rain and mists. White oak showed a reduction in the width of growth rings, but an increase in height. Response in many studies varied dramatically with soil type. Initial growth increases could be due to the nitrate in acidic deposition, but long-term effects of the removal of nutrient cations (especially calcium and magnesium) from the soil by acid deposition have not been determined. One study showed a reduction in the incidence and vigor of ectomycorrhizae on loblolly pine roots.

Surface Waters

Watershed-level research aimed at determining the effects of acidic deposition on surface waters and soil processes has been active much longer than analogous research on forests. There is sound evidence that acids in rainfall contribute to acidification of some lakes and streams in certain areas and that these acids, falling on soil or bedrock, mobilize aluminum and other heavy metals, which in turn can injure the aquatic environment. In some areas, fish populations and other aquatic life are being adversely affected by acidification. For example, about 180 lakes in the Adirondacks were reported, in studies dating from the mid-1970's, to have become acidified and to lack fish. These lakes cover roughly 18,000 acres, about 6 percent of the total lake surface area in the Adirondacks. Soil alkalinity in that region is naturally low, however, and lake acidification can be a natural process there even in the absence of acid rainfall. The degree to which acid rain has caused acidification of those lakes has not been established, although the evidence points to deposition acidity as an important influence.

Stream acidity does not seem to be increasing in the Southeast as it has in some northeastern systems. Studies in the central Appalachians indicate that undisturbed watersheds are effective in neutralizing acids received in precipitation. Nevertheless, the resulting accumulation of sulfate and net loss of cations could lead to acidification and nutrient depletion in the future. A recent finding shows the buffering capacity of some New England soils is in their mineral, not their organic layers.

Because liming affected waters temporarily reduces acidity, the cost of liming can be an approximation of the dollar value of the damage to an aquatic environment. However, liming may not fully counteract aquatic damage if heavy metal toxicity is not adequately controlled or if fish spawning grounds in streams are not limed. In addition, liming needs to be repeated every few years.

Massachusetts and New York established small-scale, experimental liming programs in 1957 and 1959 respectively. In New York the costs of treating ponds and lakes with crushed limestone have ranged from $90 to $300 per acre, depending largely on whether the site is accessible by road or boat or only by aircraft.

A recent study (Menz and Driscoll, 1983) estimated that a 5-year program for liming all the known acidified lakes in the Adirondacks would cost from $2 to $4 million per year, depending on the desired buffering level. This estimate does not include the costs of restocking fish or of monitoring chemical and biological changes in treated waters.

Soils

Several soil studies have addressed the effects of acidic deposition on chemical leaching and metal mobility. Soils in Maine, Tennessee, South Carolina, and North Carolina showed an increase of 50 to 100 percent in ion movement under treatments with simulated acidic deposition. Some sites have shown a net gain in calcium or potassium from deposition, so increased leaching may not necessarily lead to net losses of all nutrient cations. Under extremely acid conditions, soils release aluminum, which is toxic to plants; however, the release of aluminum depends not only on soil pH but also on the soil's organic matter content, cation exchange capacity, and mineralogy. Simulated acid rain at pH 4.0 seems to have little effect on aluminum mobility, but at pH 3.0 more aluminum is released. Cropland soils are generally not thought to be at risk because agricultural liming normally adds bases at rates far surpassing deposited acids.

Both nitrogen and sulfur are nutrients utilized by plants in active growth. For unmanaged forests, atmospheric deposition is often a major source of available nitrogen. Where nitrogen and (less commonly) sulfur are in short supply, their deposition in dilute acid form may take on economic value. For example, many soils in the Southeast are deficient

in sulfur. One experiment using tracer methods found that as much as 50 percent of the sulfur used by some crops in the Tennessee Valley states came from atmospheric deposition. The annual value of atmospheric sulfur in that area was then (1979) estimated to be about $0.40 per acre on the basis of the mechanically applied sulfur it replaced.

Since the average amount of ammonium-nitrogen plus nitrate-nitrogen deposited from the atmosphere is about 4½ pounds per acre per year, that amount would be worth about $1.04 per acre at an average cost of $0.23 per pound of purchased nitrogen (1981). This estimate does not consider volatility of the nitrogen, loss by runoff, season of deposition, or site of deposition, such as harvested cropland, grassland, or forest.

WHAT IS USDA'S ROLE IN STUDYING ATMOSPHERIC DEPOSITION?

In 1977, the Department of Agriculture in cooperation with the state agricultural experiment stations organized the National Atmospheric Deposition Program (NADP). Known then as Regional Project NC-141, the project was to design a national atmospheric deposition monitoring network and to conduct research on possible effects of atmospheric deposition on agricultural crops and soils, forests, surface waters, and materials. Additional cooperators on the project include the state schools of forestry, other federal agencies, industry, and scientists from other countries, notably Canada. Collection of wet-deposition samples began in 1978. The NADP network has grown to some 180 sites, including 150 National Trends Network (NTN) sites that were mandated in the 1980 Acid Precipitation Act.

The 1980 Acid Precipitation Act also authorizes the federal National Acid Precipitation Assessment Program (NAPAP), a 10-year program to provide information necessary for eventual decisions on pollutant emission controls. The Department of Agriculture has the lead responsibility in studies on the effects of atmospheric deposition on crops, forests, soils, and watersheds. The research is being done at universities, national laboratories, and experiment stations. The Department also has a formal agreement with the Federal Republic of Germany for a scientific exchange program on atmospheric deposition.

The Department of Agriculture is a key participant in the National Crop Loss Assessment Network (NCLAN), which was established in 1980 under the leadership of EPA. Activities of this network have been undertaken by scientists from EPA, USDA, several major universities, and the Argonne, Brookhaven, and Lawrence Livermore National Laboratories. NCLAN objectives are: to define the relationships between yields of major agricultural crops and doses of ozone, sulfur dioxide and oxides of nitrogen, and their mixtures, as required to satisfy the needs of economic assessment and to support the development of national standards for ambient air quality; to assess national primary economic consequences resulting from exposure of

major crops to air pollutants; and to gain understanding of the mechanisms that determine crop response to pollutant exposures.

The Forest Service together with EPA has begun a National Vegetation Survey in the eastern United States to identify forest areas that show unexplained decline. The same agencies have established research cooperatives to assess the effects of acidic deposition and associated oxidants on major forest types.

EPA has conducted a National Surface Water Survey, based on a statistical sample of lakes and stream reaches in the East and lakes in the upper Midwest, which will be used to estimate the number of acidic lakes and streams in those regions. This survey also formed part of the groundwork for the National Direct/Delayed Response Project, in which SCS scientists have furnished data on the soils and vegetation in selected watersheds to EPA's system modelers. The project will classify the watersheds according to their susceptibility or resistance to the effects of acidic deposition.

A bibliography is included in chapter 13 of this report.

Offsite Effects of Erosion and Runoff

Agricultural production can result in damages far beyond the farmer's fields and pastures. It is the greatest contributor to nonpoint source pollution. Erosion on and runoff from agricultural land damage water, air, and land offsite. Sediment decreases water storage capacity in lakes and reservoirs, clogs streams and drainage channels, causes deterioration of aquatic habitats, damages water distribution systems, and decreases cropland productivity. These damages have long been recognized. Today, new technology has brought us new problems. Erosion and runoff from agricultural lands carry chemicals to pollute the water. Irrigation in the West increases salinity.

Methods to quantify the costs of these damages have not been completely developed. This appraisal reports the estimates available. The offsite costs of water erosion are estimated to be about $6.1 billion annually. The offsite costs of wind erosion are estimated to be at least equal to those of sheet and rill erosion. These figures are preliminary and partial. Efforts are continuing to develop more precise and complete estimates.

The linkages between the reduction in soil erosion and the resultant reductions in offsite damages are not fully understood and need to be studied further. Assuming that erosion were reduced to the levels projected under the "low stress" and "high stress" conditions analyzed for this appraisal, preliminary analysis indicates that annual offsite benefits could range from $32.5 million to $145.5 million in the year 2030.

EROSION AND RUNOFF DAMAGE WATER QUALITY

The major offsite effect of erosion and runoff from agricultural land is on the quality of the water in the nation's streams, reservoirs, and lakes (CAST, 1982). Table 10-1 shows the number of states where nonpoint source pollution is reported to be a problem. In judging severity and geographic extent of nonpoint source pollution, state agencies considered the degree to which each source impaired designated uses. States assessed only a small percentage of the nation's waters, but their evaluation indicated that in 1982, 27 percent of river and stream miles were not supporting or were only partially supporting intended uses (ASIWPCA, 1984). Nonpoint sources were ranked as the principal sources of pollution by 26 states and were ranked second by another 13 states. As point sources of water pollution are "cleaned up," the relative importance of nonpoint source contributions increases.

Agricultural areas are only one source of nonpoint pollution. Other sources include areas of silviculture (forestry), mining and resource extraction, construction runoff, waste disposal, salt water intrusion, hydrologic modification, and urban runoff. These other sources can produce harmful or objectionable material in sufficient quantities to adversely affect the quality of water used by agriculture.

Since the passage of the Water Pollution Control Act Amendments of 1972, Public Law 92-500, some information has been gathered about the effects on water quality of nonpoint sources of pollution. These data tend to be

Table 10-1.--Number of states reporting nonpoint source pollution problems (number of responding states = 47)

Source of pollution	Severity			Geographic extent	
	Severe	Moderate	Minor	Widespread	Localized
Agricultural	16	20	8	29	12
Urban	11	20	12	8	35
Land-based water disposal	15	10	13	2	36
Construction	6	23	14	7	34
Dams & channels	7	18	14	5	33
Forests	4	7	21	6	27
Salt intrusion	2	9	10	1	21

Source: Association of State and Interstate Water Pollution Control Administrators (ASIWPCA), 1984.

fragmentary, often site-specific, and not generally applicable to other areas in the United States. However, some pollution data are available at the national level. Table 10-2 identifies possible agricultural and other sources of point and nonpoint source pollution.

Table 10-2.--Sources of pollution

Pollutant/Pollutant category*	Possible sources (alphabetically)
Biological oxygen demand/dissolved oxygen depletion (BOD/DO)	Agriculture (animal & plant waste); Combined sewers; Industries (particularly pulp & paper mills); Municipal wastewater treatment plants; Natural sources
Bacteria (pathogens)	Agriculture (feedlots, manured cropland, pastures, and rangeland); Combined sewers; Municipal wastewater treatment plants; Natural sources
Nutrients	Agriculture; Combined sewers; Construction runoff; Municipal wastewater treatment plants; Natural sources; Septic systems; Silviculture
Toxics	Agriculture (pesticides); Combined sewers; Industries; Land disposal of wastes; Municipal wastewater treatment plants; Silviculture; Spills; Urban runoff
Dissolved solids (salinity)	Agriculture; Combined sewers; Mining; Urban runoff
Suspended solids	Agriculture; Combined sewers; Construction runoff; Industries; Mining; Silviculture; Urban runoff

* Other categories, not of agricultural origin, are pH (see chapter 9, Atmospheric Deposition) and ammonia.

Several efforts have been made to estimate the relative magnitude of loadings from agricultural land to the nation's waterways. Table 10-3 shows the state government estimates of the relative magnitude of nonpoint and point source loadings, by selected pollutant. Results from the Resources for the Future (RFF) Environmental Data Inventory are summarized in table 10-4 (RFF, 1986).

Table 10-3.--Nonpoint and point source pollution loadings

	Source				
	Nonpoint			Point	
Pollutant	Agriculture	Other	Total		Total
Pesticides (tons/yr.)	2,064	115	2,179	N/A	2,179
Total phosphorus (thous./tons/yr.)	1,431	182	1,677	330	2,007
Biological oxygen demand (mil./tons/yr.)	27.3	3.1	30.4	3.1	33.5
Total suspended solids (mil./tons/yr.)	1,787	928	2,715	4	2,719

Source: ASIWPCA, 1984.

Table 10-4.--Agricultural nonpoint source loadings, by source and selected pollutant

	Source						
	Land use 1/						
Pollutant	Crop	Pasture & range	Forest	Other	Stream-bank	Live-stock	Total
Sediment (mil./tons/yr.)	897	337	156	193	553	---	2,136
Pesticides (tons/yr.)	2,037	27	N/A	115	---	---	2,179
Total phosphorus (thous./tons/yr.)	615	333	495	182	---	52	1,677
Biological oxygen demand (mil./tons/yr.)	14.1	6.1	6.4	2.8	0.3	0.7	30.4

Source: Resources for the Future, 1986.
1/ Includes both federal and nonfederal lands.

Pollution of Surface Water

Determining the extent to which agricultural nonpoint sources contribute to the total pollutant load in a given surface water body is difficult. Agricultural nonpoint source pollution is generated by widespread land use activities and is conveyed to waterways through natural processes such as storm runoff or groundwater seepage rather than by deliberate, controllable discharge. It is not amenable to "end of the pipe" treatment, but can be controlled by changes in land management or cultural and structural practices. Monitoring the entire U.S. rural countryside for agricultural nonpoint sources of pollution is not practical or affordable.

In addition to the presence of potential pollutants at a specific site, other factors affect the potential for a given area of agricultural land to cause pollution of surface water. These factors include the soil types present, the population density, land use, the proximity of land management activities to water bodies, the ways in which pollutants are transported to water bodies, and runoff as determined by climate and the characteristics of the land where precipitation occurs. For example, heavy clay soils may affect surface water quality more than sandy soils, which may have more potential for contributing to groundwater quality problems. Whenever land is in a disturbed state, the risk increases that site pollutants will escape the disturbed area. Land management is a human activity, and water pollution is defined as a manmade or man-induced condition. Population is thus an important factor. Moreover, the use of water by man generally determines water quality needs for an area.

The pollutants assessed in this appraisal are pesticides, nutrients, animal wastes, sediment, and salinity. Figure 10-1 displays the composite potential for nonpoint source pollution of surface water by these pollutants. Information from Animal Waste (figure 10-7), Salinity (figure 10-9), Nutrients (figure 10-3), Pesticides (figure 10-2), and Sediment (figure 10-8) data sets were combined. The analysis weighted the major agricultural pollutant categories, rating their effects on human life and health above their economic importance, in order to emphasize areas where pollutant contributions must be considered most critical. The weightings are:

Pesticides	4.0
Animal Waste	3.0
Nutrients	2.5
Salts	2.0
Sediment	1.0

Based on these weightings, a composite rating for combined potential nonpoint source problems was determined. If there was a high potential rating for three or more of the five categories (or an equivalent), the area received a composite rating of "high" for potential nonpoint source problems. If there was a high potential rating for two pollution categories (or an equivalent), the composite potential rating was

"medium," otherwise a "low" potential rating was made. Even though an area may have a low rating on the composite potential list, it could still have a high potential for one category of agricultural nonpoint source pollution. This composite approach is one possible method for establishing overall priorities for nonpoint source programs and funding decisions.

Pesticides.--Chemical compounds used to kill plant and insect pests may become toxic pollutants. In 1984, the U.S. Environmental Protection Agency (EPA) stated that 23 of the 50 states, Puerto Rico, and the Virgin Islands reported agricultural pesticides as a priority pollution problem. The reported estimates were based on interviews with state water quality agency personnel and from available information. Specific streams and lakes were not identified in this report.

Figure 10-2 indicates the areas that have a high potential for pesticide problems. The amount of pesticides applied in each area was determined from various data sources and divided by the total acres of agricultural land in the area. A composite index of runoff and application rate for each area was developed to provide a basis for comparing potential for pesticide pollution.

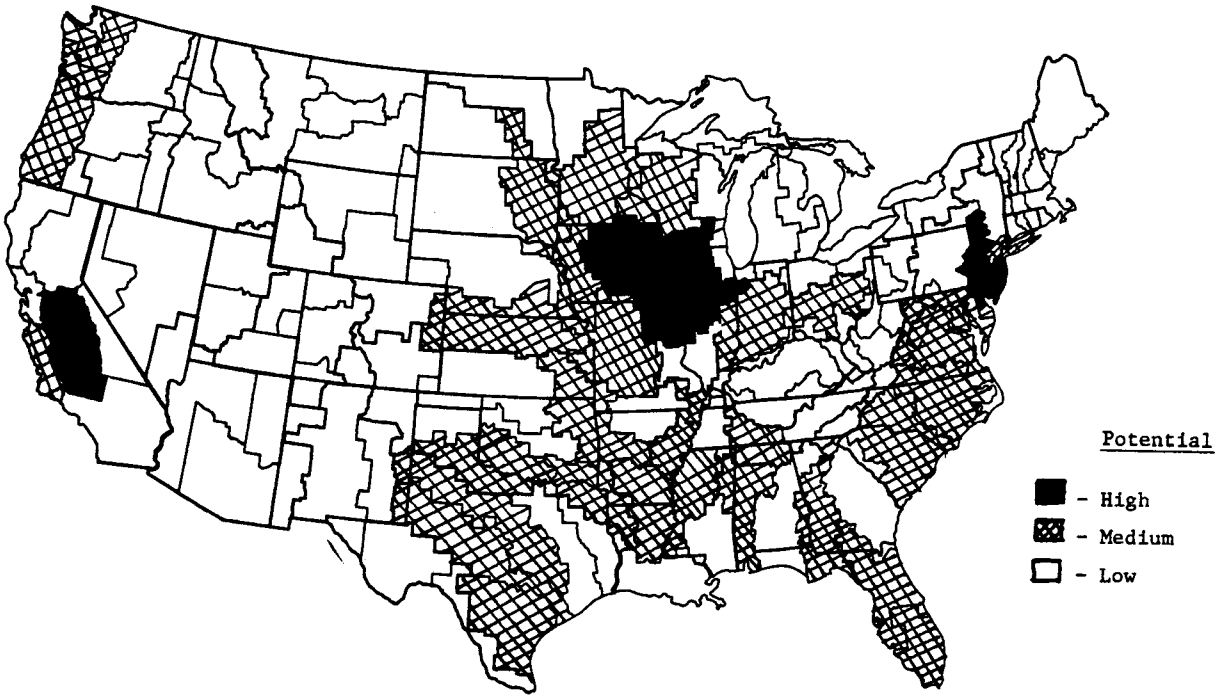

Figure 10-1.--Composite potential for nonpoint source pollution of surface waters.

Pesticide contamination of water has been recognized as a problem since the 1960's. The pesticide group of primary concern at that time was the chlorinated hydrocarbons. These chemicals have "biomagnification" effects resulting from their long period of persistence in the environment. They can be monitored by testing for their presence in fish tissue. Most of them have since been banned for agricultural use. The National Water Summary 1984 concluded that chlorinated hydrocarbon insecticides have decreased in both water and streambed material of major rivers, and no clear trends are evident in concentrations of the organophosphate insecticides and herbicides that were monitored.

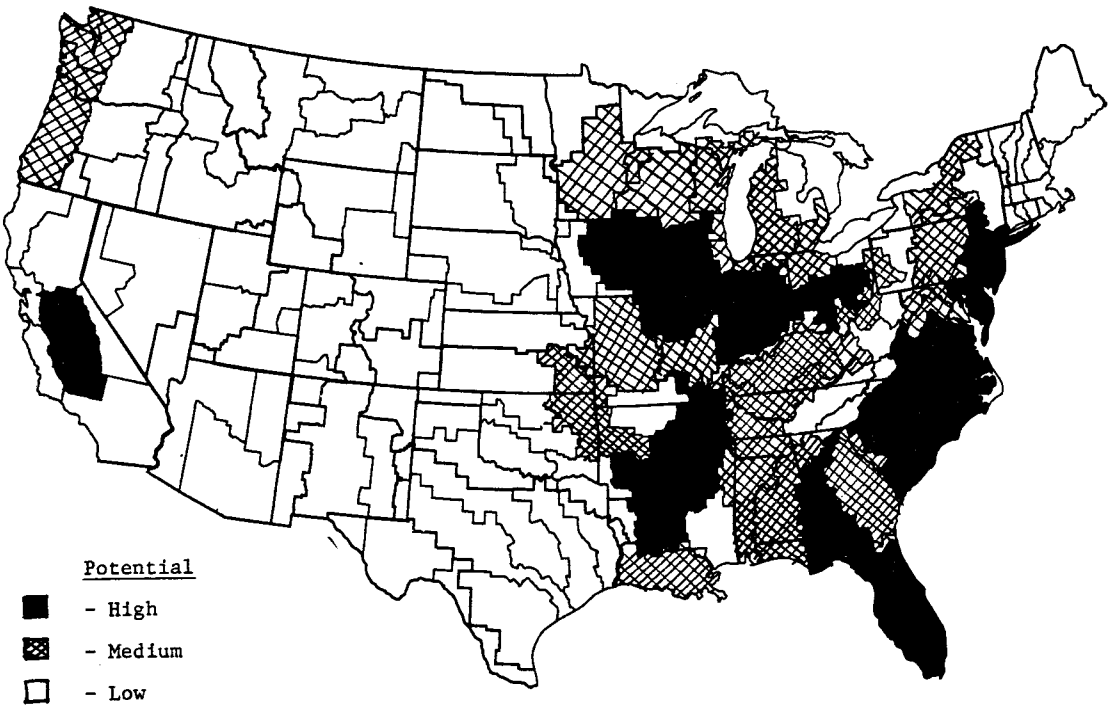

Figure 10-2.--Potential for pesticide problems.

This map identifies those areas having the greatest estimated potential for surface water pollution by pesticides. The pollution potential was determined by using estimated crop acreages for different parts of the country, multiplied by pesticide application coefficients for 184 pesticides. These values were then multiplied by an availability factor which estimated the percentage of an application leaving a field and then adjusted that figure by a runoff value for the growing season. This process estimates pesticide delivery for each area. To confirm the existence of pesticide pollution, instream and lake monitoring will be necessary.

Pollution from pesticides can occur at any location. The more recently developed pesticides are more toxic and less persistent; therefore, any adverse effects on water quality frequently will be close to the application site. It is very difficult to sample these waters and capture the chemicals for laboratory analyses. When a fish kill occurs, the chemicals may be diluted, reduced in toxicity, or washed downstream before the stream can be sampled. Pesticides with longer persistence can have an effect farther downstream, and some will accumulate in fish tissue where it can be retrieved for analyses. The use of more target-specific insecticides, better management, and improved application equipment may be reducing the total quantity of insecticide used by farmers. The trend from 1976 to 1982 shows a decline in insecticides but an increase in herbicides usage. A report on ground water contamination by agricultural chemicals is shown in the ground water section.

Nutrients.--Generally, the nutrient forms that affect water quality are particulate and dissolved phosphorus and nitrogen as ammonia, nitrite, and nitrate. The concentration of a nutrient, even more than its form, governs its effect on water quality. Nitrogen and phosphorus may have a toxic effect on water and its inhabitants or may stimulate plant growth. Overabundant nutrients--most often, phosphorus--in a water body can create a condition known as eutrophication, which is characterized by very high vegetative production and very low levels of dissolved oxygen. Periodic "algal blooms" occur, in which a thick green scum of algae covers the water surface. A lake in this condition is unattractive for recreational uses and unfavorable to fish. Eutrophication is a normal process that occurs in the later stages of a lake's existence as the lake fills up with sediment. Where the excess nutrients originate from human activity, eutrophication is not a natural process but is a result of pollution.

Nitrogen and phosphorus are frequently found in organic associations and are transported in water largely in that form. Nutrients readily change from one form to another, depending on the presence of water and oxygen, ambient temperature, pH, and other environmental factors. Phosphorus, organic nitrogen, and (to some extent) ammonium adhere more or less tightly to mineral or organic particles. Detachment and transport of these particles by water depend upon the kinetic energy of rainfall and the hydraulic energy associated with overland flow and streamflow.

Nutrient sources may be multiple and diffuse. In the agricultural environment, nitrogen and phosphorus may enter water supplies in runoff and infiltration associated with commercial fertilizer, animal wastes, crop residues, and erosion from cropland. Areas that were evaluated as having significant potential for water pollution by nutrients are displayed in figure 10-3. Potential generally increases in proportion to intensive agricultural land uses, significant cropland erosion, and (to

some extent) population density. The areas generally are heavy producers of sediment, as some nutrient forms are associated with sediment particles.

Health hazards caused by nutrient contamination of private and public water supplies are commonly due to nitrite-nitrogen pollution. Eutrophication is detrimental to fisheries and wildlife, water-based recreation, and esthetic values. Besides the costs of nutrient pollution that farmers share with the general public, there are onsite farm costs caused by wastage of nutrients lost from fields and by lowered crop yields. Individual farm wells and surface water supplies may be harmed by nutrient pollution that makes the water unfit for use.

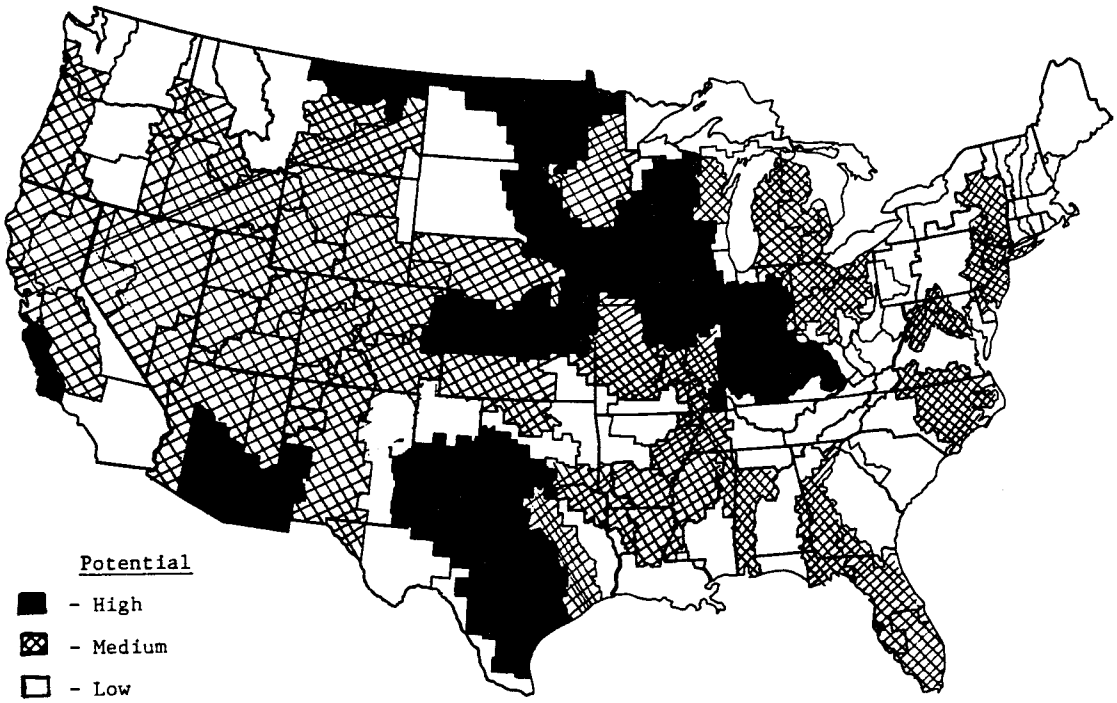

Figure 10-3.--Potential for nutrient problems.

The potential for impairment of water quality was estimated by determining nutrient concentrations by form and comparing them with the respective threshold levels at which they threaten desired water uses.

Source: WATSTORE (U.S. Geological Survey data from water quality stations)

Animal Waste. Animal wastes may cause water contamination. The primary pollutants in animal wastes are nutrients (primarily nitrogen and phosphorus), pathogenic bacteria, and organic material. Areas where livestock are concentrated, as well as fields and pastures where manure is spread, can be a source of pollutants.

The first step in identifying potential animal waste problem areas was to determine the quantity of manure produced in each area. The number of each type of animal in a county (from 1982 Agricultural Census) was multiplied by a manure production factor for that animal. Then the amounts of manure produced by all the county's livestock were totaled, and the county totals were aggregated by area. The total tons of manure were divided by the acreage of cropland plus grassland (from Agricultural Census) for each area to obtain a relative value of average tons of manure per acre (figure 10-4).

This method does not consider such factors as soil conditions, runoff conditions, proximity of waste to streams, waste management operations, etc. It does provide a beginning assessment to help focus on where the potential for animal waste problems is highest.

Figure 10-5 shows potential for pollution if additional factors are taken into account. These factors are percentage of manure needing improved

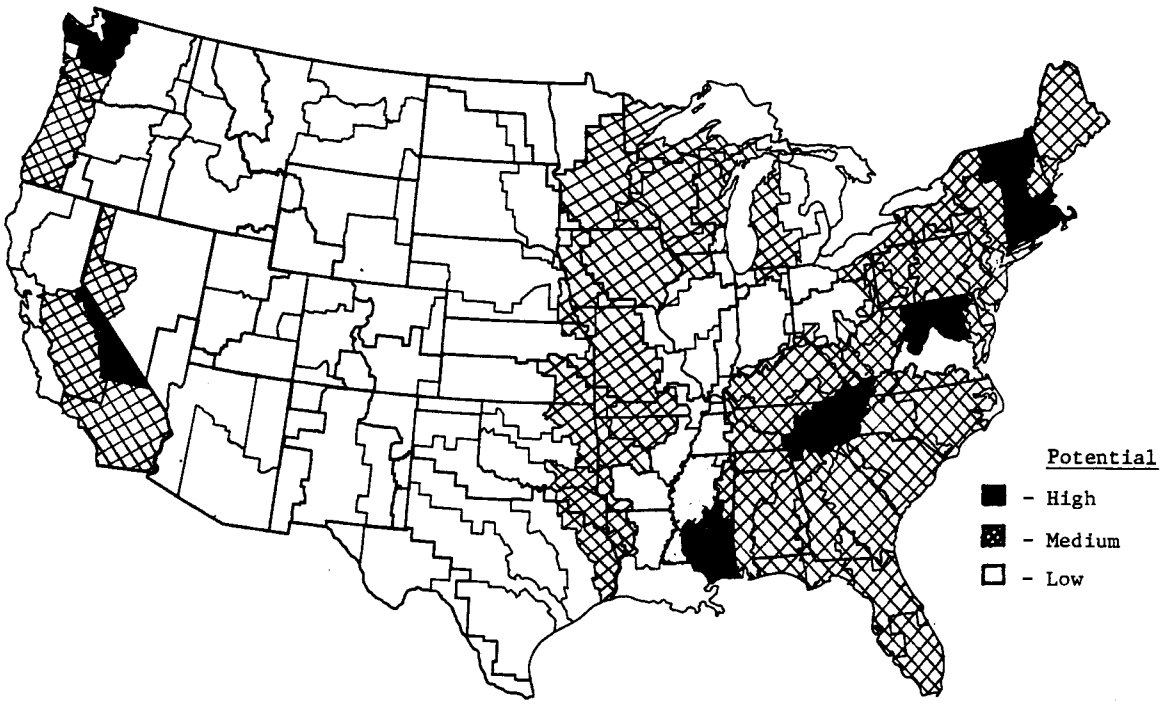

Figure 10-4.--Tons of manure per acre of cropland and grassland.

waste management, the percentage of cropland and grassland associated with animal enterprises, runoff from precipitation, ratio of feed purchased to feed produced on farm, and ratio of nitrogen (N) and phosphorus (P) available from manure to crop N and P needs.

The potential for animal waste problems is high in areas with very large populations of livestock, notably in the southeastern and southwestern parts of the United States. The large quantities of manure produced in these areas need management, often in areas where cropland and grassland are in short supply. In relatively dry regions where crops are irrigated the application of irrigation water and manure on cropland and grassland increases the potential for problems. These warmer, dryer areas have open feedlots, where rainfall concentrates nutrients and organics in runoff. Problems are also more pronounced in the humid areas along the Gulf of Mexico and the Atlantic seaboard, where there is more rainfall.

Although the analysis does not indicate areas in the northeast as highly critical, conditions there do suggest potential could be high. The growing season is short and the soil is frozen or snow-covered for long periods. Livestock enterprises must keep animals confined during the winter. Confined livestock operations generate large quantities of manure that must be handled, and less time is available to spread it. Unit costs of developing and operating waste management systems are

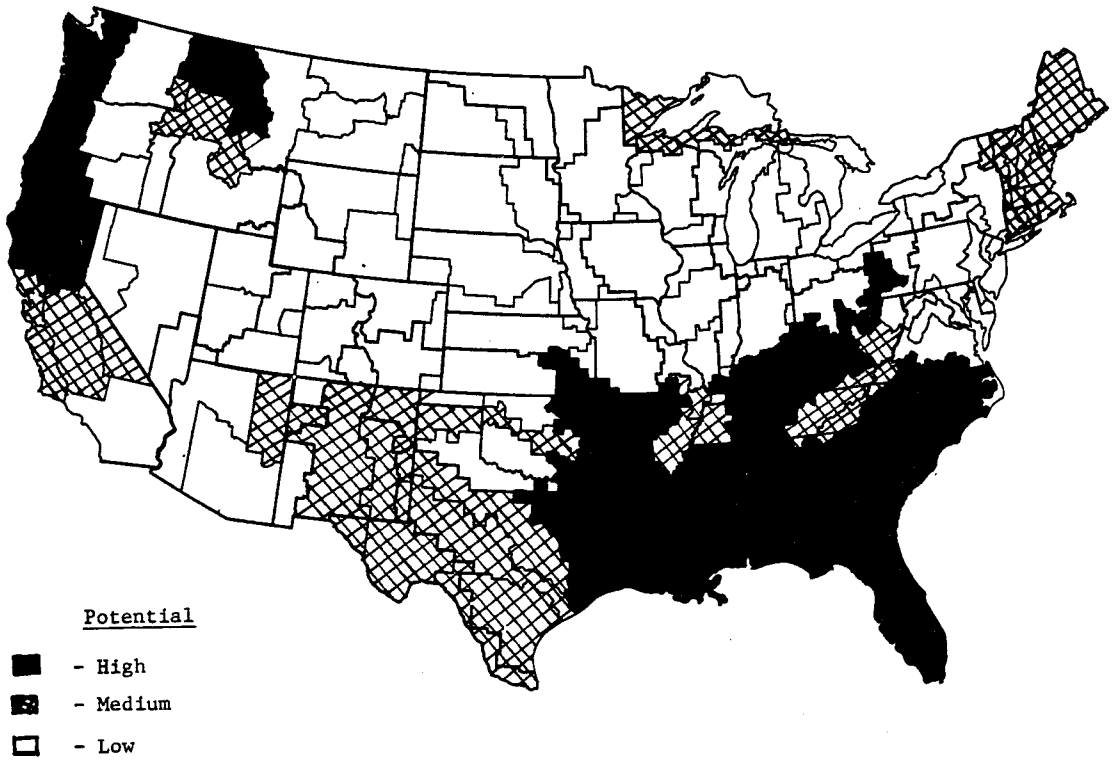

Figure 10-5.--Potential for animal waste problems.

higher than in southern areas. Often these costs are high enough to impede installation of improved systems. Much of the farmland in the north is sloping to steep, and perennial streams are abundant.

In the Corn Belt, large livestock enterprises are generally associated with commensurately large areas of highly productive cropland with moderate to flat topography. Livestock producers grow much of their own feed and cycle the manure. Managing manure here takes less intensive management than in other areas. The analysis indicates that these areas have a low to moderate potential for pollution. However, certain localized conditions cause problems that are masked because of the large area of consideration. In some areas in the Northeast and Corn Belt, large numbers of animals are concentrated on relatively small acreages of farmland, but pollution potential is low to moderate because many manure management systems have been implemented in the past 15 years.

Sediment.--It is estimated that 5 billion tons of soil per year are detached by sheet and rill, streambank, classic gully, road, and construction site erosion. This does not include soil movement by channel degradation (bottom erosion) on larger streams, flood plain scour, ephemeral gully erosion (concentrated flow erosion on cropland), and mass wasting (landslides, creeps, etc.). Much of the detached soil is deposited near the location where movement begins (fig. 10-6). It settles on features such as terraces, toes of slopes, edges of fields, and in furrows and ditches. However, about 2.6 billion tons of sediment annually reach small streams. While streambank and classic gully erosion account for only 17 percent of the estimated erosion, they account for about 30 percent of the sediment yield to small streams. If the

Figure 10-6.--This sediment was eroded from surrounding fields during one heavy rainfall.

contribution from ephemeral gully erosion were included, the proportions of both erosion and sediment yield derived from stream and gully erosion would be much greater.

The amount of sediment reaching the oceans (500 million tons per year) is less than 10 percent of total erosion and less than 20 percent of sediment entering small streams (Curtis et al., 1973). Great quantities of sediment are deposited on flood plains and in ponds, reservoirs, channels, and wetlands. Figure 10-7 shows the potential for sediment (total suspended solids) problems by aggregated subareas (ASA's) as determined from data provided by Resources for the Future (RFF).

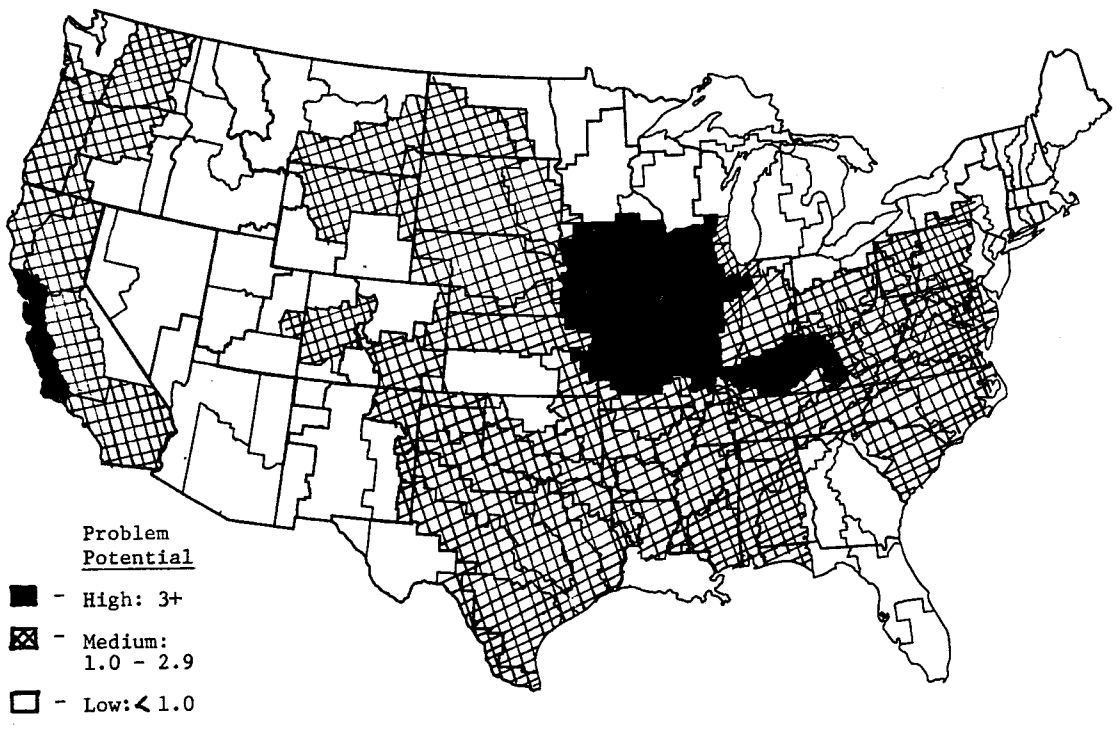

Figure 10-7.--Estimated sediment yield (tons per acre per year).

Potential was determined by estimating the percentage of sheet and rill erosion that becomes sediment in small streams. It was assumed that sediment delivery rates are higher in areas where streams are more numerous and closely spaced and where the surface soils have more fine particles (silt and clay). Also estimated were amounts of pollutants adsorbed by sediment particles moving into streams, including nutrients (N and P), organics, and pesticides.

Sources: (1) 1982 National Resources Inventory (USDA-SCS, 1984)
(2) USGS Surface Soil Surveys
(3) USDA Soil Survey Laboratory Data State Reports

Salinity. Most salts are readily soluble in water and thus are subject to transport. Salts are carried as dissolved solids and as suspended solids attached to sediment. Table 10-5 shows that, on the average, rivers across the country carry a heavier weight of minerals as dissolved solids than as suspended sediments. Yet the problems of soil salinity and high salt concentrations in streamflows are almost exclusively limited to arid and semiarid regions. Concentrations of dissolved solids in rivers draining the more humid areas of the midwestern, eastern, and Pacific states rarely exceed 300 milligrams per liter (mg/l), whereas salt concentrations commonly exceed 800 mg/l in streams in the watersheds of the Rio Grande and Colorado Rivers and in the Great Basin.

A major factor is the amount of water available year-round for transporting the salts. Other factors are the geologic age of the landscape and the accessibility of salt-bearing geologic formations. The geologic youthfulness of the west in comparison with the great river basins of the eastern United States means that water has not had as much time to leach salts from the soil and adjacent formations. In the arid and semiarid west, the most saline formations tend to be near the valley floors. These lowland areas also tend to have the lowest annual precipitation and the least opportunity for natural leaching of salts from the soils and underlying formations. Many soils remain quite saline even after hundreds of thousands of years of exposure to the hydrologic cycle.

Salinity in surface water and ground water results from both natural and manmade causes. Natural causes include salt contribution of saline springs, weathering of the earth's surface through erosion and solution, and the concentrating effects of evaporation and transpiration. Human-caused saline problems result from the acceleration of erosion, the concentrating effects of agricultural consumptive use of water, and deep percolation of irrigation waters that dissolve salts from underlying rock formations. This study looked at salinity resulting from human activities. Surface water and ground water are so interrelated that no distinction can be made between salinity problems which reside primarily in one or the other. Figure 10-8 shows areas with potential for salinity problems.

In the western United States the largest agriculture-induced increase in salinity is due to the concentrating effects of evapotranspiration and loadings associated with irrigation (see chapter 5). On most irrigated fields, the water that infiltrates into the soil is more important in moving salts than is the surface runoff. In a few places, so much irrigation-related erosion occurs that heavy loads of salt are carried off in conjunction with the transported sediments, but in general,

irrigators try to control runoff to get the maximum amount of water into the soil where it can reach plant roots.

Table 10-5.--Relative transport of dissolved and suspended solids

Selected streams near oceans in the conterminous 48 states Sampling location	Weight of material transported Dissolved solids	 Suspended sediments	Ratio of dissolved to suspended material
	----kg/day(avg.)---		
Saco R. at Cornish, ME	1.60E+05 1/	7.70E+04 1/	2.08
Connecticut R. at Thompsonville, CT	2.40E+06	1.40E+06	1.71
Hudson R. at Green Island, NY	3.60E+06	9.80E+05	3.67
Delaware R. at Trenton, NJ	2.30E+06	1.50E+06	1.53
Potomac R. at Chain Bridge, DC	4.00E+06	3.40E+06	1.18
James R. nr. Cartersville, VA	1.30E+06	1.40E+06	0.93
Pee Dee R. nr. Rockingham, NC	1.10E+06	9.00E+05	1.22
Edisto River nr. Givhans, SC	2.60E+05	2.90E+04	8.97
Savannah R. nr. Clyo, GA	1.50E+06	5.90E+05	2.54
Satilla R. nr. Atkinson, GA	1.70E+05	1.00E+05	1.70
Peace R. at Arcadia, FL	2.60E+05	4.00E+04	6.50
Alabama R. nr. Claiborne, AL	6.40E+06	8.80E+06	0.73
Pascagoula R. nr. Benndale, MS	1.20E+06	4.50E+06	0.27
Mississippi R. nr. Belle Chasse, LA	2.70E+08	1.00E+09	0.27
Guadalupe R. at Victoria, TX	1.70E+06	2.70E+06	0.63
Rio Grande R. nr. Brownsville, TX	3.40E+06	3.00E+06	1.13
Sacramento R. at Freeport, CA	4.30E+06	3.80E+06	1.13
Klamath R. nr. Klamath, CA	3.00E+06	1.10E+07	0.27
Tualitin R. at West Linn, OR	2.00E+05	1.00E+05	2.00
Willamette R. nr. Portland, OR	3.60E+06	1.80E+06	2.00
Columbia R. at Warrendale, OR	4.30E+07	9.30E+06	4.62
Skagit R. nr. Mount Vernon, WA	1.30E+06	3.20E+06	0.41
Average ratio			2.07

Source: Derived from unpublished data produced by the National Stream Quality Accounting Network (NASQAN) program, administered by the Geological Survey.

1/ Values are in scientific notation: 1.60E+05 = 1.60×10^5 and 7.70E+04 = 7.70×10^4.

Water normally becomes more saline as it moves downward through a river basin. Irrigation tends to aggravate this increase in salinity by:

- accelerating the leaching of salts through irrigated soils, subsoils, and geologic formations;
- inducing the erosion and transport of salty sediments; and
- concentrating salts in surface water and groundwater when part of the irrigation water is used by plants or evaporates from wet soils or water surfaces.

In the last case the concentration of salts increases, but the volume of salts transported does not. When salt concentration is combined with limited soil drainage, applying irrigation water tends to stop or reduce the transport of salts and to cause them to accumulate at the site.

The most critical salinity problems are commonly hundreds of miles from the source of the salt. Water use impairments caused by salinity can be broadly classed as agricultural and nonagricultural impairments. By far the most common agricultural impairment is reduced crop yields. Another possible impact is physiological upset and death of livestock.

Nonagricultural impairments of water supplies caused by salinity are often ill-defined. Salinity in water can increase human health risks, reduce the effectiveness of household cleaning compounds, cause metal corrosion, and coat the inside of pipes and boilers. The effect of salinity on aquatic habitat is less clear than other impacts, but in general increased salinity levels increase mortality and reduce the growth rate of most freshwater species.

Salts and salinity have a definite effect on household cleaning, particularly as they constitute hardness. Generally, water hardness is measured in units of milligrams per liter (mg/l) of calcium carbonate. Hardness varies from soft (0-8 mg/l) to very hard (above 200 mg/l). The main disadvantage of hard water for cleaning is that calcium and magnesium ions react to soaps by forming soap curds, which wastes the soap and adds to the cleaning problem. Dissolved solids may cause other cleaning problems such as water spotting on glass.

Salinity greatly complicates water treatment and consequently increases treatment costs. Dissolved solids do not respond to the usual settling and filtration techniques used for suspended materials. Removing dissolved substances requires ion exchange, chemical precipitation, distillation, or the latest method of reverse osmosis.

Corrosion caused by specific ions is a widespread problem in individual and municipal water supply systems. A 1976 study estimated that almost

half of the 100 largest cities in the United States distribute water that is in some degree corrosive.

The presence of calcium carbonate can benefit plumbing for a time because, at the proper pH, calcium carbonate is deposited inside the pipes, providing some protection against corrosion. As deposition increases, however, plumbing and household appliances often become clogged and require replacement.

Salinity has similar effects on industrial water users. As with domestic use, a fine line separates industrial deterioration caused by corrosion and that caused by the clogging effect of calcium carbonate.

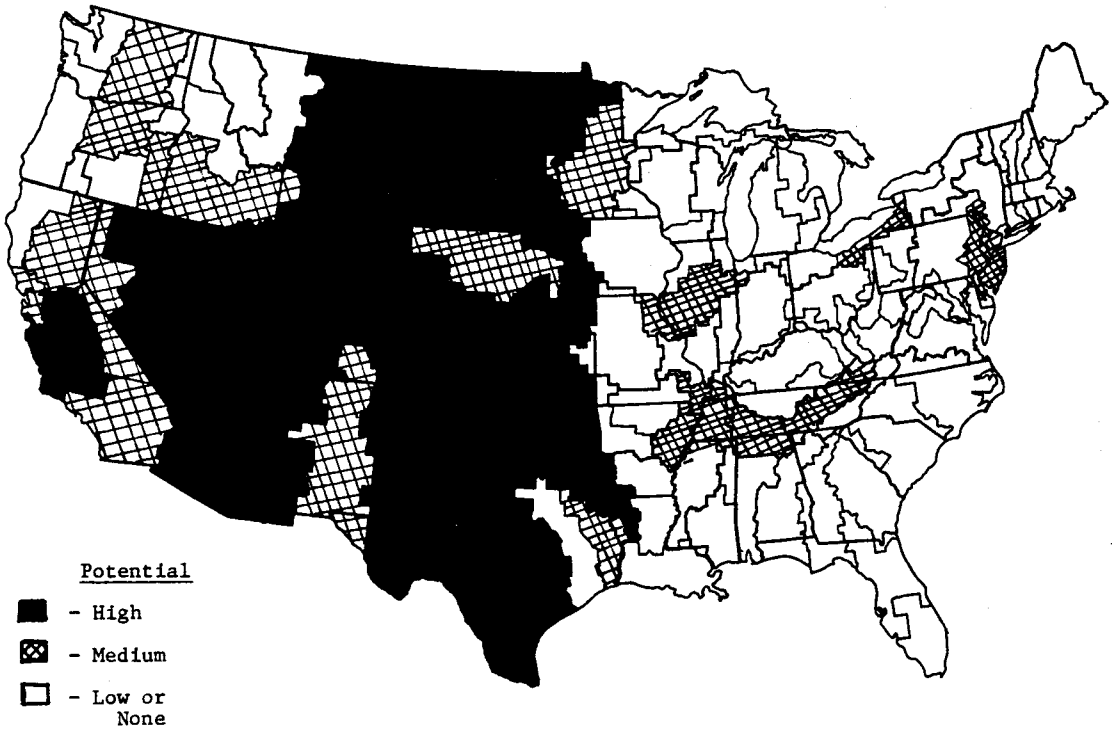

Figure 10-8.--Potential for salinity problems.

To assess potential, indicators of total dissolved solids, adjusted sodium adsorption, and chloride concentration were checked; total solid loads were analyzed, using data for agricultural acreages, areas affected by saline or sodic soils, and irrigated acres as modifying and/or contributing factors.

Sources: (1) U.S. Geological Survey National Stream Quality Accounting Network (NASQAN) stations in ASAs
(2) Published and unpublished data from EPA and USGS

Pollution of Ground Water

Ground water is the water contained in fractures, cracks, cavities, and pore spaces in subsurface geologic formations. The term recharge applies to water entering the ground water system and the term discharge applies to water leaving it. Geologic formations permeable enough to yield appreciable amounts of ground water to wells are termed aquifers, and intervening formations of very low permeability are termed confining formations. The upper boundary of the zone of complete water saturation in the ground water system is called the water table.

The amount of stored ground water beneath the land areas of the world is about 35 times greater than the combined amount of water in all rivers, freshwater lakes, saline lakes, and inland seas. In the United States, aquifers are present practically everywhere but vary widely in the yields water wells can deliver. About half of the water used for drinking water supplies in the United States comes from wells.

Ground water naturally contains various mineral substances that have been dissolved from the local geologic formations. In general, the longer the water remains in the earth, the higher the concentrations of dissolved substances. Water in deep aquifers thus tends to be more mineralized than water in shallow aquifers. Faults in rock systems may act as conduits for ground water flow or may be sealed so tightly with clay or mineral deposits that the ground water flow is blocked. Improper disposal of manmade waste or overapplication of other materials may add extraneous substances to ground water. These actions sometimes degrade the quality of the ground water so that it no longer meets water quality standards for a specific designated use.

In EPA's 1984 Section 305(b) reports, 42 states provided limited information on ground water conditions. This information is largely anecdotal and must be tied to information gained through other studies. Thirty-five states reported some problems with ground water contamination. The most commonly reported sources of contamination are industrial and municipal landfills and lagoons, underground storage tanks, pesticide applications, septic tanks, and chemical, oil, and brine spills. The most commonly reported pollutant groups are chlorinated solvents, pesticides, miscellaneous hydrocarbons (such as gasoline), metals, salinity, and radionuclides. Several states reported problems with ground water depletion and saltwater intrusion.

Although there is no national data base to confirm it, there are examples of the contamination of ground water by nonpoint sources. Ground water pollution from prior and current agricultural use of pesticides and nutrients is being documented. Synthetic organic pesticides are of concern because of their environmental persistence and potential health effects. Nitrates in ground water from fertilizer applications and animal waste have long been recognized as an indicator of nonpoint pollution.

Many states have only limited information on pesticides and nutrients in ground water. However, interest in these contaminants is increasing, and many efforts to gather data are under way. Limited funding for monitoring programs appears to be a major cause of this knowledge gap. Many field studies have been conducted across the nation on agricultural contamination of ground water, but most of them focus on nutrients. Information is steadily accumulating on management practices that reduce loss of nitrate fertilizer to ground water. Pesticide contamination has drawn less attention. Research on the stability and transport of pesticides in ground water is on the increase.

A large number of states do not have laws or regulations governing the application of pesticide or fertilizer. Many existing laws and regulations need updating. In some states the institutional authority for addressing pesticide contamination of ground water is still unclear.

At present, nitrates in ground water are regulated under stricter standards than are pesticides. The large number of pesticides and the lack of information on their persistence in ground water make it difficult to set standards defining pesticide contamination.

A report on ground water contamination by agricultural chemicals in the conterminous United States was prepared for SCS by the Environmental and Ground Water Institute of the University of Oklahoma. As here defined, agricultural chemicals are pesticides and nutrients (primarily nitrogen) originating from applications of fertilizer or of animal waste. Findings on the reported contamination of ground water are given in table 10-6.

Saltwater Intrusion into Ground Water

Water obtained from wells is frequently contaminated by saltwater intrusion. The salinity of ground water generally increases as depth increases. This phenomenon is related to the original deposition of the salt-bearing formations, the movement of ground water, and the movement of individual ions over time.

However, the salinity of ground water is also traceable to other factors, such as proximity to oceans, leakage of wells, upconing of salt under wells, and leaching from surface sources. The effects of salinity may extend for 20 or 30 miles or even more from the source of the salinity toward the area where ground water is being withdrawn.

In 1977, the Environmental Protection Agency conducted a survey of saltwater intrusion. The EPA study does not include a precise assessment of intrusion linked to surface infiltration from agricultural practices. The most frequent cause of saltwater intrusion is excessive pumping, or ground water mining, which has caused lateral intrusion of salt water in 27 states and vertical intrusion in 11 states, according to the EPA

study. Agriculture is not implicated except as a heavy user and consumer of water. Other sources of saltwater intrusion, reported in only a few states, are improper disposal of oilfield brines, faulty well casings, layers of salt water in thick limestone formations, and dredging (which may cause vertical intrusion or upwelling of salt water). Of these, only faulty well casings (six states affected) may relate to surface infiltration from irrigation.

Saltwater intrusion problems, state by state and region by region, are discussed in detail in Chapter IV, Volume III, Part A, "Salt Water Intrusion of Ground Water in the Contiguous United States," Environmental and Ground Water Institute, University of Oklahoma.

Table 10-6.--Ground water contamination by nutrients and pesticides ("n" means nutrients; "p" means pesticides. Absence of an entry indicates that no significant contamination is apparent or that data were not available.)

State	Confirmed*		Suspected	Nonagricultural**
	Regional	Localized		
Alabama		n, p	n, p	
Arizona		p		n
Arkansas				
California	n, p			
Colorado		n, p		
Connecticut	n, p			
Delaware	n	p		
Florida	n, p			
Georgia	n	p		
Idaho		p	p	n
Illinois		n, p	n, p	
Indiana		n, p		
Iowa	n	p		
Kansas		n, p		
Kentucky			n, p	
Louisiana		p		
Maine	n, p			
Maryland		n, p		
Massachusetts	p			
Michigan		n, p		
Minnesota		p	p	n
Mississippi				
Missouri		n, p		
Montana		p		
Nebraska	n, p			n

Table 10-6.--Ground water contamination by nutrients and pesticides--Continued

State	Confirmed*		Suspected	Nonagricultural**
	Regional	Localized		
Nevada				n
New Hampshire				
New Jersey	n, p			
New Mexico		n	p	
New York	n, p			
North Carolina		n		p
North Dakota				
Ohio		n, p		
Oklahoma	n			p
Oregon		n		
Pennsylvania		n, p		n
Rhode Island	p			
South Carolina		p		n
South Dakota	n, p			n
Tennessee		n, p		
Texas	n, p	n, p		
Utah		p	n	
Vermont		n, p		
Virginia			n, p	
Washington	n, p			
West Virginia		p		
Wisconsin		n, p		
Wyoming			n, p	
TOTALS	14n, 12p	17n, 25p	6n, 8p	8n, 2p

* Contamination has been documented by ground water monitoring or by published studies.

** Contamination exists but is due to handling or to nonagricultural activities (for example, phosphate mining).

WIND EROSION REDUCES AIR QUALITY

Wind erosion in the United States moves about 2 billion tons of soil annually. Windblown soil not only robs the land of good topsoil, it also becomes an air quality problem. Respiratory ailments of man and animals are exacerbated. Highway and air vision is impaired. Dust can permeate offices, homes, and factories. Pesticides may be carried long distances. Where dust from soil blowing settles on plant leaves it impairs the plants' ability to use sunlight in photosynthesis. When airborne dust accumulates on leafy vegetables, the quality of the crop may be seriously damaged. Larger windblown particles can damage young plants by abrasion or cut them at ground level.

Some efforts have been made to place economic values on offsite damages resulting from wind erosion. A recent study in New Mexico (Huzar and Piper, 1985) was based on a survey of households and businesses in the state which asked respondents to estimate how much damage, if any, they were experiencing. The answer was about $466 million annually, or the equivalent of an average $3.00 per ton of wind erosion. This estimate suggests that the offsite costs of wind erosion may be larger than had been thought, possibly even comparable to those of water erosion.

Wind erosion is a key factor in reducing visibility in the central United States; as figure 10-9 shows, visual range declines sharply along the north-south line of the Great Plains. In the eastern states atmospheric sulfate outranks windblown dust as a cause of impaired visibility (compare figure 9-3 for conditions in the Northeast).

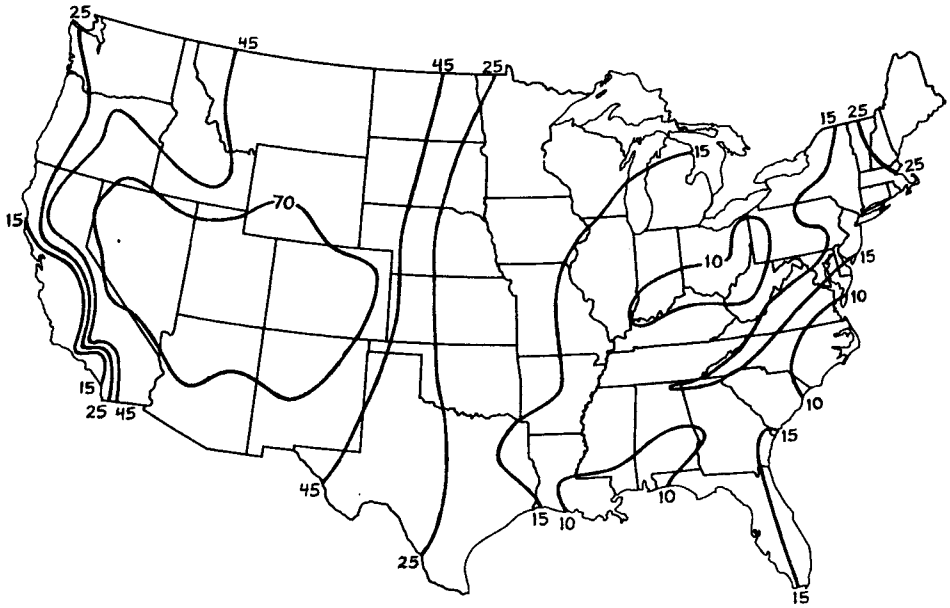

Figure 10-9.--Average annual visual range (in miles) in the contiguous United States.

HOW GREAT ARE COSTS OF OFFSITE DAMAGES CAUSED BY AGRICULTURAL PRODUCTION?

Quantifying the value of the damages caused by erosion and runoff is extremely difficult. No complete estimate is possible. No recognized methodology exists for setting a value on the damage caused to aquatic ecosystems, aside from the impact on recreation. Some costs are accrued or hidden: for instance, ditch clearing or dredging of waterways may be postponed for lack of funds or other reasons. However, studies completed by the Conservation Foundation indicate the offsite costs of all water erosion in 1980 were approximately $6 billion, of which $2.2 billion can be attributed to erosion from cropland (table 10-7).

For estimating costs, the offsite effects of erosion can be divided into instream and offstream effects. Instream effects are those caused by sediment, nutrients, and other erosion-related contaminants in streams and lakes. These contaminants affect aquatic organisms, water-based recreation, water-storage facilities, and navigation. Offstream effects are those that occur before the contaminants reach a waterway, during floods or windstorms, or after water is taken from the waterway to be used by industries, municipalities, or farms (Clark et al., 1985).

Table 10-7.--Summary of damage costs of water erosion

Type of impact	Single-value estimate	Cropland's share
	(million 1980 dollars)	
Instream effects		
Biological impacts	not estimated	
Recreational uses	2,000	830
Water-storage facilities	690	220
Navigation	560	180
Other instream uses	900	320
Subtotal--Instream (rounded)	4,200	1,600
Offstream effects		
Flood damages	770	250
Water-conveyance facilities	200	100
Water-treatment facilities	100	30
Other offstream uses	800	280
Subtotal--Offstream (rounded)	1,900	660
Total effects (rounded)	6,100	2,200

Source: Conservation Foundation

Sediment Deposition

Sediment has other offsite effects besides its effects on water quality. Sediment can cause unfavorable conditions in receiving waters or on land when it affects a designated use such as transportation or agricultural and wildlife areas. Deposition of sediment derived from soil erosion decreases water storage capacity in lakes and reservoirs (fig. 10-10), clogs streams and drainage channels, causes deterioration of aquatic habitats, damages water distribution systems, and decreases cropland productivity (see chapter 8, Upstream Flooding).

Enough sediment to cover the State of Rhode Island to a depth of 5 feet is dredged each year from drainage ditches, streams, rivers, reservoirs, lakes, and harbors. The Corps of Engineers, between 1979 and 1983, dredged an average 242 million cubic yards annually from rivers and harbors (Table 10-8). About the same amount is removed annually by other government agencies and private concerns.

It should be noted that extensive and continuing streambed scour has occurred downstream of several large instream water-control structures on the Missouri and other major rivers. Accordingly, control of upstream erosion may be only marginally effective in reducing river sedimentation and associated dredging costs.

Figure 10-10.--Parts of this public recreation area, once a manmade lake, can no longer be used because of sediment eroded from nearby construction sites.

Table 10-8.--Corps of Engineers dredging costs & volume, 5-year averages (1979-1983)

Division	Annual average Cubic yards dredged (1,000)	Cost per ton (1984 dollars)
Lower Mississippi Valley	98,876	0.72
Missouri River	68	1.49
North Atlantic	19,005	2.61
North Central	7,215	3.50
New England	1,007	5.18
North Pacific	28,222	1.42
Ohio River	2,203	1.76
Pacific Ocean	38	7.74
South Atlantic	43,218	1.51
South Pacific	9,064	1.93
Southwestern	23,968	1.00
Total U.S.	241,885	1.29

Figure 10-11.--U.S. Army Corps of Engineers operational divisions (adapted from map supplied by the Corps of Engineers).

Aquatic Habitat

There is no commonly accepted method of estimating the costs of erosion and runoff to the biological community. However, the absence of an overall estimate does not mean the costs are small. Sediment can cause damage to aquatic organisms, directly or indirectly, as by destroying the organism's required habitat. Suspended solids can block off sunlight from aquatic plants, reduce the oxygen supply in fish spawning areas, and clog the gills of fish. Silt may smother fish eggs and cover food sources. Sediment and excess nutrients can cause turbidity, which interferes with feeding habits of fish. The reduction in sunlight reduces the population of aquatic plants, of the shellfish and other invertebrates that feed on the plants, and of the fish that feed on both.

The National Fisheries Survey (1982), conducted by the United States Environmental Protection Agency and the United States Department of the Interior's Fish and Wildlife Service, estimated the extent of damage from all sources to aquatic habitat in rivers and streams. The survey did not deal with lakes or wetlands. The quality of aquatic habitat is impaired for more than four-fifths of the nation's stream fish communities. Table 10-9 gives estimates of the extent of the problems.

The major impairments of water quality for aquatic species are:

- turbidity, affecting 42 percent of perennial streams and 34 percent of all streams;
- high water temperature, affecting 28 percent of perennial streams and 26 percent of all streams;
- nutrient surpluses, affecting 16 percent and 13 percent respectively;

Table 10-9.--Estimated miles and percentage of streams where problems adversely affect fisheries

	All streams		Perennial streams	
	(miles)	(%)	(miles)	(%)
Water quality	535,084	56.0	433,987	65.1
Water quantity	649,102	68.0	387,874	58.2
Usable habitat	464,885	48.7	387,024	58.1
Fish community	309,630	32.4	261,018	39.2
Total adversely affected 1/	773,330	81.0	508,332	76.3

Based on data collected for the National Fisheries Survey (1982).
1/ More than one limiting factor can operate in a particular reach.

- toxic substances, affecting 13 percent and 10 percent respectively;
- low concentrations of dissolved oxygen, affecting 11 percent and 10 percent respectively.

The percentages for "all streams" are lower because intermittent streams are included in this category; intermittent flow restricts fish habitat so severely that it can preclude effects of other factors.

In terms of miles affected, nonpoint sources are more damaging than point sources. Nonpoint sources contribute to water quality problems in 38 percent of all streams and cause major problems in 18 percent (table 10-10). Agricultural sources of pollution adversely affect 29 percent of all streams and cause major problems in 17 percent. This is consistent with the 1981 report of the Council on Environmental Quality (CEQ), which states that 50 percent of the nation's water quality problems are a function of nonpoint-source runoff and that the single largest cause of these problems is agricultural practices. Municipal and industrial point sources are located on (or have the potential to affect) about 20 percent of all waters; they are adversely affecting over 10 percent of waters and are causing major problems in 5 percent.

Stream habitat conditions limit the fish community in about 49 percent of all waters. The predominant limiting factors are a lack of adult and juvenile habitat (in 40 percent of waters) and of egg and larvae habitat (in 28 percent). Major components of aquatic habitat, such as pools, spawning gravels, overhead cover, and riffles, are absent or degraded in many waters. The major causes of habitat problems are excessive siltation, bank erosion and sloughing, natural causes, and channelization. Habitat problems and water quality problems are related. Excessive siltation and bank erosion are directly implicated in loss of adult, juvenile, larvae, and egg habitat. Siltation is largely associated with natural and agricultural sources.

Significant limiting factors also occur within the fish communities, including fish kills (15 percent of all waters) and contamination of fish flesh (9 percent of all waters). Probable sources of these problems are natural causes, pesticides, and other noxious or toxic substances.

Inadequate water supplies adversely affect the fish community in 68 percent of all waters and 58 percent of perennial waters. Major water quantity problems include:

- below-optimum flows, occurring in 32 percent of waters;
- low flows, occurring in 23 percent of waters;
- excessive fluctuations in flow, occurring in 17 percent of waters.

Natural conditions are the primary cause of these problems; they affect flow in half of all waters. Agricultural diversions adversely affect flow in 14 percent of all waters.

Table 10-10. Probable sources of water quality problems, by stream mileage affected

Probable source	All streams		Perennial streams	
	Miles	Percentage	Miles	Percentage
Total nonpoint source contribution	367,244	38.4	330,840	49.6
Agricultural sources	281,241	29.5	250,637	37.6
Natural sources	212,389	22.2	149,893	22.5
Total point source contribution	117,684	12.3	116,572	17.5
Silviculture/logging	71,736	7.5	68,981	10.3
Municipal point sources	63,816	6.7	62,703	9.4
Feed lots	59,947	6.3	53,775	8.1
Individual sewage disposal	47,823	5.0	47,097	7.1
Industrial point sources	47,097	4.9	46,069	6.9
Urban runoff	40,376	4.2	38,027	5.7
Mining (nonpoint)	31,847	3.3	30,894	4.6
Combined sewers	29,246	3.1	29,246	4.4
Construction activity	29,110	3.1	29,110	4.4
Mining (point)	28,686	3.0	28,686	4.3
Grazing	21,970	2.3	19,515	2.9
Other	19,445	2.0	18,524	2.8
Dam releases	19,314	2.0	19,314	2.9
Landfill leachate	5,504	0.6	5,504	0.8
Bedload movement	5,299	0.6	5,299	0.8
Roads	3,569	0.4	3,569	0.5

Based on data collected for the National Fisheries Survey (1982).

Trends.--Most of the nation's streams provide suitable habitat for aquatic species. Table 10-11 shows the stream miles that are inhabited by sport fish species, fish species federally designated as threatened and endangered, and fish species designated as of special interest by state governments. These species were used as indicators of habitat quality in the National Fisheries Survey. Sport fish species are widely distributed. At least one species of sport fish is present in 73 percent of all stream miles. Nonsport fish species are somewhat less widespread than sport fish species but tend to be more abundant where they occur. Commercial fish species occur in 17 percent of all waters, indicating that freshwater commercial fish populations are an important part of our overall aquatic resources.

The most widespread sport fish species are largemouth bass and rainbow trout. Largemouth bass inhabit 27 percent of all waters and rainbow trout inhabit 22 percent. They are typical respectively of the warm-water and cold-water fish communities. Both species occupy the top of the aquatic food chain and are intolerant of poor water quality. Their wide distribution may result in part from past intensive stocking in an effort to extend their ranges, but it also suggests that conditions in most perennial streams are generally suitable for fish communities.

The common carp, an introduced species, is the most prevalent nonsport fish, occurring in 19 percent of all waters. The native green sunfish, which ranks as both a sport and nonsport fish in different states, is second only to the largemouth bass in distribution, occurring in over 25 percent of all waters.

Table 10-11.--Streams that provide habitat for fish, by fish class, miles, and percentage

Fish class	All streams		Perennial streams	
	(miles)	(percent)	(miles)	(percent)
All sport fish	701,780	72.6	636,260	95.5
Anadromous sport fish	102,145	10.6	100,216	95.5
Commercial fish	163,005	16.9	153,377	23.0
All nonsport fish	657,606	68.1	582,895	87.4
Anadromous nonsport fish	20,198	2.1	19,540	2.9
Threatened/endangered species	7,720	0.8	7,720	1.2
Species of special concern	23,204	2.4	21,450	3.2
No fish	204,074	21.1	18,298	2.7

Based on data collected for the National Fisheries Survey (1982).

Less than 1 percent of all waters contain species that have been federally designated as threatened or endangered, and only 2.4 percent contain state-listed species of special concern.

Twenty-one percent of all streams contain no fish. Most of these reaches, however, are dry during part or all of the year. In a normal water year, 69 percent of streams are usable all year round as fish habitat; 14 percent are not usable as fish habitat during any part of the year because of low flow or no flow. The rest are usable as fish habitat only during part of the year, primarily in spring and summer. Most of the waters that contain fish are used throughout the year, for spawning and hatching, as nursery habitat, and for overwintering. Twelve percent of all waters serve as migration routes.

According to the National Fisheries Survey, the ability of the nation's waters to support sport fish has changed only slightly during the last 5 years. Overall, 91 percent of the streams have maintained their status, while 5 percent have been degraded and 4 percent have improved. This is consistent with the Council of Environmental Quality's determination that water quality was maintained at a stable level during the 5 years preceding 1981, even though population and other growth pressures increased.

About 46 percent of the nation's streams are rated fair in terms of their ability to support sport fish populations; about one-third are rated poor. Many of these latter streams are intermittent and have little potential for improvement. The state fishery biologists responding to the National Fisheries Survey surmise that without control of problems that stem from human actions, a dramatic decrease in the nation's fish communities could occur in streams where present capabilities are marginal. Higher ranked streams could decline in numbers, and the number of streams that cannot support fish and streams with only minimal ability to support sport fish could increase.

Instream Damages

Total instream damages due to erosion are estimated at $5.7 billion annually. Damages resulting from erosion on cropland are estimated to be $2.1 billion annually or about 37 percent of the total. Table 10-12 summarizes the cost of the instream damages discussed below. Damages were estimated for the nation and then assigned to farming regions according to the procedure used by Ribaudo (1986). Water quality problems found in the Southeast were due primarily to pollution from point sources; this finding does not mean that the actual contribution of soil erosion is minor. Also, the nationwide water quality data used refer only to streams, not to lakes and reservoirs.

Recreation opportunities.--Sediment can greatly reduce the suitability of water for recreational uses. Sport fishing, swimming, and boating are directly impaired. Silt-laden water is more dangerous; a rough estimate is that about 100 drownings occur annually as a result of turbidity. For people who are picnicking or walking or playing near the water, turbidity and sedimentation diminish the quality of the recreational experience. The aggregate impact of less attractive water bodies may be very high because so many people are affected. About 40 percent of the total damage to recreation opportunities is attributed to cropland erosion.

Water storage facilities.--Sediment reduces the storage capacity of lakes and reservoirs, changes the temperature of the water, and provides increased opportunities for the growth of water-consuming plants. Of the 690 million acre-feet of total reservoir capacity in the United States, sediment fills up an estimated 1 million acre-feet each year. An estimated 15 percent of the reservoirs are losing storage capacity at rates exceeding 3 percent per year and 2 percent are losing capacity at rates exceeding 10 percent per year. If present sedimentation rates continue, in 30 years about 20 percent of the nation's small reservoirs will be half filled with sediment and in many instances their utility will be seriously impaired. About 31 percent of the total damages are attributed to sediment eroded from cropland (Clark et al., 1985).

Transportation.--Sediment damages to transportation systems are manifested in costs associated with the maintenance of channels and

Table 10-12.--Instream damages resulting from erosion

Farming region	Damage to--				
	Recreation 1/	Water storage	Transportation	Other	Total
	(millions of 1984 dollars)				
Northeast	525	34	113	185	857
Lake States	180	57	45	80	362
Corn Belt	561	57	104	71	793
Northern Plains	60	126	27	66	279
Appalachian	164	46	86	76	372
Southeast	---	46	128	62	236
Delta States	64	46	157	89	356
Southern Plains	316	160	61	76	613
Mountain	140	307	118	66	631
Pacific	547	274	76	261	1,158
Total	2,557	1,153	915	1,032	5,657

1/ Includes marine fishing.

harbors, transportation delays, accidents, operation and maintenance of equipment, and cleanout of roadside ditches. The largest damage costs to transportation are associated with the maintenance of channels and harbors for navigation. Between 1979 and 1983 the Corps of Engineers spent an average of $457 million annually (1984 dollars) dredging rivers and harbors. The Corps is responsible for dredging about half the sediment; other government agencies and private concerns remove the rest. Many of the reported dredging costs cover only the actual sediment removal and do not include the cost of disposal. Studies by the Corps and the General Accounting Office indicate that proper sediment disposal can double or even triple dredging costs. Commercial groundings were estimated to cause about $60 million worth of damage in 1980.

Other instream damages.--Other instream effects include damages to commercial fisheries and to preservation values. Erosion-related pollutants cause the same problems for commercial fisheries as for recreational fisheries. Preservation values represent the value that people place on clean water. About 40 percent of the damages to commercial fisheries and preservation values are attributed to cropland erosion.

Offstream Damages

Offstream damages occur before sediment and associated pollutants reach a waterway, during floods, or after water is diverted from a stream for offstream use. Table 10-13 summarizes estimated annual offstream damages.

Table 10-13.--Offstream damages

	Area affected				
Farming region	Flood	Water conveyance	Water treatment	Other	Total
	(millions of 1984 dollars)				
Northeast	97	8	24	188	317
Lake States	65	8	15	172	260
Corn Belt	102	50	10	141	303
Northern Plains	79	37	6	37	159
Appalachian	90	22	11	147	270
Southeast	83	11	6	83	183
Delta States	125	14	6	115	260
Southern Plains	88	34	19	101	242
Mountain	104	64	14	125	307
Pacific	159	89	15	85	348
Total	992	337	126	1,194	2,649

Flood damages.--Sediment increases the frequency and depth of flooding, primarily by aggradation of streambeds, and causes severe property damage when flood waters drop their sediment load in inhabited areas. Damages of this kind accounted for about 12 percent of the nation's total flood damages, or about $1.0 billion in 1984 (Clark et al., 1985). Erosion from cropland causes about 32 percent of this damage.

Sediment deposited by flood waters can cause two types of damage on cropland. One is the long-term loss in yield associated with the deposition of relatively infertile material on good agricultural land. The value of this loss has not been estimated. The other loss is damage to the current crop that occurs when sediment buries growing crops or covers plants with a thin film of sediment that interferes with photosynthesis and respiration. The amount of this damage ranges from $5 to $40 per acre of flooded cropland, averaging about $20 per acre. Nationwide, the loss of production caused by sediment deposition ranges from $150 to $500 million annually. Table 10-14 summarizes estimated damage of this type to crop production.

Other offstream damages.--Suspended solids reduce the efficiency and decrease the durability of water-using equipment, such as hydro-electric power plants and water cooling facilities, thus adding to the cost of operation. Farmers who use irrigation water containing sediment and other erosion-related contaminants may incur increased costs in addition to realizing lower yields because of dissolved salts. About 35 percent of these other offstream costs are attributed to cropland erosion.

Water conveyance systems.--Sediment can cause various problems in water conveyance facilities. Some of it settles in drainage ditches before the

Table 10-14.--Damage to growing crops

Farming	Floodprone cropland (Thousand acres)	Floodprone cropland (Percent of region's cropland)	Annual damages 1/ (millions of 1984 dollars)
Northeast	963	6	2.9
Lake States	3,308	8	9.9
Corn Belt	14,216	15	42.7
Northern Plains	10,452	11	31.3
Appalachian	5,344	24	16.0
Southeast	2,444	13	7.3
Delta States	9,877	45	29.6
Southern Plains	5,249	12	15.8
Mountain	3,925	9	11.8
Pacific	4,821	21	19.5
Total	60,599	14	181.6

1/ Assumes 15 percent of cropped floodprone acres receive annual sediment damage of $20 per acre.

water reaches a waterway. Annual sediment removal and weed control in the Nation's 110,000 miles of irrigation canals is a significant cost. According to the Bureau of Reclamation, sediment removal accounts for 10 to 10 percent of the $300 million annual cost of canal maintenance, and weed control accounts for 5 to 15 percent. Fifty percent of the cost of sediment removal from water conveyance systems is associated with cropland erosion.

Water treatment facilities.--As the turbidity of a water supply increases, so also do the investment required and the operation and maintenance costs of the water-treatment facility. Sedimentation basins must be built, chemical coagulants added, and filters cleaned more frequently. Although most water used for industrial purposes does not need to be of high quality, much of it may nevertheless require treatment to remove suspended solids. Thirty percent of the increase in costs for water treatment is associated with cropland erosion.

REDUCING OFFSITE EFFECTS OF EROSION: WHAT CAN WE DO?

To achieve water quality, we must first know how much agricultural sources contribute to the total pollutant load, how much various control practices reduce this load, and the effect that reducing the pollutants will have.

Once the pollutants and the problems they cause are known and understood, then the offsite effects of soil erosion and agricultural runoff can be controlled in three basic ways.

One approach is to prevent pollutants from being created in the first place. In the case of soil erosion, this means preventing the erosion from occurring and preventing the associated contaminants from being carried off the land. This can be accomplished through the installation of resource management systems.

For a resource management system to be effective in reducing nonpoint source pollution, it must decrease the availability, prevent the detachment, or stop the transport process of the pollutants. Systems that solve one water quality problem must not increase the potential for another problem. A system that adequately controls the target pollutant is the "best resource management system" for solving the existing water quality problem.

The same kinds of soil and water conservation practices that are applicable for protection or improvement of soil resources are used where water quality is an objective. Resource management systems may include one or a combination of management, vegetative, and structural practices.

Management practices, such as nutrient management and pesticide management, limit the availability of the pollutant to runoff. This is done by incorporating the pollutant into the soil, scheduling its application to low-runoff periods, reducing the quantities applied, or changing the form in which it is applied. Management practices have a great advantage because they are flexible and relatively low in cost, can be quickly initiated, and often reduce the land user's costs. However, a disadvantage is that a land user can quickly weaken their effectiveness by not following good management techniques.

Vegetative practices limit pollutant movement by reducing soil erosion. They protect the soil from the impact of raindrops and overland flow. They are effective where pollutants are attached to sediment or where sediment is a pollutant. Vegetative practices such as crop rotations, reduced tillage techniques, and winter cover crops protect both soil and water. Advantages are that they are flexible and are generally relatively inexpensive to implement; however, the landowner's income may drop when a rotation requires more grass crops. A disadvantage is that the land user can quickly undo any benefit by plowing at the incorrect time of the year.

Structural practices are alterations of the landscape. They reduce the length of the slope to control the amount of runoff and the steepness of the slope to control the velocity. Other practices, such as grassed waterways, use a combination of structural and vegetative practices to reduce the depth of flow. Their main advantage is permanence. These practices generally become part of the farming system for a substantial period. Disadvantages are that they can be costly to install and need continued maintenance.

Barriers to the widespread adoption of resource management systems are primarily lack of knowledge of application benefits, excessive cost, and scarcity of financial/technical assistance programs.

The second approach is to attempt to collect and reduce pollutants after they leave a field but before they cause any damage. For agricultural pollutants, this policy can involve constructing sedimentation basins and filter strips along streams.

The third approach is to allow the problems to occur and to compensate for them afterward: for instance, by dredging reservoirs and treating drinking water supplies.

The efficiency and attractiveness of each of these strategies depend on both the particular situation being addressed and the relative magnitudes of on-farm and off-farm effects. One of the most critical elements in reducing the offsite effects of soil erosion is the dissemination of research knowledge and the application of that knowledge to practical problems. This will become more vital in the years ahead.

Alternative Strategies to Control Nonpoint Pollution and Cropland Erosion

Resources for the Future (RFF) has developed a data base and modeling system to assist in the study of pollution control at the national level. The model can simulate the results of alternative actions directed at controlling one or more nonpoint source pollutants at a geographic scale ranging from a single county to virtually the entire country. It takes account of the relative contributions of point sources of pollutants, thus permitting analyses of problems deriving from both point and nonpoint sources (table 10-15). The RFF national water network model explicitly takes into account the effect of water flow on the polluting potential of soil erosion. Because streams and rivers move over great distances, sediment-related pollution at one point can result from erosion that has occurred at many widely separated locations hundreds of miles upstream.

RFF examined the effect of cropland erosion control on deliveries of phosphorus to various points in the nation's water network. Phosphorus was selected as the test pollutant for the simulations, not because of

Table 10-15.--National erosion and water pollutant discharge estimates, point and nonpoint sources (TPY: tons per year)

Source of pollutants	Erosion	Pollutant discharge		
		Total suspended solids	Total phosphorus	Total Kjeldahl nitrogen
	---(million TPY)---		---(thousand TPY)---	
Nonpoint sources 1/				
Cropland	1,836	900	615	3,204
Pasture	190	95	91	292
Range	562	253	242	778
Forest	783	344	495	1,035
Other rural lands 2/	453	195	170	659
Streambanks	553	553	<1	<1
Gullies	295	197	<1	<1
Roads	167	112	<1	<1
Construction sites	80	54	<1	<1
Other nonpoint 3/	-	12	64	691
Point sources	-	4	330	1,495
Total	4,919	2,719	2,007	8,154

1) Includes both federal and nonfederal lands.
2) Includes farmsteads, other land in farms, mines, quarries, pits, and other rural lands.
3) Includes livestock runoff, dissolved nutrient runoff, acid mine drainage, and urban runoff.

Source: Resources for the Future, Environmental Data Inventory

its own special characteristics, but rather because it has varied and ubiquitous origins. This feature is shared by a number of important pollutants. Consequently, findings with respect to phosphorus apply to those others also.

The Department of Agriculture estimated the acreage of sheet and rill erosion on nonfederal rural lands in the United States as part of the 1982 National Resource Inventory (NRI). Together with these erosion estimates, RFF used sediment delivery ratios for each type of land (e.g., cropland, pasture, range, and forest) based on watershed size to predict sediment delivery yields at the county level countrywide, including both federal and nonfederal lands. The county level data were also used to develop estimates of pollutant discharges from cropland for the RFF national water quality model, which is organized by county. The data show that erosion is a major contributor of pollutant loadings to the nation's water and accounts for 80 percent of the national total of phosphorus, 73 percent of nitrogen, and 99 percent of total suspended solids (see appendix table 10-14). Cropland erosion accounts for over a third of these totals.

Figure 10-12 shows the estimate, in milligrams per liter (mg/l), of phosphorus concentration in rivers and streams nationwide. The relatively "dirty" areas (1.0 mg/l or more) far outnumber the relatively "clean" areas (0.2 mg/l or less). Since the objective is to attain the greatest level of improvement for the available erosion control

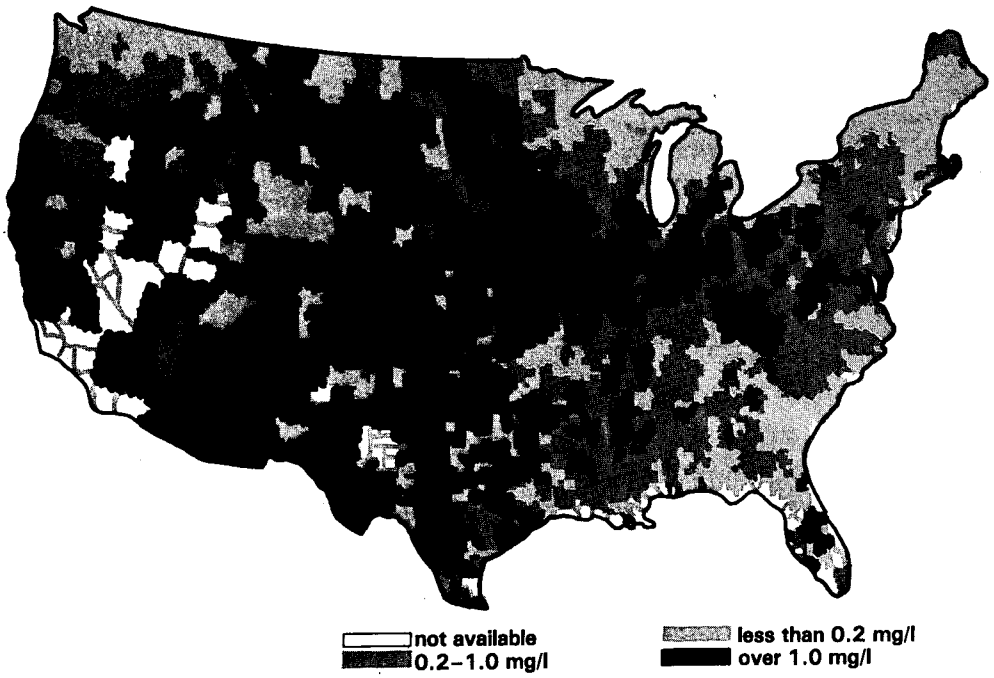

Figure 10-12.--Estimated phosphorus concentrations in rivers and streams. Source: National water network model developed by Resources for the Future.

resources, and not simply to meet a given standard, it would pay to control first those areas where the improvements for a given effort were the largest. To determine these areas the model first simulated the effects of totally eliminating cropland erosion as a source of phosphorus loadings, and noted those areas for which that elimination sufficed to improve water quality to the "clean" level. The model was then allowed to permit less than complete erosion control if it was still possible to reach and maintain this level of improvement. By following this series of steps the model identified those counties that met the conditions, as well as the necessary gross soil erosion reductions, as shown in figure 10-13.

The result of the model's projections is shown in figure 10-14. Because cropland controls appear worthwhile in relatively few areas, few differences appear between the condition before control (fig. 10-12) and the condition after control. The reason is that cropland's contribution to sediment-related pollutants (such as phosphorus) is often relatively minor. Erosion from other sources (such as rangeland and forests) may contribute more than half of the total nonpoint pollutant load. In many areas natural sources such as streambank erosion are equally important. Control of only one pollutant source, cropland, will thus prove ineffective except in areas where crop production is a major land use. If efforts to improve the quality of the nation's water are to be suc-

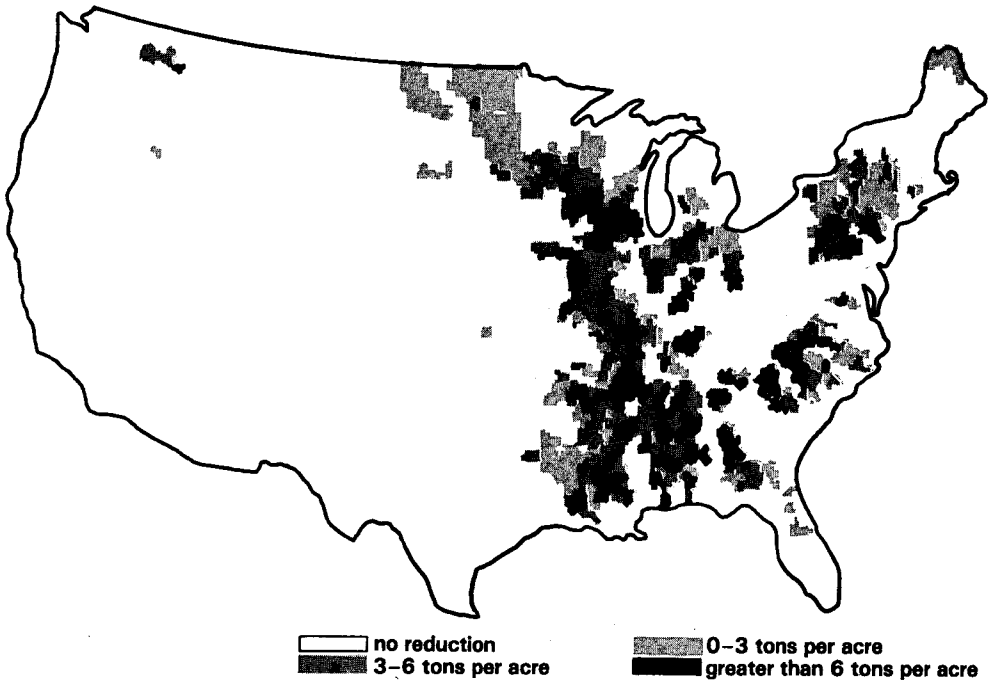

Figure 10-13.--Counties where reduction of sheet and rill erosion on cropland would bring phosphorus concentrations in surface waters into compliance with EPA's recommended standard. Source: RFF model.

cessful, they must be broadened to cover several concurrent sources of nonpoint source pollution. Where it is requisite to reduce erosion from several sources, the degree of reduction desired for any one source depends on the degree of reduction attainable for other sources.
In summary, the model simulation shows that:

- If cropland erosion is the only nonpoint source controlled but cropland is only one of several nonpoint sources of the pollutant affecting water quality, then controlling cropland erosion will improve water quality enough to meet recommended standards in only a few regions (most of them east of the Great Plains).

- Because of pollution downstream, erosion control must be applied in some regions which do not have pollution or sediment problems.

- While water quality is obviously related to erosion, the relationship is very complex and far from proportional.

At present, water quality programs are generally conducted as if problems were confined by state boundaries. The RFF model simulations vividly demonstrate that this assumption is untrue. Individual states cannot deal effectively with nonpoint problems within their borders without coordinating their policies with those of states upstream.

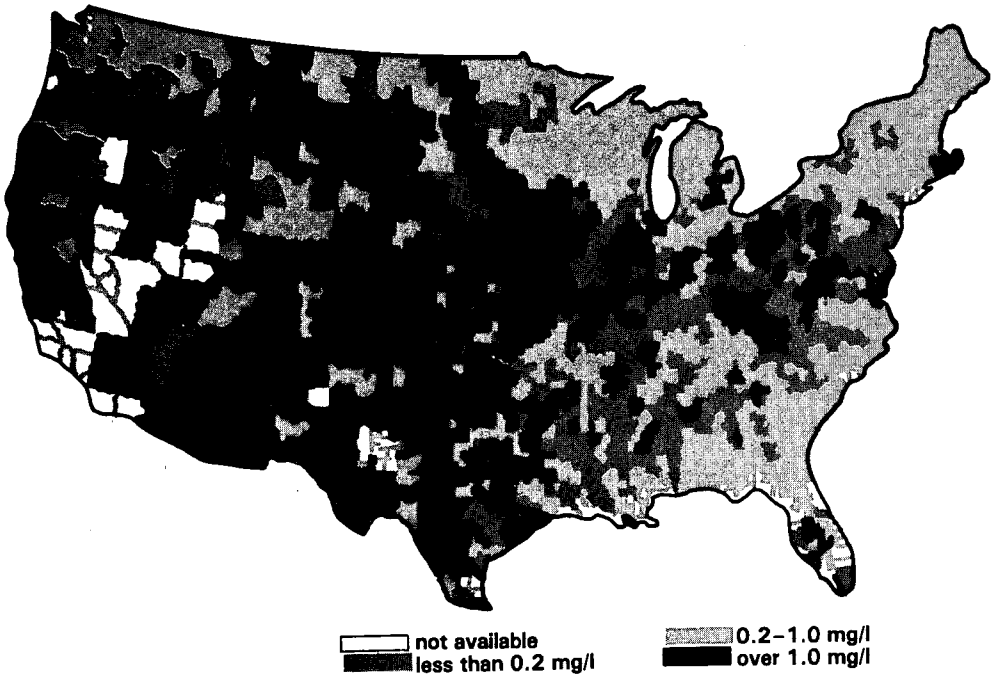

Figure 10-14.--Projected phosphorus concentrations in surface waters if sheet and rill erosion on cropland were reduced to specified levels in selected counties. Source: RFF model.

Ripple Effects of Controlling Cropland Erosion

The RFF model identified 47 aggregated subareas (ASA's) where total phosphorus concentrations in 1982 exceeded EPS's recommended standards and where reduction of cropland erosion would improve water quality sufficiently to meet the standards (fig. 10-15, and see appendix table 10-1). RFF estimated that to meet the standards, gross sheet and rill erosion for the 47 ASA's would have to be reduced by 560.7 million tons. Achieving this much erosion reduction would alter agricultural resource use in this country, both interregionally and intraregionally. Cropping practices in the affected ASA's would have to be altered or land withdrawn from cropping. Commodities would have to be produced either with new practices or in other regions of the country.

To project what those changes would be, analysts used the linear programming model developed by the Center for Agricultural and Rural Development (CARD) at Iowa State University. The CARD model was run in the year 1990 to estimate the short term effects of reducing erosion in the designated areas. The projections were compared to a baseline that differs in two significant respects from the intermediate scenario described in chapter 12. First, export demands were set higher. Because the CARD model does not project the production of surplus commodities, higher export demands were needed to make the model project a level of

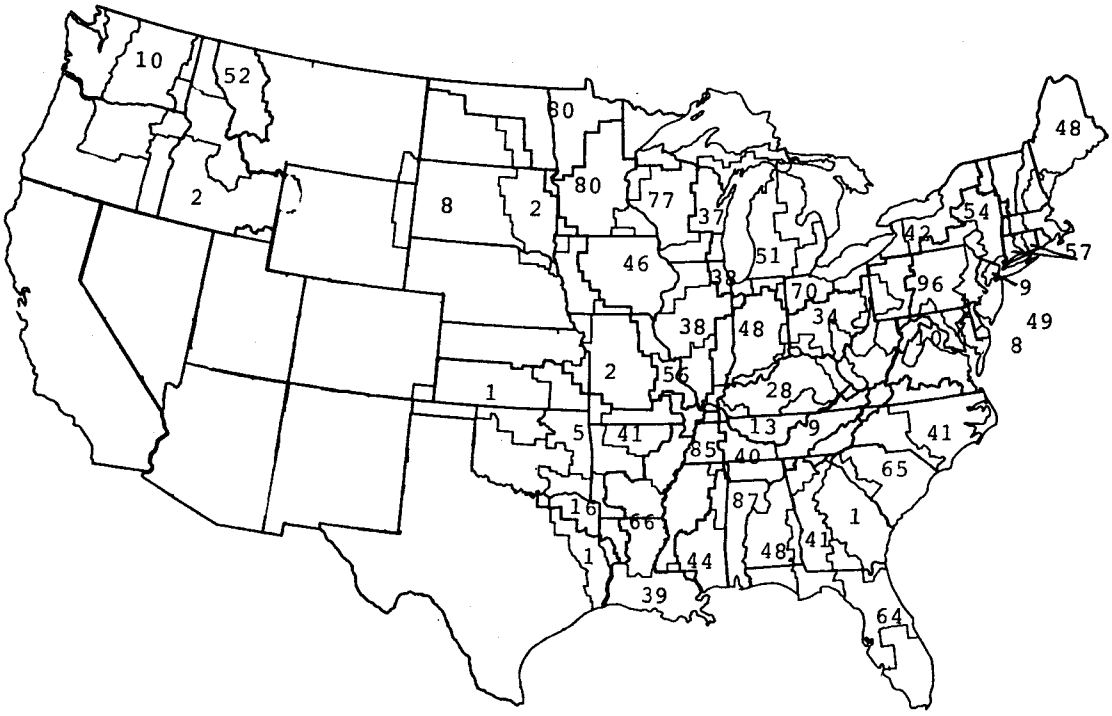

Figure 10-15.--Percentage of erosion reduction from 1982 NRI levels that would be required to reduce phosphorus loading to EPA recommended levels, by aggregated subareas. Source: Resources for the Future.

production comparable to 1982. Second, the Conservation Reserve program provided for in the Food Security Act of 1985 was not simulated in the analysis.

Erosion. To improve water quality to the desired level, erosion would need to be reduced in the 47 ASA's by 560.7 million tons, or an average of 31 percent. Because erosion would increase in other ASA's as land use intensified there, erosion at the national level was projected to be reduced by only 282 million tons. This 282 million tons represents a 28-percent decrease in gross sheet and rill erosion nationwide. The model projects the required reduction by projecting changes in crop mixes, location of production, and cropping practices (rotations, tillage systems, and conservation practices). For example, conventional fall tillage would be used on 8 million fewer acres, and the acreage in conventional spring tillage would increase, as would the acreage in conservation tillage and no-till.

Land Use. The model projected that the total acreage of land required for crop production would decrease by half a million acres. It projects some shifting of production among regions. The acreage of cropland was projected to be 1 million acres more in the Southeast and 2.3 million acres more in the Corn Belt for this analysis than for the same conditions without the erosion reductions. Half a million acres fewer were projected in the Northeast and Delta regions and 2.4 million acres fewer in the Northern Plains. Smaller reductions were projected in the Southern Plains and Mountain regions.

Figure 10-16.--Changes in cropland use projected to result from actions taken to improve water quality by reducing erosion.
Source: CARD model.

These interregional shifts in cropland use are projected because the actions needed to reduce erosion in the selected regions create changes in comparative advantage among regions in crop production, transportation, and livestock feed requirements. For example, the erosion restrictions imposed in the Lake States were quite severe. To meet them the model projected soybean production, which on many soils is accompanied by higher rates of sheet and rill erosion, to decrease by a million acres in the region. Livestock production, particularly pork, also was reduced in the Lake States. The crop production was projected to move to the Corn Belt and Southeast regions and the livestock production to the Corn Belt, the Northern Plains, and the Southern Plains.

Commodity Production. Because the erosion restrictions would make corn and soybeans relatively more expensive to produce, the model projected more consumption of wheat and sorghum by livestock. Since the wheat belt is in the West and almost all sorghum is produced in the Corn Belt, Northern Plains, and Southern Plains, livestock production, seeking comparative advantage, was projected to shift into those regions.

Because of the realignment resulting from erosion restrictions, the total cost of production was projected to increase by $377 million, or 0.66 percent. Increases were projected for all expenses of transportation and production except pesticides. Pesticide expenditures were projected to decrease by $2.5 million (less than 0.07 percent), which is not a significant decline at the national level.

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Wildlife Habitat

When we use our agricultural lands, we change the quantity and quality of the habitat the land provides for wildlife and, therefore, the number and species of animals that can live there. USDA has developed a system for expressing these changes in numerical form so that we can easily compare the results of actions we have taken or intend to take. This system rates the diversity of the structure of the habitat as compared to that of the natural vegetation of the site. The lower the index, the less the current vegetation resembles that growing on the site before people began to use it. As figure 11-1 shows, the structure of the habitat has been changed to the greatest degree in the regions where we use the land most intensively. The value of vegetation as habitat is affected by, and therefore can be improved by, the management practices that farmers apply.

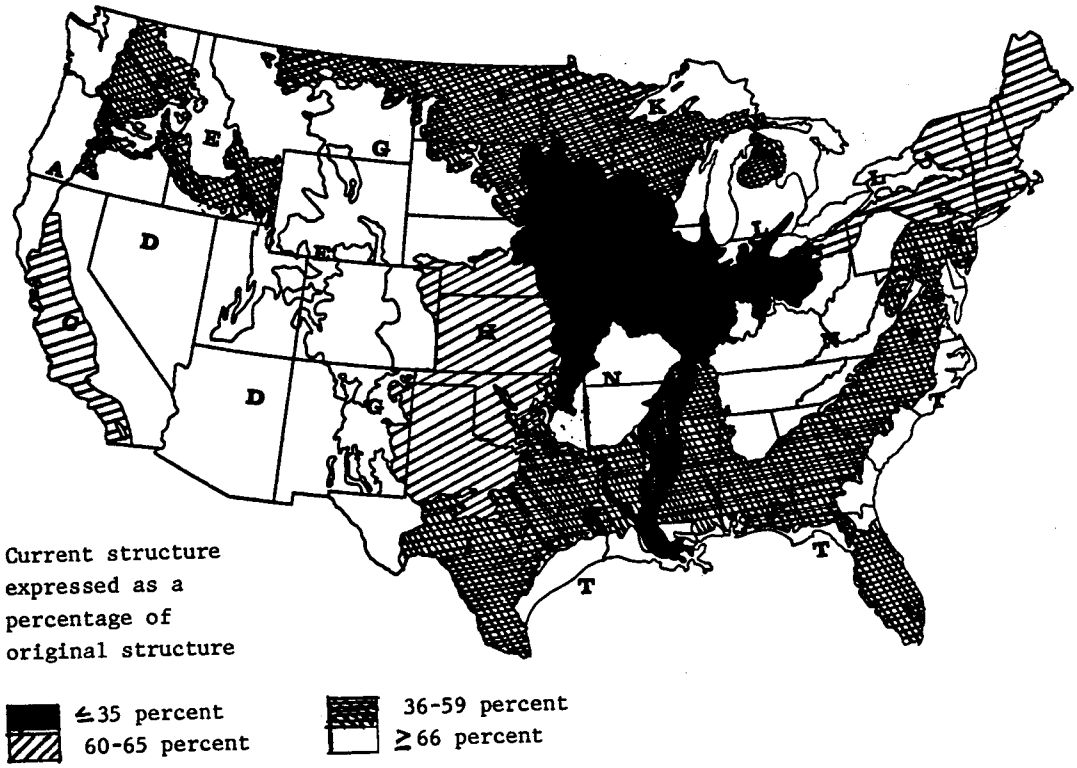

Figure 11-1.--Habitat structure index, by land resource region.

HABITAT STRUCTURE: SPACES FOR SPECIES

Habitat can be described as a structure--a series of layers, each of which occupies a distinct volume of space and supports a specific type of vegetation, or cover (Short and Burnham, 1982; Short and Williamson, 1985). Some habitats contain more layers than others, thus accommodating more wildlife species. Habitats can be evaluated and compared on the basis of the diversity of their structure--the number of habitat layers present and the extent and distribution of each habitat layer.

In this report, the maximum number of layers that the habitat may contain is seven. These are: the water, the surface of wetland or shallow water areas, the subsurface, the surface vegetation or understory, the midstory vegetation or shrub layer, the tree boles, and the tree canopy (fig. 11-2 and table 11-1).

Each wildlife species uses certain habitat layers. Table 11-4 shows which layers some species use.

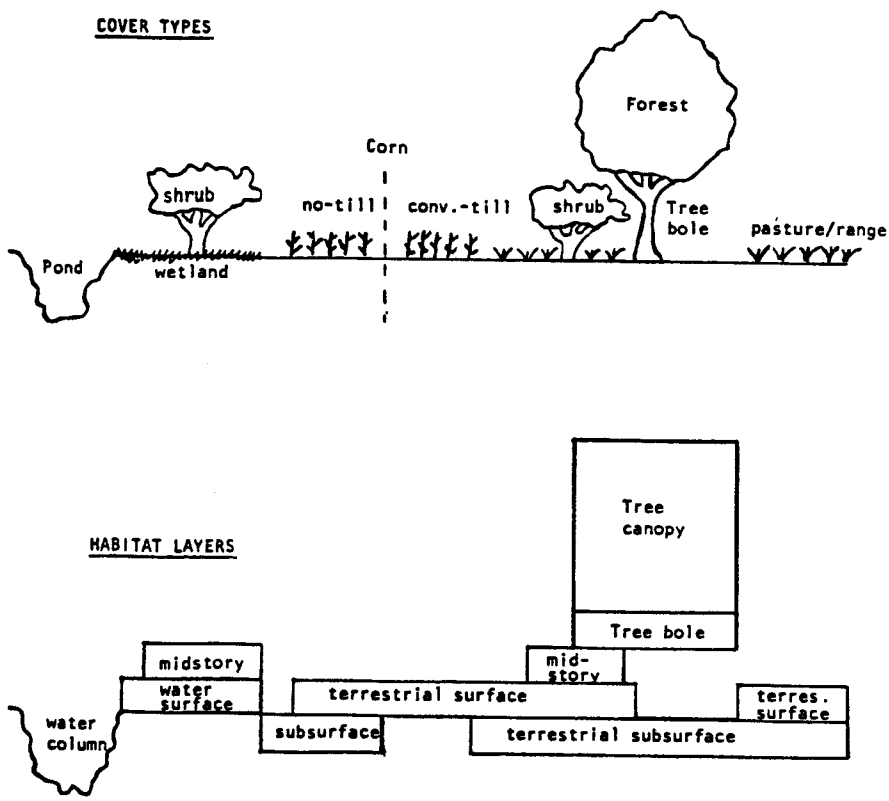

Figure 11-2.--Cover types and habitat layers.

Information about the extent of the various layers can be used to estimate how much of an area can provide habitat for specific species. Each acre of a given habitat layer, however, does not necessarily provide habitat of equal quality and would not necessarily support the same number of wildlife. The way that farmers and ranchers manage their land affects the quality of the habitat available in the layer. For example:

- Draining wetlands reduces habitat.
- Leaving winter cover, especially residue over 7 inches in height, on croplands improves habitat.
- Improving range condition improves habitat.
- Permitting dense brush to invade grasslands reduces habitat. So does completely clearing brush.

Table 11-1.--Criteria defining habitat layers

Layer		Criteria
1)	Water column	Water layer between the surface of a body of water and the bottom (usually 6 or more feet deep).
2)	Water surface (wetland)	Land surface-water interface classified as wetland (water depth usually less than 6 feet).
3)	Terrestrial subsurface	Extends downward from 10 cm (4 inches) below the apparent surface.
4)	Understory (terrestrial surface)	Vegetation that extends from 10 cm (4 inches) below the apparent surface up to 50 cm (20 inches) above the apparent surface and provides at least 5 percent cover when projected to the surface (500 m^2/ha or 2,200 ft^2/acre).
5)	Shrub midstory	Vegetation at a height of 50 cm (20 inches) up to 8 m (25 ft) that provides at least 5 percent cover when projected to the surface (500 m^2/ha or 2,200 ft^2/acre).
6)	Tree bole	Tree trunks having a diameter at breast height of at least 20 cm (8 inches) and a stand density of at least 12 per hectare (5 per acre).
7)	Tree canopy	Vegetation structure 8 m (25 ft) or more above the terrestrial or aquatic surface, that provides at least 5 percent cover when projected to the surface (500 m^2/ha or 2,200 ft^2/acre).

- Allowing livestock to graze the understory vegetation in forests reduces habitat.
- Clearcutting, which eliminates large trees needed by many species that use the tree bole layer, reduces habitat.
- Monoculture, which reduces the interspersion of cover types, reduces habitat.

These effects of management must be considered in assessing the habitat provided by an area. For this report, the extent of each layer was estimated by multiplying the acreage of land in each major agricultural use as reported in the 1982 NRI by the factors in appendix A11-1. Table 11-2 shows the adjusted acreage of each layer as a percentage of the total area for each of the 20 land resource regions in the 48 conterminous states. Land resource regions are broad areas of generally similar climate and land and are characterized by similar patterns of use.

Table 11-2.--Habitat layer values

Land resource region	Habitat layer value*						
	1	2	3	4	5	6	7
A	0.04	0.02	0.92	0.32	0.57	0.46	0.77
B	.02	.01	.74	.76	.21	.08	.14
C	.03	.02	.78	.70	.09	.09	.24
D	.03	.02	.94	.75	.32	.06	.10
E	.03	.02	.94	.71	.28	.19	.32
F	.02	.04	.57	.86	.01	.00	.01
G	.01	.01	.91	.90	.10	.01	.03
H	.01	.00	.77	.86	.14	.00	.01
I	.01	.00	.93	.83	.52	.00	.00
J	.03	.01	.85	.82	.19	.02	.05
K	.08	.15	.82	.47	.31	.25	.63
L	.04	.07	.54	.51	.15	.10	.24
M	.02	.01	.47	.62	.08	.06	.09
N	.03	.01	.90	.44	.46	.32	.57
O	.07	.14	.45	.56	.16	.19	.23
P	.03	.09	.81	.42	.45	.32	.61
R	.06	.06	.89	.28	.56	.39	.72
S	.05	.04	.81	.42	.42	.26	.51
T	.16	.20	.67	.35	.38	.22	.47
U	.16	.17	.78	.58	.22	.11	.30

*Percentage of area that provides habitat layer.

1 = water column
2 = water surface (wetlands)
3 = subsurface
4 = understory
5 = midstory
6 = tree bole
7 = tree canopy

The habitat structure index for an area is calculated by expressing the number and quality of layers present now as a percentage of the layers present when the area retained its potential natural vegetation--that is, before the area had been extensively changed by human action. Table 11-3 shows the habitat structure index for each of the land resource regions.

As the table shows, the diversity of the vegetation has been greatly reduced in many regions. Diversity has been most reduced in the central and upper Midwest (index of 0.29), where the habitat character has been changed from primarily forest and prairie to mixtures of cropland, pasture, and woodlots. It has been changed least in the Appalachian region (index of 0.86). In general, about half the land resource regions have a moderate degree of habitat diversity, and six of them retain at least two-thirds of the diversity of the natural vegetation.

Table 11-3.--Habitat structure index for land resource regions

Symbol and name		Habitat structure index
A	Northwestern Forest, Forage, and Specialty Crop Region	0.66
B	Northwestern Wheat and Range Region	.59
C	California Subtropical Fruit, Truck, and Specialty Crop Region	.64
D	Western Range and Irrigated Region	.66
E	Rocky Mountain Range and Forest Region	.77
F	Northern Great Plains Spring Wheat Region	.58
G	Western Great Plains Range and Irrigated Region	.81
H	Central Great Plains Winter Wheat and Range Region	.63
I	Southwest Plateaus and Plains Range and Cotton Region	.52
J	Southwestern Prairies Cotton and Forage Region	.49
K	Northern Lake States Forest and Forage Region	.55
L	Lake States Fruit, Truck, and Dairy Region	.29
M	Central Feed Grains and Livestock Region	.29
N	East and Central Farming and Forest Region	.86
O	Mississippi Delta Cotton and Feed Grains Region	.34
P	South Atlantic and Gulf Slope Cash Crops, Forest, and Livestock Region	.59
R	Northeastern Forage and Forest Region	.65
S	Northern Atlantic Slope Diversified Farming Region	.51
T	Atlantic and Gulf Coast Lowland Forest and Crop Region	.68
U	Florida Subtropical Fruit, Truck Crop, and Range Region	.51

Table 11-4.--Wildlife species and groups: feeding and breeding habitat

	Feeding							Breeding						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Canvasback	1	2							2					
Snapping turtle	1	2								3	4			
Eastern painted turtle		2	3								4			
American coot		2	3						2					
Beaver		2	3	4	5				2	3				
Muskrat		2		4					2	3				
Blue-winged teal		2		4					2		4			
Wood duck		2		4									6	
Plains pocket gopher			3	4						3	4			
Badger			3	4						3	4			
Coyote			3	4	5					3				
Grasshopper sparrow				4							4			
Meadowlark				4							4			
White-tailed jackrabbit				4							4			
Canada goose				4							4			
Pintail				4							4			
Red-winged blackbird				4							4			
Mallard				4							4			
California quail				4							4			
Hungarian partridge				4							4			
Kestrel				4									6	
Mourning dove				4							4	5		7
Horned lark				4							4			
Woodcock				4							4			
Prairie dog				4						3				
Scaled quail				4							4			
Greater prairie chicken				4							4			
Ring-necked pheasant				4	5						4			
Eastern cottontail				4	5						4			
Bobwhite				4	5						4			
Gray fox				4	5					3	4			
Clay-colored sparrow				4	5						4			
White-tailed deer				4	5						4			
Elk				4	5						4	5		
Mule deer				4	5						4			
Antelope				4	5						4			
Sage grouse				4	5						4			
Sharp-tailed grouse				4	5						4			
Black-capped chickadee				4	5	6	7						6	
White-breasted nuthatch				4	5	6	7						6	
Red-bellied woodpecker				4	5	6							6	
Eastern fox squirrel				4	5		7						6	7
Blue jay				4	5		7							7
Eastern wild turkey				4	5		7				4			
Ruffed grouse				4	5		7				4			
Raccoon				4	5		7			3	4		6	
Hairy woodpecker					5	6							6	
Northern oriole							7							7

1 - Water column 2 - Water surface 3 - Subsurface
4 - Understory 5 - Midstory 6 - Tree bole
7 - Tree canopy

Preserving Wetlands

Wetlands are a productive and invaluable public resource. In the past, however, extensive acreages of wetlands have been converted to other uses, with attendant loss of wetland values. Such conversion is continuing, although at a slower rate. The wetlands conservation provisions of the Food Security Act of 1985 are designed to discourage conversion for agricultural use.

Wetlands constitute habitat crucial to many forms of wildlife. Wetlands are also important in maintaining ground water supplies and water quality; protecting shorelines from erosion; modifying climatic extremes; storing floodwaters; and trapping sediments, which can pollute waterways, smother fish eggs, and contaminate shellfish.

Much--perhaps more than half--of the wetland acreage in existence at the time of the first European settlers has been lost to other uses. Estimates of historical wetland acreages vary widely--from 127 million to 215 million acres. The net loss of wetlands to agricultural uses between the mid-1950's and the mid-1970's was over 11 million acres--an annual loss of about 550,000 acres. More recently the rate of loss has slowed: the present rate of conversion is about 300,000 acres per year.

Conversion continued in spite of federal and state restrictions and regulations. Some federal and state tax laws (authorizing tax credits for investment, deductions for expenses, and special provisions for resource depletion) still reduce the costs of converting wetlands. Many state and local property tax codes, for example, tend to discourage preservation ot wetlands by private owners. However, "Swampbuster" provisions in the Food Security Act of 1985 (Public Law 99-447), which restrict or prohibit federal commodity payments and loans to farmers who produce crops on newly converted wetlands, are designed to discourage the conversion of wetlands to agricultural uses.

Not all wet soils are wetlands. Excess water is the dominant hazard or limitation to use on 309.3 million acres of nonfederal land in the United States, 233 million acres of which is used for agriculture. These soils, which are affected by poor soil drainage, wetness, high water table, and overflow, have a "w" following the roman numeral that designates their land capability classification. Table 11-5 describes the "w" soils in more detail and gives acreages of each type. Only one-third of the "w" soils are wetlands.

There are 90 million acres of wetlands in the United States. An estimated 12.5 million acres are in federal ownership and control and the rest are nonfederal wetlands; most of the latter--65.3 million acres, or about 83 percent--are privately owned. State governments own about 13 percent of nonfederal wetlands.

Wetlands vary in type from permafrost in Alaska to everglades in Florida to desert wetlands in Arizona. Wetlands have been classified according to several systems. Tables 11-6 and 11-7 show wetland acreage using the system of Fish and Wildlife Circular 39 (Shaw and Fredine).

Table 11-5.--Vegetative cover on wet soils by class and type in the United States, 1982

Wet soils		Vegetative cover					
Type	Description	Cropland	Pasture	Range	Forest	Other	Total
		(million acres)					
Wet soil by class in "w" subclass							
IIw	Wetness problem that can be corrected by drainage	65.0	10.8	2.5	16.1	1.9	96.3
IIIw	Severe limitation that requires special drainage to grow most crops	33.3	8.4	4.0	20.7	2.9	69.3
IVw, VIw, VIIw	Very severe limitations that make drainage measures impractical or not feasible	8.7	7.0	11.2	33.2	8.0	68.1
Total nonfederal wet soils		107.0	26.2	17.7	70.0	12.8	233.1
Wetland							
	All nonfederal wetland in Types 1-20	4.0	5.4	6.7	41.8	18.3	76.2

Source: 1982 National Resources Inventory

Table 11-6.--Acreage of nonfederal wetlands, by vegetative cover (1982 NRI)

Wetland 1/		Vegetative cover					
Type	Description	Cropland	Pasture	Range	Forest	Other 2/	Total
		(million acres)					
1 & 2	Seasonally flooded basins or flats and waterlogged meadows	3.7	4.3	3.6	17.8	2.2	31.7
3-8	Freshwater marshes, swamps, or bogs	0.2	1.0	1.9	23.9	9.5	36.4
9-11	Inland saline flats, marshes, or open areas	0.1	0.1	0.6	.1	1.1	1.9
12-20	Coastal flats, salt meadows, marshes swamps, and open water	0.0	.1	0.6	.1	5.5	6.2
All nonfederal wetlands in Types 1-20		4.0	5.4	6.7	41.8	18.3	76.2

1/ The 1982 NRI inventoried wetland types 1-20 on nonfederal lands as described by Shaw and Fredine in Circular 39, Fish and Wildlife Service, USDI.

2/ Other lands are a residual category that includes refuges and parks.

Large acreages of wetlands have been lost. Figure 11-3 shows where wetlands have been drained for other uses. Loss of wetlands between the mid-1950's and mid-1970's was concentrated to a large degree in the Southeast and Lower Mississippi Delta. The largest losses occurred in Louisiana and Mississippi, with more than 1.7 million acres each; Arkansas lost more than 1.4 million acres. Wetland losses in the North Carolina pocosin area and in Minnesota's prairie pothole region were also substantial: over 500,000 acres lost in each. Table 11-8 shows the type of wetlands converted (using the newer classification system described by Cowardin and others) and the use made of the converted wetlands. The primary cause of wetland loss has been agricultural conversion.

Table 11-7.--Acreage of wetland types, by farming region

Farming region	Wetland type 1-2	3-8	9-20	Total 1-20
	(million acres)			
Northeast	2.39	4.83	0.64	7.86
Lake States	2.40	14.28	.01	16.68
Corn Belt	1.72	.38	.01	2.11
Northern Plains	3.04	1.80	.38	5.21
Appalachia	2.43	2.45	.37	5.25
Southeast	8.25	10.04	1.62	19.90
Delta States	5.71	1.65	2.88	10.23
Southern Plains	2.08	.21	.66	2.94
Mountain	1.95	.26	1.12	3.33
Pacific	1.75	.50	.32	2.57
Hawaii & Puerto Rico	.01	.07	.03	.11
United States	31.71	36.45	8.03	76.19

Source: 1982 Natural Resource Inventory.

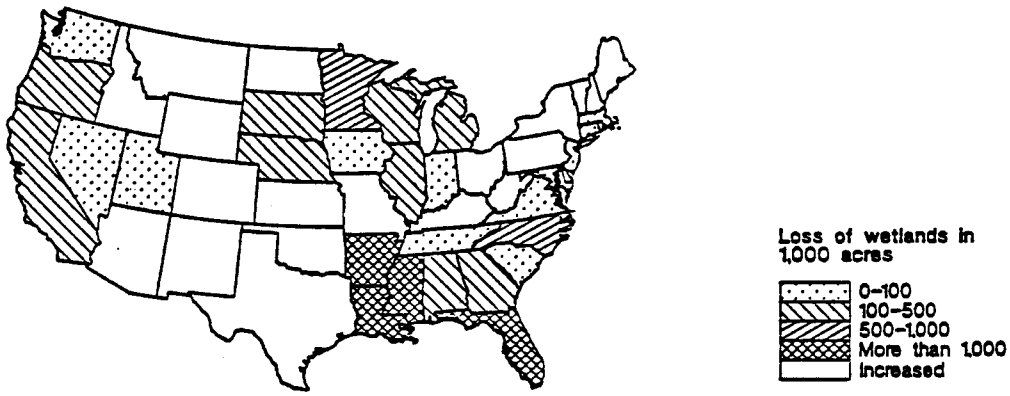

Figure 11-3.--Wetlands loss, mid-1950's to mid-1970's (Heimlich and Langer, 1986).

Remaining wetlands need protection. Nearly half of the remaining nonfederal wetlands and almost all the palustrine wetlands in the United States are potentially subject to conversion for agriculture. The 1982 NRI reported the acreage of wet soils and of wetlands that have potential for conversion (appendix table A11-2). "Potential for conversion" means that similar lands were being converted in the years preceding the inventory. About 5.2 million acres of wetlands have high or medium potential for conversion (table 11-9). The wetland areas most likely to be drained and converted to agricultural uses are in two general categories:

- small wetland areas, either natural or man-induced, that interfere with a farmer's agricultural operation; and
- relatively large areas presently in mature hardwood stands where the value of the timber helps to offset the costs of clearing the land, where land drainage and shaping costs are relatively low, where outlets are readily available for the drainage water, and where continued profitable ownership of the land requires the development of an annual income from the land. Although some wetlands have been converted directly to agricultural uses, about half were originally forested and may have entered agricultural use after being cut over for timber.

Table 11-8.--Sources and uses of converted wetlands, United States, mid-1950's to mid-1970's

Wetland type	Use of land converted			
	Agriculture	Urban	Other	Total
	(million acres)			
Palustrine:				
Vegetated:				
Forested	6.2	0.4	0.2	6.8
Emergent	4.6	0.4	0.3	5.3
Scrub/shrub	1.0	0.1	*	1.1
Subtotal	11.7	0.9	0.6	13.3
Non-vegetated	0.1	*	0.1	0.2
Subtotal	11.8	1.0	0.7	13.5
Lacustrine	0.1	*	*	0.2
Estuarine	*	0.2	*	0.2
Marine	0	*	*	*
Total 1/	12.0	1.2	0.7	13.8

* = less than 100,000 acres.
1/ Totals may not add due to rounding.
Source: Frayer et al.

DISCOURAGING "SWAMPBUSTING": The Food Security Act of 1985

To help conserve wetlands, Title XX, Subtitle C, Sections 1221 and 1222 of the Food Security Act of 1985 (Public Law 99-447) makes producers ineligible for certain USDA programs if they convert wetlands for the production of agricultural commodities. The law defines wetlands as lands that are predominantly hydric soils and on which the prevalent vegetation is hydrophytic.

Hydric soil is soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation. The criteria for identifying hydric soils are based on specific soil properties. USDA has published a list of soils that meet the hydric soil criteria ("Hydric Soils of the United States 1985"). Soils can be added or deleted from the list if new information indicates changes may be appropriate.

Wetland areas are further defined by the type of their hydrophytic vegetation. All plants in a particular area and their weighted values must be taken into account to determine if the area is normally wet, dry, or in a transition zone. The U.S. Fish and Wildlife Service, in cooperation with SCS and other agencies, has developed a national list of plant species that occur in wetlands. The group has established panels to review regional lists of wetland plants and assign indicator status to the plants.

Table 11-9.--Wetland having high and medium potential for conversion to cropland

Farming region	Acreage
	(thousand acres)
Northeast	469
Lake States	742
Corn Belt	371
Northern Plains	553
Appalachia	567
Southeast	1,288
Delta States	546
Southern Plains	124
Mountain	205
Pacific	320
Contiguous U.S.	5,185

Source: 1982 NRI.

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Resource Projections: What might the future hold?

This section discusses a detailed, in-depth analysis conducted over a period of years by researchers from several universities and by USDA analysts with expertise in the conservation and use of natural resources. Long term trends of agricultural commodity demand, resources available, and changes in technology were analyzed with computer models. A number of alternative scenarios were analyzed; three are discussed in this section. The analysis suggests that, assuming intermediate rates of increase in export demand and in agricultural productivity, resources would be more than adequate to meet projected needs for food and fiber. Meeting the highest levels of demand considered at the lowest rate of productivity increase projected would require use of all available cropland by 2030.

Note: The analyses discussed in this section are not predictions of future conditions. They are projections of future scenarios based on a set of assumptions about technology growth, export demand, and agricultural management, assuming constant prices and stability in other aspects of the production environment.

The preceding chapters in this report described the status and conditions of the nation's soil, water, and related resources and evaluated the capability and limitations of those resources for meeting current demands. The Soil and Water Resources Conservation Act of 1977 also directs USDA to analyze resource capability and limitations for meeting future demands. In response to this directive, USDA first analyzed the major forces that affect future demands on our soil and water and made separate projections of the highest, lowest, and intermediate rates of change that could reasonably be expected in each of these forces. These forces include commodity demands, non-agricultural demands for land and water, production technology, productivity losses stemming from soil erosion, and the policy and institutional environment. These projections and their interactions for the "intermediate" scenario were analyzed using a mathematical model of the nation's agricultural sector developed by the Center for Agricultural and Rural Development (CARD) at Iowa State University. This chapter describes these separate and combined projections of resource conditions under various situations.

THE "INTERMEDIATE" CONDITIONS

Commodity demands are projected to increase. Commodities are produced in response to domestic and export food needs and needs for raw materials in industry. Demands for agricultural commodities--food, feed, and fiber--therefore determine resource use, resource deterioration, and conservation needed.

Domestic demands depend largely on population and income and are relatively easy to project, given acceptable population and income projections. Population and income estimates (appendix table A12-1) from the Bureaus of Census and Economic Analysis, Department of Commerce, indicate that our resources will have to respond to the demands of a population that is larger and has much greater purchasing power than the present one. As table 12-1 shows, however, domestic demand for major commodities will rise only slightly. The Census Bureau's projections of population by state show significant differences in population trends among states and among regions (appendix table A12-2); regional shifts in population could be expected to significantly affect resources in some areas.

Export demands, as the last few years have demonstrated, are volatile, depending as they do on global economic conditions, weather and climate patterns, and politics. U.S. exports expanded rapidly in the 1970's--tripling in tonnage and sextupling in value--and then rapidly declined. The rise was fueled by world economic growth, expansion of credit, new trade with previously closed economies, and a weak dollar (Drabenstott, 1985). The subsequent collapse resulted from the global recession in 1981, which strengthened the dollar, fostered trade barriers, and forced restructuring of debt in many developing nations, requiring austerity,

discouraging imports, and encouraging exports. At the same time, international competition increased because of increased productivity worldwide. This increase in productivity resulted partly from the advances of the Green Revolution and partly from agricultural policies offering price incentives and subsidies to farmers. Twenty-five countries, including former net importers such as Finland, Saudi Arabia, and the People's Republic of China, now have farm surpluses (Avery, 1986).

Although the farm export picture is not as bright as it seemed a decade ago, it is unlikely that exports will stagnate or decline permanently. World population and income will continue to grow, and American farms will become more competitive because of improved production efficiency and advanced processing and marketing. For this report, USDA's Economic Research Service (ERS) developed projections of future export levels. Figure 12-2 shows the projected trends in exports for the top three commodities.

Available land and water resources are projected to diminish. Estimates of land supplies used in this report are taken from the 1982 National Resources Inventory (NRI). There are 421.4 million acres of nonfederal cropland, of which 416 are privately owned; 539.2 million acres of nonfederal pastureland and rangeland; and 393.7 million acres of nonfederal forest land, according to the 1982 NRI. As more land and water are needed for nonagricultural uses in the future, less will remain for agriculture, simply because nonagricultural uses of land and

Table 12-1.--Projected domestic and export demand for wheat, corn and soybeans, 1980-2030

	1980	1990	2000	2030
		(billion bushels)		
Corn:				
Domestic	0.7	1.5	2.0	2.1
Export	2.3	2.4	3.2	5.3
Livestock	4.1	3.3	2.5	2.5
Soybeans:				
Domestic	0.2	0.3	0.3	0.4
Export	0.7	0.9	1.3	2.4
Livestock	1.1	1.0	1.2	1.4
Wheat:				
Domestic	0.7	0.8	0.8	0.9
Export	1.5	1.5	1.8	2.8
Livestock	0.1	0.3	0.0	0.0

Source: Economic Research Service. Agricultural Statistics.

water are more profitable than agricultural uses. NIRAP projections indicate that 1.5 million acres of agricultural land will be converted to nonagricultural uses every year for the next 50 years (table A12-4). Of these 1.5 million acres, 63.8 percent was projected to come from cropland, 17.5 percent from pastureland and rangeland, 13 percent from forest land, and 5.7 percent from other sources.

Estimates of water supplies used in this report are based on inventories taken in the Second National Water Assessment and augmented from U.S. Geological Survey data (Smith et al., 1984). Estimates were prepared of surface water, rechargeable groundwater, and non-rechargeable groundwater supplies. The surface water supply estimates for the intermediate scenario represented "dry" weather conditions; that is, in 8 years of every 10, streamflows could be expected to be greater than those used for the analysis. Planning for "dry" rather than "average" flow minimizes problems and periodic disruptions that are inevitable if "average" flow is fully used.

In this analysis, withdrawal and consumption of water for agriculture are assumed to occur only if water is available after nonagricultural needs are met. Use of surface water for all purposes, however, is not allowed to exceed 70 percent of average flow. Thirty percent must remain in the stream to provide survival habitat for aquatic life. However, if interjurisdictional treaties or compacts require outflows greater than 30 percent, the treaty requirement must be met.

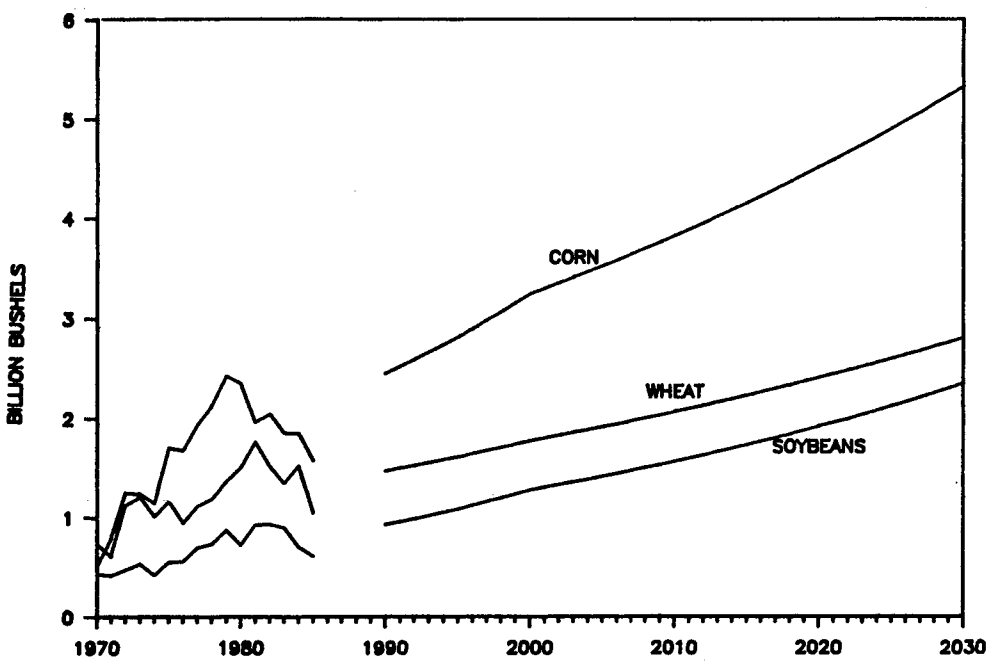

Figure 12-1.--Exports of major agricultural commodities, 1970-85 actual, 1990-2030 projected.
See appendix table A12-3 for projected demands for major commodities.

Changes in technology are projected to more than compensate for lost resources. According to the Office of Technology Assessment (1986), advances in biotechnology and information technology will revolutionize plant and animal production within 15 years.

The estimates of productivity improvement used in the RCA analysis were developed in a symposium held in 1982 (English et al., 1984). Symposium participants estimated future productivity increases, based upon their work in agricultural research. Their estimates of the "most probable" rates of increase ranged from 0.746 percent per year for alfalfa to 2.646 percent for soybeans. Figure 12-2 shows projections of increases in productivity for major commodities. Under these projections, yields of feedgrains, wheat, and soybeans would double, and livestock productivity would increase 60 to 70 percent over the next 50 years.

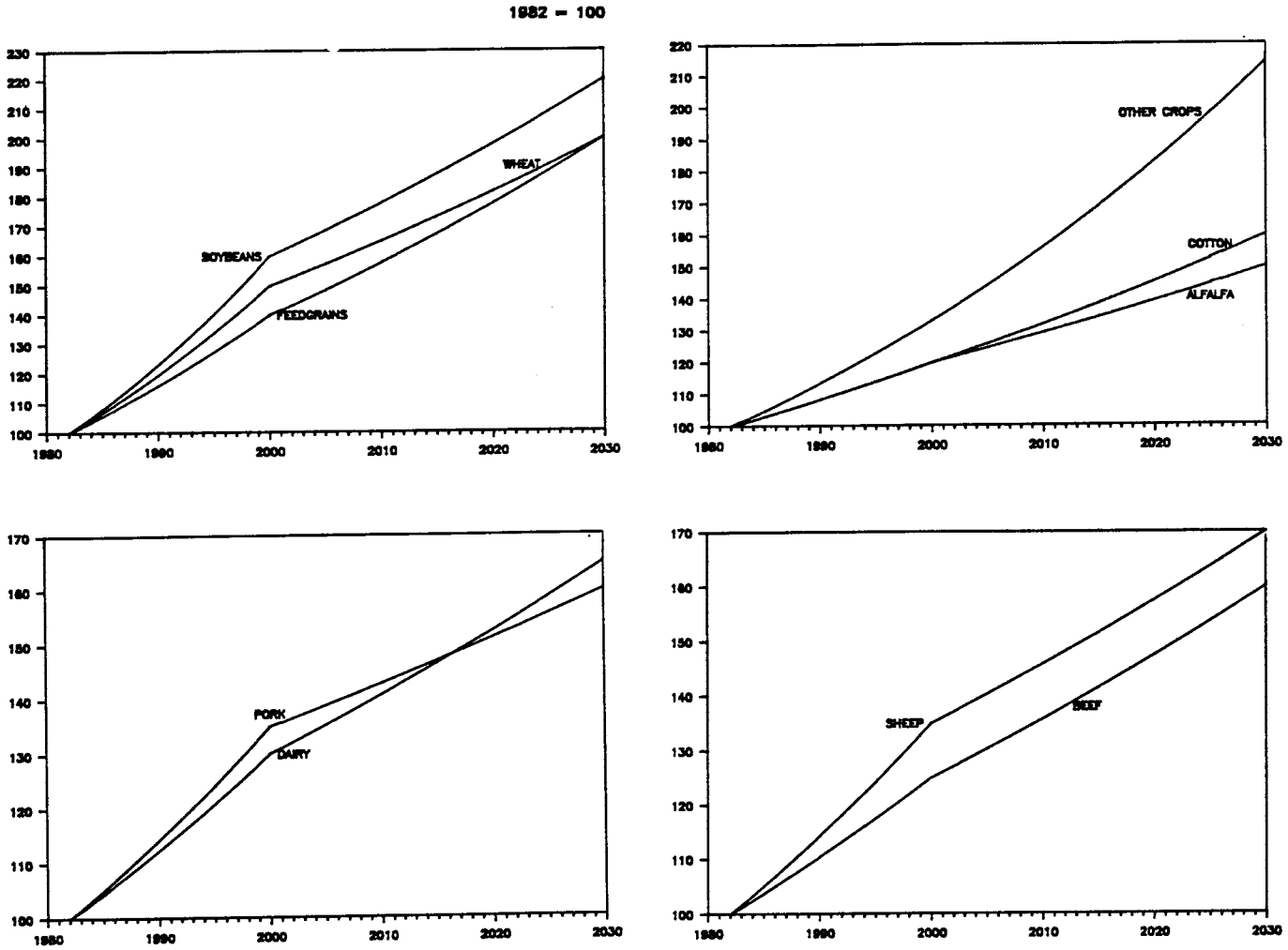

Figure 12-2.--Projected increases in productivity resulting from new agricultural technology, 1980-2030 (English et al., 1984).
See appendix tables A12-5 and A12-6.

Weather and climate, an extremely important set of conditions, were not explicitly projected over the next 50 years. Implicitly, the trends of the past 30 years were extrapolated through the yield projections. Should predictions of a "greenhouse effect" and depletion of atmospheric ozone prove accurate, the effects on agricultural production would produce conditions much different from those projected in this analysis.

o How important are the technology and export projections?--Changes in technology and in the demand for agricultural commodities in the export market are major forces at work in the agricultural sector. Each has a significant effect on land use, soil loss, water use, cost of production, and crop distribution. During development of the CARD/RCA model, several tests were made to determine the relative effect technology and exports have on model results; that is, how sensitive model results are to these two parameters. In this "sensitivity" analysis, the model was solved four times, once for each combination of two export levels and two levels of technology.

The effects of exports and technology on the projections of the acreage of cropland required for the production of commodities were analyzed. Many natural resource variables were projected for the year 2030, but all are tied in one manner or another to the cropland requirement. Figure 12-3 shows the relationship among technology levels, export levels, and

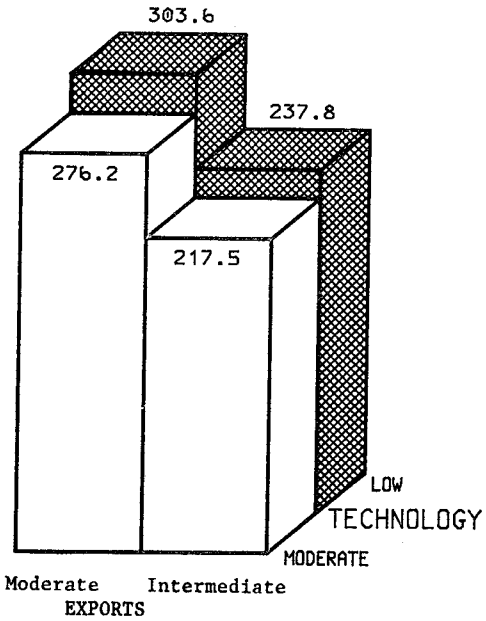

Figure 12-3.--Cropland projections under alternative technology and export assumptions, in acres (CARD).
The technology levels used were the yield rates labelled "most probable" and "low" in table A12-5. The export demands used were the moderate and intermediate projections shown in tables A12-7 and A12-8.

acreage required. Cropland needed ranges from 217.5 million acres in the moderate technology/intermediate export case to 303.6 million acres in the low technology/moderate export case.

Public policy fosters resource conservation. Future conditions of the resource base will depend upon resource supply, commodity demands, and production technology and how they interact to determine resource use. Such use is also conditioned by social factors: law, policy, and custom. Social factors change over time and are even more difficult to project than the other factors that affect resource use. The analysis assumes the conservation provisions of the Food Security Act of 1985 will be implemented. It also assumes that in the future, commodities will be produced only to meet demands; no surpluses will be produced.

Both the Conservation Reserve and Conservation Compliance features of the Food Security Act of 1985 were incorporated into the analysis. To simulate the Conservation Reserve, 40 million acres were removed from the cropland available to the model. These acres were prorated across the country. A total of 69.4 million acres are eligible for the Conservation Reserve under the "3T" criterion; 15 million of the least productive acres eroding at 15 tons per acre or greater were removed from the cropland available to the model. A total of 89 million acres are eligible under the "2T" criterion; 25 million of the least productive acres eroding at 10 tons per acre were removed from consideration in the model.

Conservation compliance was simulated by establishing limits on the percentage of cropland that would be eroding at more than 5 tons per acre. In 1990, no more than 40 percent of the cropland in production was projected to erode at more than 5 tons per acre; this approximates the percentage of cropland reported eroding at more than T in the 1982 NRI. The percentage that could be projected to erode at more than 5 tons per acre was reduced to 25 percent in 2000 and to 15 percent in 2030.

Other conservation provisions of the Food Security Act of 1985 include the "sodbuster" and "swampbuster" provisions that discourage new farming of highly erodible soils and the conversion of wetlands for crop production. In the analysis all conversion from potential cropland into available cropland was disallowed.

THE PROJECTED RESULTS: Rising Productivity Reduces Resource Requirements

Projected commodity production does not greatly exceed 1982 levels. Projected production of the major crop and livestock commodities is shown in table 12-2. Production is projected to decline from 1982 to 1990 because projected increases in demand are not great enough to absorb the 1982 surplus production. In addition to the crops shown, the linear programming model projects the production of barley, cotton, hay, nonlegume hay, oats, peanuts, sorghum for grain, sorghum for silage, sunflowers, and summer fallow. The model calculates the pattern of production that would give the required production of the 11 crops for the least total cost and still not exceed the level of resources available. Crops that were not projected in the CARD model include vegetable crops, tree and fruit crops, rice, tobacco, and other minor crops. Acreage required for these latter crops is projected by the NIRAP model and subtracted from the acreage available to the CARD model.

Less cropland is projected. Since the mid 1950's--with the exception of a few years during the 1970's--agriculture has had excess capacity. Potential production has been greater than the available market. In recent years, excess capacity has gone up sharply because of a sharp decline in exports. A recent study by ERS shows excess capacity in 1985 was equivalent to about 45 million acres (Dvoskin, 1986). Some of those acres were producing surplus commodities and some were idled under land diversion programs. Assuming that in the future, no surpluses were produced, significant gains in productivity were made, and demands increased only modestly, excess capacity would increase. Analysis using the linear programming model projects that production to meet demand would have required about 309 million acres harvested in 1982 had no surpluses been produced (fig. 12-4). Under "intermediate conditions," production to meet demand in 2030 is projected to require slightly more

Table 12-2.--Production in 1982 and projected "intermediate" production, 1982-2030, selected agricultural commodities

		Actual	Projected			
		1982	1982	1990	2000	2030
Corn	million bushels	8.4	6.5	7.2	7.8	9.9
Soybeans	million bushels	2.3	2.4	2.2	2.7	4.1
Wheat	million bushels	2.8	2.4	2.5	2.6	3.7
Beef	million cwt.	.4	.4	.4	.4	.5
Pork	million cwt.	.2	.2	.2	.2	.3
Dairy	million cwt.	1.4	1.2	1.3	1.3	1.6

Source: CARD.

than 218 million acres harvested. Under intermediate conditions assuming implementation of the conservation compliance provision of the Food Security Act of 1985, the same number of acres would be required in 2000. Without the erosion constraints used to simulate conservation compliance, the analysis projects production would require 213 million acres in 2000, but that requirement would rise to 217 million in 2030.

The analysis assumes that the acreage of cropland will change only slightly before 1990. It projects that cropland will decline dramatically after that date, especially in the Plains and Mountain States primarily because the model projects that crops could be

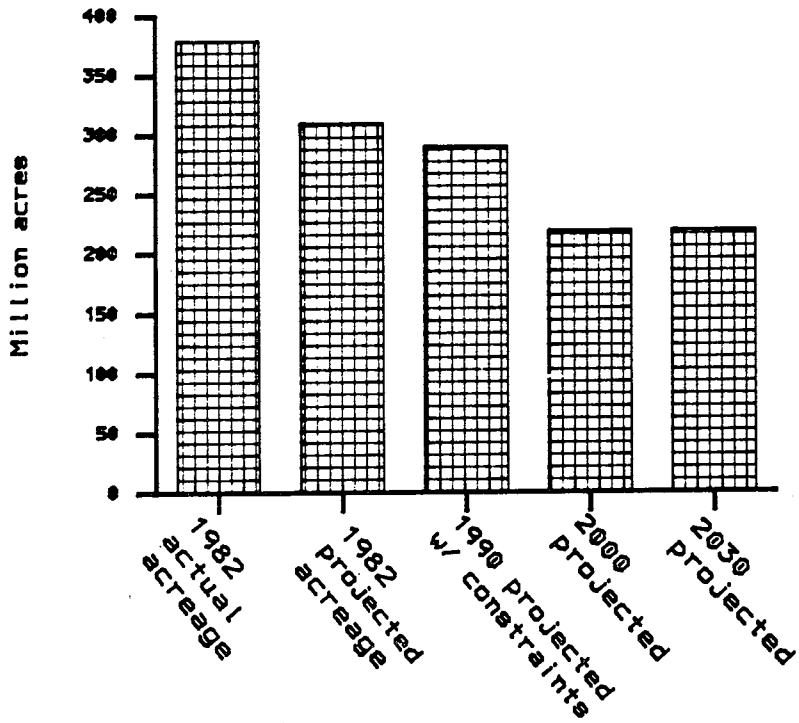

Figure 12-4.--Projected acreage in crops, 1982-2030, assuming intermediate conditions.
Source: 1982 actual acreage--Ag. Statistics.
1982-2030 projected acreage--CARD.
The 1982 actual and projected figures differ because actual acreage includes surplus production and acres on which crops failed. In addition, the model projects slightly more efficient production than occurs in the real world. Projected acreage in 1982 and 1990 are similar because the model is constrained to keep most cropland in production during that period. Acreage constraints are removed by 2000.

produced for lower cost elsewhere (fig. 12-5). In reality, such shifts in production take time to occur because of existing investments in production resources and costs of resource adjustments, which may not be fully accounted for in the model.

Figure 12-6 shows the projected cropland in 2030 assuming implementation of the Conservation Compliance provisions of the Food Security Act of 1985 and compares those projections to conditions if the provisions were not implemented. The figure shows slight reductions in acreage resulting from conservation compliance in the Southern Plains and the Mountain States because the model does not include wind conservation measures and must shift wheat production to areas where wind erosion is not a hazard.

Less irrigation water is projected. The acreage of irrigated cropland is projected to decline. Of the 60 million acres developed for irrigation in 1982, slightly more than 30 million acres are projected to be irrigated in 2030. This is far less than the acreage projected by studies based on historical trends.

The need for irrigation water is projected to decrease as the acreage of irrigated land decreases from 54.5 million acre-feet in 1990 to 17.7 million acre-feet in 2030 (net depletion). Increases in efficiency of water use are expected to lower the need for water, but perhaps more importantly, water sources will become more expensive as competition among users becomes keener and as water tables decline.

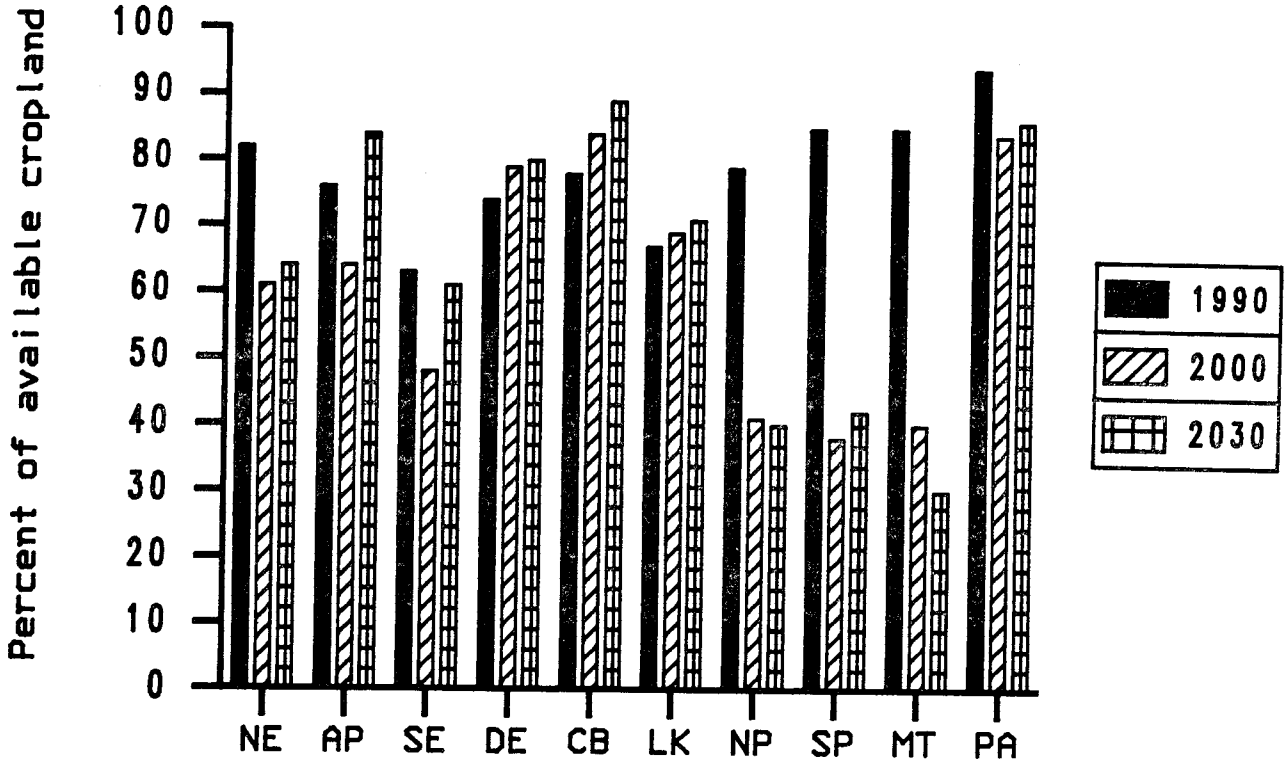

Figure 12-5.--Projected cropland in each farming region, 1990-2030 (CARD).

Less erosion is projected. For the crops considered in the model, erosion will decrease from 6.9 tons per acre annually in 1990 to 3.7 tons per acre annually in 2030 (fig. 12-7). Total erosion from cropland in major crops is projected to decline from 1.8 billion tons to 0.78 billion tons during the same period. The decline in wind erosion results from the projected decline of cropland in regions where wind erosion is a hazard. The decline in sheet and rill erosion results partly from the decline in acres and partly from the increased use of conservation tillage. The combination of cost savings and the conservation compliance requirements of the Food Security Act of 1985 is projected to make some form of conservation tillage near-universal by 2030 (fig. 12-8).

To project the effects that implementation of the conservation provisions of the Food Security Act would have on cropland erosion, an analysis was made using all "intermediate" conditions except those designed to simulate the Conservation Reserve and conservation compliance. Omitting conservation doubles the projected erosion (table 12-3). Distribution of land among types of tillage is identical to figure 12-8; use of conservation tillage in the model is based on the assumed costs of energy, not conservation. The same number of acres, but not the same acres, are protected by terraces in the two analyses. Contouring is used on 15.5 million acres and stripcropping on 4.5 million acres when conservation compliance is assumed. When conservation compliance is not considered, contouring is used on only 2.3 million acres and stripcropping on 2.6 million.

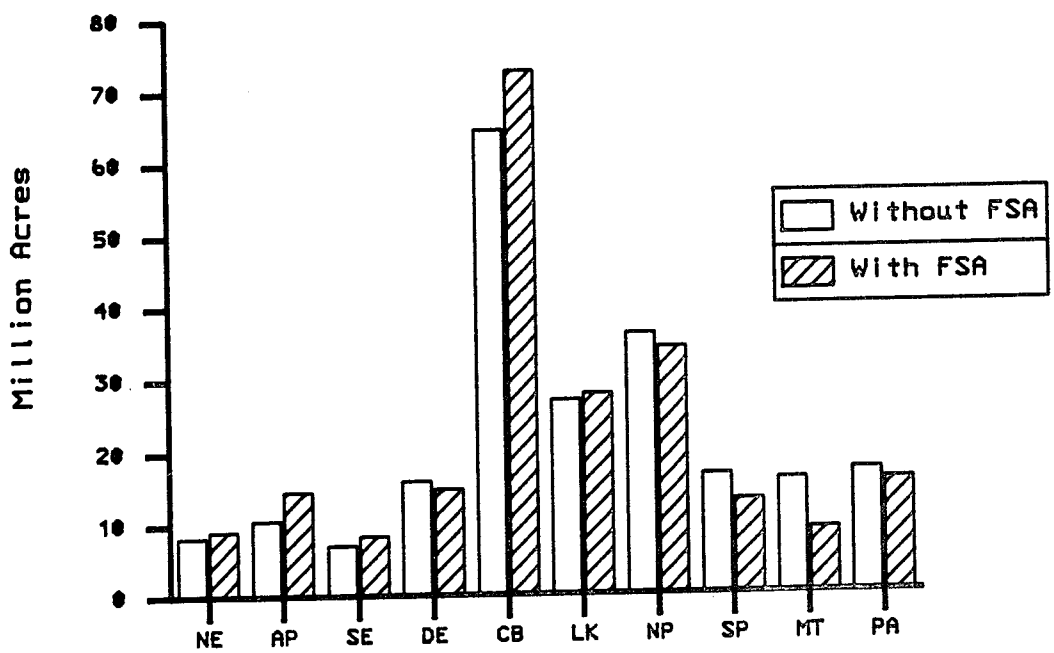

Figure 12-6.--Projected cropland in each region in 2030 with and without implementation of the Conservation Compliance provisions of the Food Security Act of 1985 (CARD).

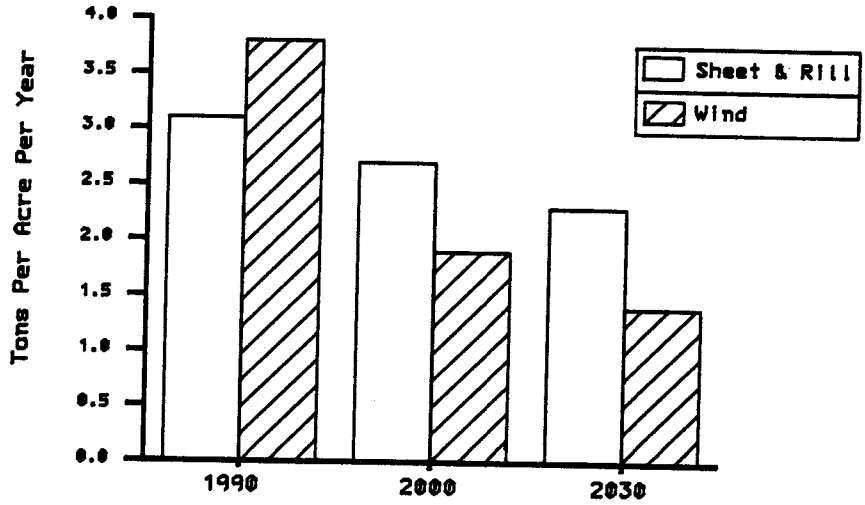

Figure 12-7.--Projected erosion rate, 14 major crops, 1990-2030 (CARD).

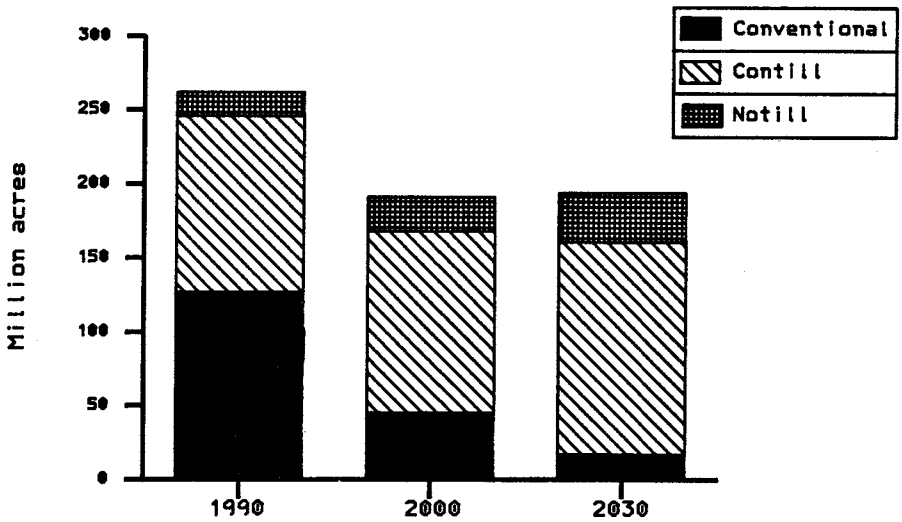

Figure 12-8.--Projected distribution of cropland in major crops among tillage systems, 1990-2030, intermediate conditions (CARD).

Farming may change in ways that modify the projected land use. The projections of cropland needs in the "intermediate" future are not predictions of future occurrences. They show cropland estimated to be needed assuming specific demand and productivity trends and with all other factors, fixed. They do not account for all cropland available but not harvested. The projections do not incorporate "frictional" categories such as land in failed crops and in cropland not farmed. The acreage in these categories has been estimated to range between 14 and 35 million acres (Quinby, 1986). Therefore, the 218 million acres projected for 2030 in the intermediate scenario represents a "floor" of land use, under-representing future cropland acres by a minimum of 14 million acres and probably by more. The distance from "floor" to "ceiling" is substantial; the nation's excess capacity in agriculture--now estimated at 44 million acres--is projected to increase under the intermediate scenario. These results are startling viewed in the context of history and recent experience and compared to other

Table 12-3.--Erosion on projected land in major crops in 2030, with and without implementation of the Food Security Act (FSA) of 1985

	Without FSA			Assuming full implementation of FSA		
	Erosion rate		Total	Erosion rate		Total
	Sheet and rill	Wind	erosion	Sheet and rill	Wind	erosion
	(tons per acre)		(million tons)	(tons per acre)		(million tons)
Northeast	4.3	0.4	33.0	3.2	0.3	28.2
Appalachia	3.5	0.7	37.5	1.7	0.6	39.8
Southeast	2.6	1.2	17.2	1.6	0.7	20.6
Delta States	4.5	0.8	67.8	2.7	0.7	41.3
Corn Belt	4.6	0.9	346.4	3.2	0.8	280.7
Lake States	2.5	1.0	78.6	2.0	1.0	72.5
Northern Plains	2.1	4.1	242.9	2.1	2.1	136.3
Southern Plains	2.7	12.6	228.3	1.5	6.5	90.3
Mountain States	1.8	11.1	179.1	0.8	3.7	31.3
Pacific States	4.2	2.6	80.2	1.0	1.8	35.4
Total			1,310.9			776.4

Source: CARD.

1/ No constraints on land used or erosion.

2/ To simulate conservation compliance, no more than 40 percent of cropland was permitted to erode at more than 5 tons per acre in 1990, no more than 25 percent in 2000, and no more than 15 percent in 2030. Cropland in crops other than major crops is not considered.

long-range agricultural projections (for comparisons with other recent studies see page 12-20). Essentially, the projections of the intermediate scenario are saying that because of advances in agricultural technology, increasing supply will outstrip increasing demand, resulting in continued downward pressure on agricultural commodity prices and land values. Higher per-unit-cost farms will not be able to produce competitively. The projected gap between cropland available and cropland needed, even after accounting for the Conservation Reserve, means that some combination of several possible outcomes is likely to occur: 1) land will be idled (even abandoned); 2) government programs will serve to keep demand abreast of supply, allowing higher per-unit-cost farming to continue; 3) alternative land uses will become attractive because of the decline in land prices (these uses could be alternative crops such as trees or exotics, or nonagricultural uses); or, 4) familiar crops will continue to be produced but with a production system using more land relative to labor and capital inputs because of lower land prices. Some of these outcomes could lower production or increase cropland needed, compared with the projections under the intermediate case.

The RCA analysis implicitly assumes that the incentives for the application of inputs over the next 50 years will remain approximately as they are in the present. This assumption is undoubtedly false. Incentives that exist in an era of prices higher-than-market and "set aside" acres on virtually every farm would change in the decision-making environment implied by the projections methodology: market-clearing prices and no government-subsidized surpluses. This difference in input-use incentives coupled with lower land prices would serve to alter production toward "land-using" technologies and away from "land-saving" technologies (Crosson and Brubaker, 1982, p. 22).

OTHER SCENARIOS: How might conditions vary?

In addition to the intermediate projections, two scenarios were developed to represent states of high and low stress in resource use and condition. In the high stress scenario, fewer resources were assumed to be available, increases in productivity resulting from new technology were assumed to be lower, and exports were assumed to be higher. In the low stress scenario, the opposite conditions were assumed.

Resources available to agriculture could vary slightly. In the "intermediate" future scenario, the amount of land converted from agricultural and other rural uses was assumed to be 1.5 million acres per year, 63.8 percent or 957,000 acres of which was assumed to come from established cropland. In the high stress scenario, this figure was increased to 1.7 million acres per year, again with 63.8 percent assumed to be cropland. In the low stress scenario, the conversion rate was assumed to be 1.0 million acres annually.

In the high stress scenario, water use was assumed to be 90 percent as efficient as in the intermediate case. In the low stress scenario, water use efficiency was assumed to be 110 percent of that in the intermediate scenario and surface water supplies were assumed to be greater because average levels of precipitation (those that occur in 8 of 10 years) were assumed to occur continuously. In the intermediate scenario, water use was not permitted to exceed the supply available in dry years.

Export demand is extremely volatile. The greatest chance of error in the long range projections lies in estimates of agricultural commodity exports. The volatility of the past few years may well be exacerbated by world economic, climatic, and political conditions. In establishing brackets on either side of the future, higher and lower export levels were analyzed (fig. 12-9). The high export levels used in the high stress scenario were developed using the NIRAP model. For the low stress situation, the standard deviation of the 1970-85 export trend was deducted from the export level used in the intermediate projections.

Slight changes in rates of increase in productivity cause big changes in results over time. In the 1984 RCA Technology Symposium (English et al., 1984), agricultural experts and technical specialists estimated several levels of possible future productivity for several agricultural commodities (fig. 12-10). Their high and low productivity projections were incorporated in the low and high stress scenarios (appendix tables A12-5 and A12-6).

ALTERNATIVE RESULTS: Using resources to the limit

Table 12-4 shows the projected production of corn, wheat, and soybeans for the three scenarios. Figure 12-11 shows the cropland required for that production. Meeting the high export demands using low technology

Table 12-4.--Projected crop production, 2030, for alternative scenarios.

	Corn	Soybeans	Wheat
		(billion bushels)	
High stress	17.0	6.6	6.4
Intermediate conditions	9.9	4.2	3.7
Low stress	9.3	4.0	3.4

Source: CARD.

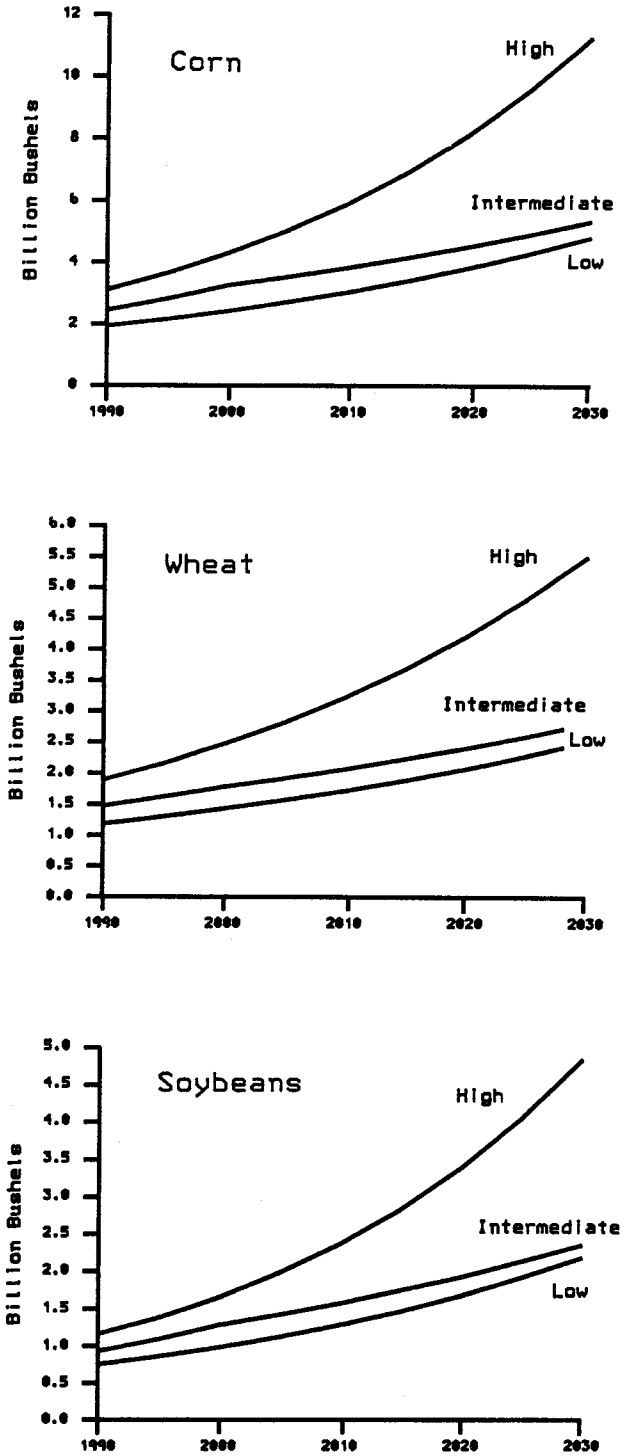

Figure 12-9.--Alternative projections of export demand, 1990-2030 (USDA-ERS).

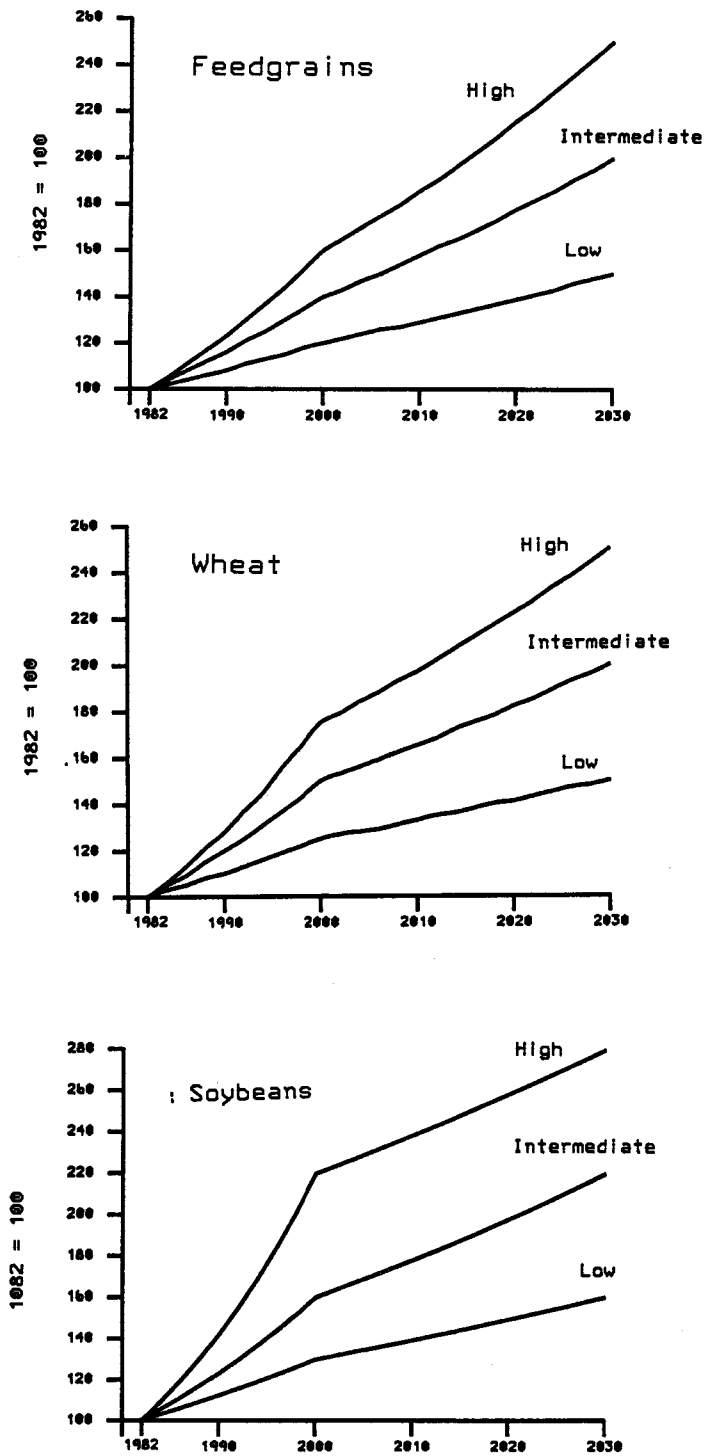

Figure 12-10.--Alternative projections of yield increases, 1990-2030 (English et al., 1984).

would require the use of all available cropland, with the exception of the 40 million acres in the Conservation Reserve. The analysis was structured to test whether resources are sufficient to meet needs without using the Conservation Reserve lands or the highly erodible land and wetlands protected under the "sod-buster" and "swamp-buster" provisions of the Food Security Act of 1985. The analysis indicates that they are.

This high stress scenario, however, would occur in a period of very high commodity prices, which would provide market incentive for returning Conservation Reserve land to cultivation, draining wetlands, and plowing highly erodible land. It is likely that a large share of these lands would be under cultivation in a high stress future, exacerbating erosion, environmental degradation, and onsite and offsite social costs.

Under the high stress scenario, irrigation would be practiced on 68.4 million acres, more than double the acreage irrigated in the intermediate scenario. Under the low stress scenario, only 20 million acres would be irrigated; only 6.5 million of those acres would be in the major crops.

In the low-stress scenario, the combination of high productivity, increased water use efficiency, and lower demands would reduce water use to 30 million acre-feet per year for all crops and to 8 million for the major crops. The high stress scenario, however, requires 100 million acre-feet of water, three-fourths of it for major crops.

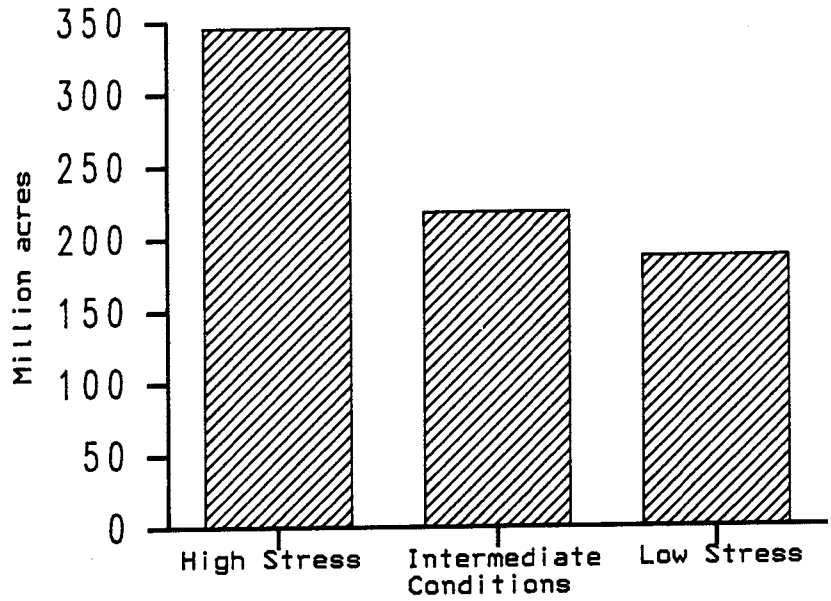

Figure 12-11.--Projected acreage of cropland in 2030, alternative scenarios (CARD).

The erosion rates and total erosion for the three scenarios are shown in figures 12-13 and 12-14. The erosion restrictions imposed to simulate the results of the Conservation compliance provisions of the Food Security Act were not imposed on the high stress scenario. In this high stress future requiring all available cropland, commodity prices would be very high. Farm producers would not be as inclined to participate in commodity programs. Therefore, less cropland would be affected by the conservation compliance provisions. Because of the absence of erosion restrictions, the high stress scenario projects use of conventional tillage on a higher percentage of cropland and no-till on a lower percentage than is projected for the scenarios with erosion restrictions (fig. 12-12). Even so, 77 percent of cropland is projected to be in conservation tillage or no-till in 2030 under the high stress scenario.

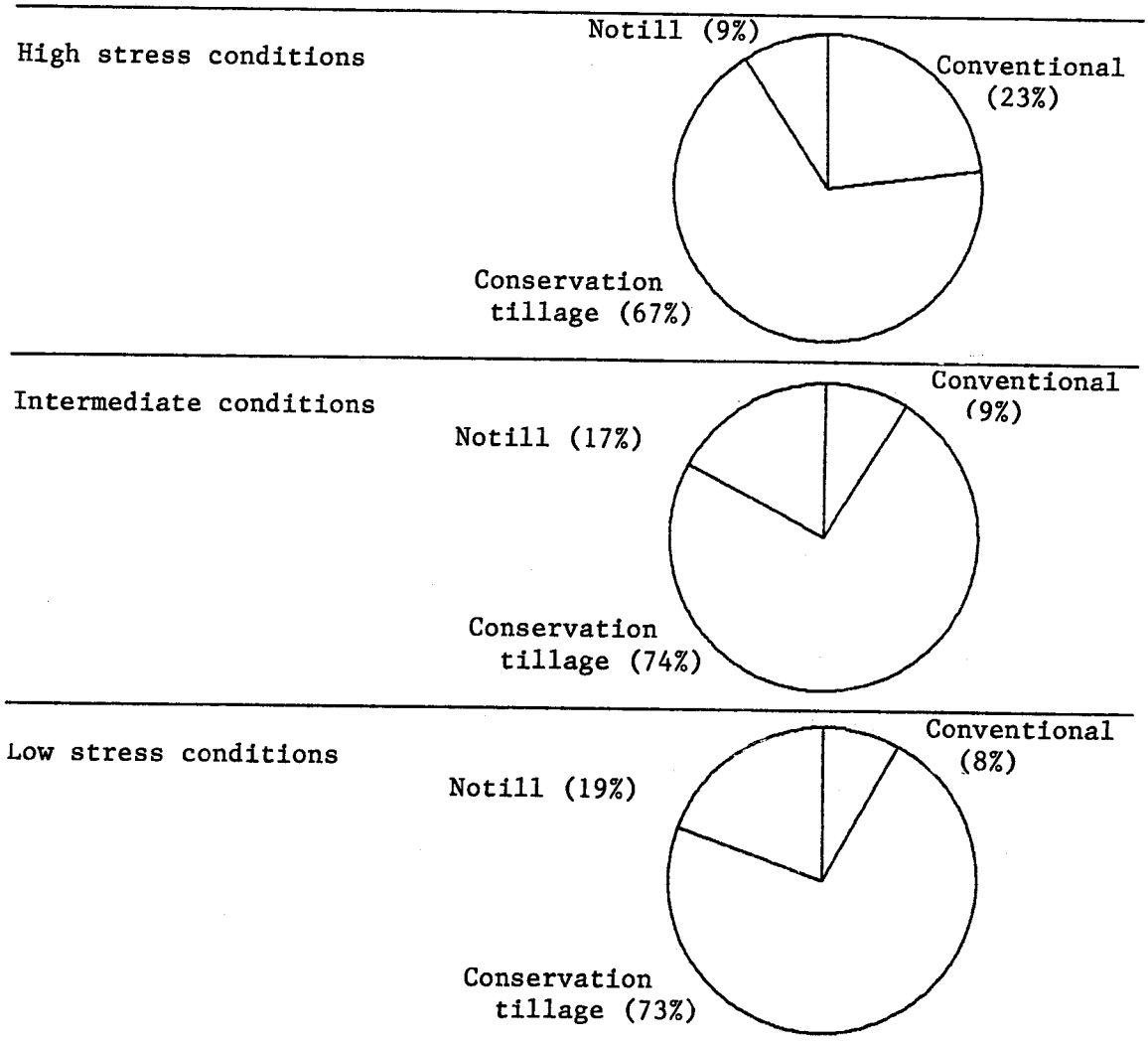

Figure 12-12.--Projected distribution of cropland in major crops among tillage systems, 2030, for alternative scenarios (CARD).

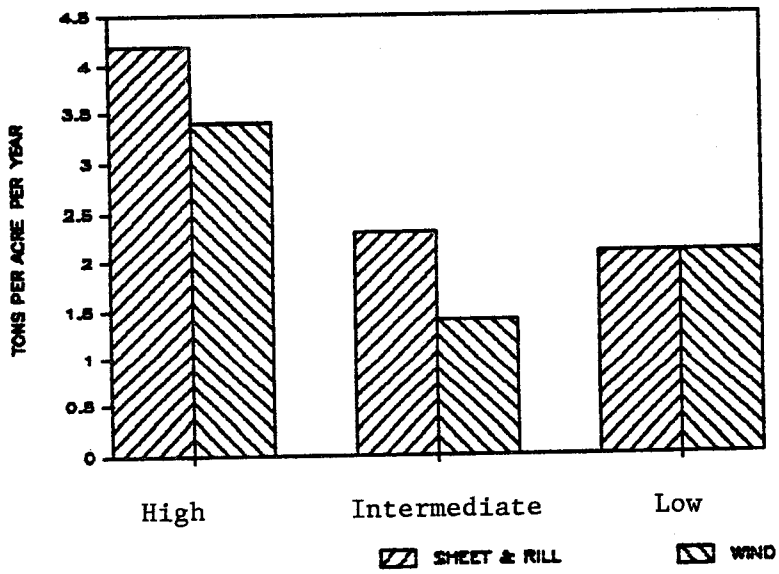

Figure 12-13.--Projected erosion rates on land in major crops, 2030, alternative scenarios (CARD).

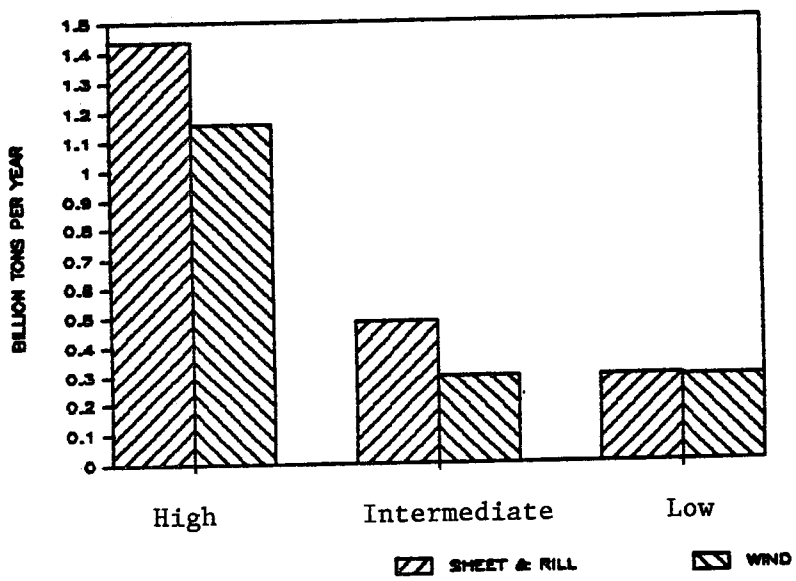

Figure 12-14.--Projected total erosion on land in major crops, 2030,alternative scenarios (CARD).

OTHER POSSIBILITIES: What have other studies projected?

This section compares the Second Appraisal projections with the results of other recent studies in which resource use and economic needs were projected for various periods of time. Comparisons are made with projections developed in the First RCA Appraisal (USDA, 1981), an Economic Research Service study utilizing the National Interregional Agricultural Projection System model (NIRAP) (Quinby, 1986), and a study by Resources for the Future (Crosson and Brubaker, 1982). Table 12-5 compares the projections of cropland needed.

Table 12-5.--Projections of cropland required, selected studies

Analysis	Cropland needed in: 2000	2010	2030
	(million acres)		
2nd RCA Appraisal	218		218
1st RCA Appraisal	386		389
NIRAP			385
RFF (1982)		447	

First RCA Appraisal

For the first appraisal under the 1977 Resources Conservation Act, resource needs were projected to 2000 and 2030 using essentially the same techniques as the second appraisal: major resource use factors were projected independently with an accounting of their interactions estimated by the CARD model at Iowa State University.

The modeling system used at Iowa State at that time differed in several respects from that used in the current analysis. The 1980 model did not incorporate an internal pasture/range/forest sector nor an internal livestock production sector. The marketing/transportation system incorporated 28 market regions rather than the current 31. Technological change was projected utilizing regional production functions developed at CARD. Productivity reductions resulting from erosion were projected by the Yield/Soil Loss Simulator developed by the Economic Research Service.

First Appraisal results differ markedly from those shown in the present study (appendix table A12-8). The Second Appraisal projects cropland needs of almost 220 million acres while the First Appraisal central case projected almost 390 million acres. These differences are tied to differences in the demand and productivity projections used in the two analyses.

Projected export demands for the major commodities are higher in the Second Appraisal than the First. Projected domestic demands for many crops are smaller in the Second Appraisal than the First. Projections of total demand for corn and wheat, therefore, are at about the same levels in both appraisals. Projected demands for sorghum grain and soybeans are higher in the Second Appraisal, and projected demands for all other major crops are less than those used in the first analysis.

RCA projections of cropland use differ in the two appraisals primarily because projections of productivity increases, including livestock productivity increases, differ. The First Appraisal projected an average annual productivity increase of 1.1 percent per year to 2000 and 0.8 percent thereafter. The Second Appraisal used average increases ranging from 1.0 percent per year to 2.6 percent per year (alfalfa and soybeans, respectively) to 2000, and from 0.7 percent per year to 1.2 percent per year (alfalfa and feedgrains) thereafter (fig. 12-15). These differences in annual rates of change would have a considerable effect on yields over 50 years.

Differences in projections of cropland required to provide feed for livestock account for much of the difference in the two RCA appraisals. The Second Appraisal projects a 91-million acre decrease in cropland required between 1982 and 2030. About 65 million acres of that is reduction in acres planted to hay, silage, or feedgrain for livestock (fig. 12-16). In the Second Appraisal, livestock production and pasture/range forage are sectors of the CARD system and the model is allowed to project the least-cost mix of forages and grains that will supply the necessary nutrients. For the First Appraisal, livestock production and feed requirements were based on NIRAP projections.

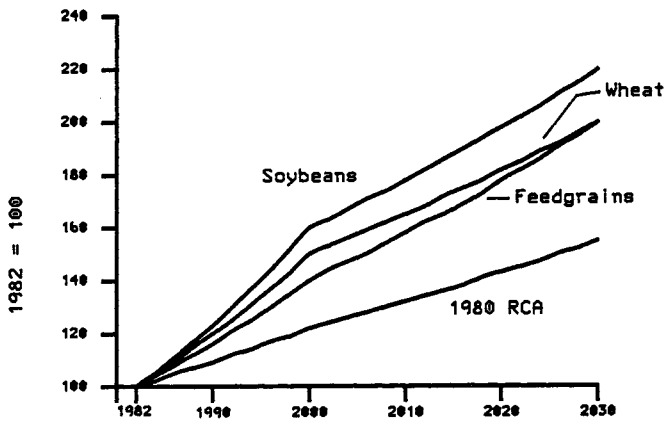

Figure 12-15.--Productivity indices used in the First and Second RCA Appraisals.

NIRAP

NIRAP is a systems simulation model that traces its origins to the early 1970's in ERS (chapter 13). Used originally for the ERS portion of the Water Resources Council's OBERS projections, it has since been under continuous development and is now a key component of ERS' long-run outlook reporting system. NIRAP projections are based on trend extrapolation as modified by long run supply-demand equilibrium equations and resource constraints. NIRAP projections of exports, domestic (nonfeed) commodity demands, and acreages of crops not analyzed by the CARD model were used in both the First and Second RCA Appraisals.

Even though the Second RCA CARD analysis and the NIRAP projections used identical demand levels and coordinated productivity assumptions, they differed substantially in projections of total cropland needs. In 2030, NIRAP projects 387 million acres of cropland would be harvested or in summer fallow (Quinby, fig. 1) while the Appraisal projects 218 million acres. This results because NIRAP projects greater production of feedgrains and substantially lower yields. NIRAP feedgrain demands are based on historical patterns, changes in production of animal products, changes in feeding efficiencies, and changes in prices as interpreted by an elasticity matrix; CARD compares the relative cost of nutrients in alternative feeds, including pasture/range forage. By 2030, CARD projects utilization of 453 million tons of forage from private pasture/rangeland as a nutrient source; NIRAP projects use of 146 million tons.

The remaining difference in NIRAP and CARD projections of cropland acreage lies in the yield projections. NIRAP projects lower yields through time than CARD, giving more weight to recent trends in its projections for rates of increase until 2000. NIRAP ties yields to production inputs and, with declining real commodity and land prices through time, tends to project use of fewer purchased inputs per acre and, hence, lower yields.

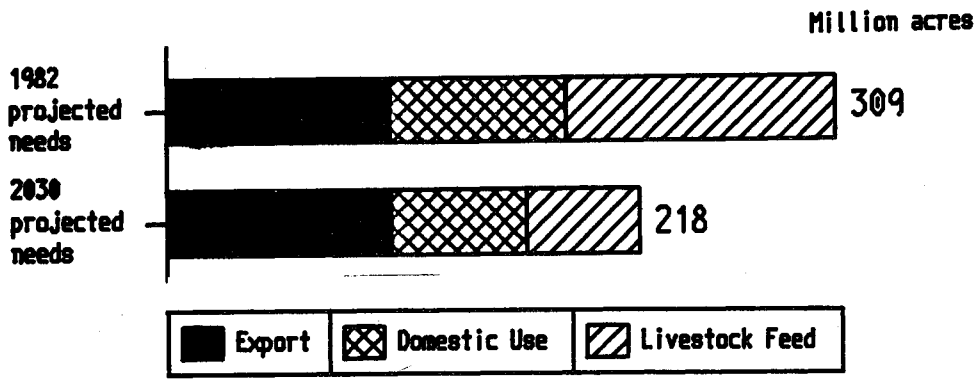

Figure 12-16.--Projected cropland needed to meet demands in 1982 and 2030, by type of demand (CARD).
(About 385 million acres were actually used in 1982.)

Resources for the Future

A Resources for the Future study (1982) projected commodity production and resource use in the United States for 1990 and 2010. This analysis indicated that by 2010, the nation would require 446.9 million acres in crop production--more than double the projections of the Second RCA Appraisal for either 2000 or 2030. The RFF analysis assumed export and productivity rates based on experience from the late 1970's. It used higher export demands and lower yield increases than those projected in the Second Appraisal (tables 12-6 and 12-7).

Table 12-6.--Total demand, RFF study and Second RCA Appraisal

	RFF	SECOND APPRAISAL	
	2010	2000	2030
		million tons	
Wheat			
export	77.2	53.4	84.2
domestic	30.9	23.5	25.9
total	108.1	76.9	110.1
Feedgrains 1/			
export	184.1	100.0	163.9
domestic	206.1	177.2	184.6
total	390.2	277.2	348.5
Soybeans			
export	83.8	38.6	70.7
domestic	48.5	43.8	53.8
total	132.3	82.4	124.5

1/ Corn, grain sorghum, oats, and barley.

Table 12-7.--Average yield comparison, RFF study and Second Appraisal

	RFF	SECOND APPRAISAL	
	2010	2000	2030
		tons per acre	
Wheat	1.19	1.84	2.18
Feedgrains 1/	3.24	3.77	4.73
Soybeans	1.21	1.71	2.00

1/ Corn, grain sorghum, oats, and barley.

Other Projections

Many students of resource use and other analysts have developed projections of crop production and resource use over the past two decades, with markedly varied conclusions. Most support a notion of impending resource scarcity. Included among them are the Club of Rome study of the early 1970's (Meadows et al.), the National Agricultural Lands Study (1981), the work of Martin Abel (1982), and the Global 2000 report to the President (1980). The opposite camp includes work by Heady (1982), The Resourceful Earth (essentially a rebuttal of Global 2000), and the Second RCA Appraisal.

The truth in any long-range projections can only be told in the event. The projections prepared for the Second RCA Appraisal were developed with the best current thinking on trends affecting resource use. The unforeseen and the imponderable, however, can quickly render projections obsolete. Projections must be continually revised and updated to reflect new thinking and the unfolding of new trends.

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Resource Appraisal:
Data Collection and Analytic Tools

This chapter describes the major inventories and analytic tools used in the appraisal.

DATA SOURCES

National Resources Inventory (NRI)

The 1982 National Resources Inventory (NRI) is one of the most comprehensive studies ever made of the United States' nonfederal soil, water, and related resources. It provided much of the data used in preparing the 1985 RCA appraisal.

The 1982 NRI was designed by the Iowa State University Statistical Laboratory and conducted by the Soil Conservation Service (SCS) with cooperation from the Forest Service and other federal agencies. Data were collected by census, area sampling, and point sampling methods. Data were edited for compatibility and reasonability in a computer at Iowa State University.

For the census method, the most recent census statistics were collected to establish county base data. These data consist of (1) water areas larger than 40 acres and perennial streams wider than one-eighth of a mile and (2) acreage of federal land. All other land in the county is considered nonfederal rural land, for which area and point sampling data were collected.

Area sampling was used to estimate the acreage of land in various uses and conditions, such as urban and built-up land, farmsteads, critically eroding areas, water bodies, and windbreaks. In this method, each county was divided into strata and a primary sampling unit (PSU) was selected from each stratum. Nearly 350,000 sampling units were used, roughly 3.5 percent of the nonfederal land area in the U.S. Each unit was outlined on an aerial photograph, and data elements were delineated within the sampling area. Delineated elements were measured and validated by field inspection. Measurements were then expanded according to the sampling rate and added to provide state, major land resource area (MLRA), and national estimates.

Point sampling was used to collect the most detailed information, such as kinds of crops, the extent to which conservation tillage and other conservation practices were used, soils characteristics, treatment needs, and the data needed to determine rates of erosion. Inventory specialists also collected information on prime farmland, wetlands, saline and alkaline areas, and flood prone areas. Points were selected in each sampling unit and onsite data were collected from each point. The data were expanded according to the acreage represented by the points and added to provide state, MLRA, and national estimates.

The NRI results are basic statistics, not data analyses. They are estimates, not absolute values. They constitute a data base which can be analyzed to identify many issues relative to the status and condition of the nation's nonfederal resources.

Water Data

National Water Data Exchange (NAWDEX) is a national confederation of water-oriented organizations working together to improve access to water information. The Water Resources Division of the U.S. Geological Survey (USGS) indexes data held by NAWDEX participants to provide a central source of water data. The Water Data Sources Directory identifies over 400 organizations that collect water data; more than 375,000 sites for which water data are available and the geographic location of those sites; types ot data, parameters, periods of time, and frequency of measurement for which data are available; and the media in which records are stored. Although it is not the function of NAWDEX to provide data storage and retrieval services for its users, NAWDEX does have direct access to some large water data bases:

- Water Data Storage and Retrieval System (WATSTORE). The USGS collects data at 16,000 stream-gauging stations, 1,000 lakes and reservoirs, 5,200 surface water quality stations, 1,020 sediment stations, 30,000 observation wells, and 12,500 ground-water quality wells. Records are stored in WATSTORE files:

  (1) surface-water, quality-of-water, and ground-water data measured on a daily or a continuous basis,

  (2) annual peak values for streamflow stations,

  (3) chemical analyses for surface- and ground-water sites,

  (4) water-data parameters measured more frequently than daily,

  (5) geologic and inventory data for ground-water sites, and

  (6) summary data on water use.

  In addition to storage and retrieval, WATSTORE can provide a variety of products ranging from simple tables to complex statistical analysis.

- Storage and Retrieval System (STORET). The U.S. Environmental Protection Agency (EPA) manages STORET, a system containing over 40 million individual observations of water-quality parameters. Data can be provided as printed tables, statistical analyses, graphic displays, or in a machine-readable form.

- Environmental Data and Information Service (EDIS), Iowa Water Resources Data System (IWARDS), and the Nebraska Natural Resources Information System (NNRIS) are examples of state-governmental organization data banks.

- National Stream Quality Accounting Network (NASQAN). USGS designed the data-collecting network to obtain overviews of the quality of our streams by river basins. NASQAN is one of several data bases designed for a particular purpose that is accessible to NAWDEX users.

Flood Damages: Data Sources

The most comprehensive information on the magnitude and trends of the nation's flooding problem is published in the Second National Water Assessment, prepared by the Water Resources Council (WRC) and its member agencies, under the authority of Public Law 89-80. Other sources of data used in this report are the 1977 National Resources Inventory (NRI) published by the Soil Conservation Service (SCS), the National Oceanographic and Atmospheric Administration/National Weather Service (NOAA/NWS), and the National Flood Insurance Program. A regression analysis was made of the NOAA/NWS data to establish trends.

The data for the 1980 appraisal came primarily from the WRC Second National Water Assessment, SCS open file material, and the Federal Emergency Management Agency (FEMA) community flood insurance reports.

New data sources used in this appraisal are the 1982 National Resources Inventory, updated FEMA flood insurance reports, NOAA/NWS flood database material, and SCS open file material from River Basin Study Reports and Public Law 83-566 watershed plans. Only limited use was made of the River Basin Study Reports.

National Fisheries Survey

The data in this report are derived from the results of the National Fisheries Survey (1982). This survey was conducted jointly by the U.S. Environmental Protection Agency and the U.S Department of the Interior Fish and Wildlife Service. It was based on a statistically selected sample of 1,303 river segments across the country which represented all flowing waters in the conterminous 48 states, including main-stem impoundments. The survey excluded the Great Lakes, estuaries, coastal waters, and wetlands. The waters thus defined amount to 955,155 stream miles, of which about 69.8 percent (666,518 miles) are perennial streams.

State fish management experts, with an average of 9 years of experience in the selected cataloging units or watersheds, were queried. Forty percent of the reaches had been quantitatively or qualitatively sampled, and sampling had been done in surrounding cataloging units for an additional 33 percent. Twelve hundred and eighty-five questionnaires, 98.5 percent of the total distributed, were completed and returned.

Survey respondents were asked to provide information on four basic issues: the fish species occurring in each reach, the time of year during which the segment is usable as fish habitat, conditions adversely affecting fish in the reach, and trends in reach conditions. The respondents also described kinds of fisheries data available for the reach.

ANALYTIC TOOLS

Estimating Erosion

Sheet and rill erosion.--Sheet and rill erosion is estimated by the Universal Soil Loss Equation (USLE). The equation is: A = RKLSCP. In this equation, the soil loss, A, is expressed as a function of factors that represent the physical and climatic conditions of a specific site and factors that represent what the farmer is doing on that site. The factors that represent the physical and climatic forces of the site, if considered alone, estimate the sheet and rill erosion that could theoretically occur on the soil if it were in continuous clean-tilled fallow. Physical and climatic factors in the USLE are the erosive force exerted by rainfall and runoff (R), the degree to which the soil resists those forces (K), and the length and steepness of the slope of the soil, represented by a nonlinear factor (LS). The RKLS factors provide an estimate of the inherent erodibility of a soil. The C and P factors estimate the degree to which use and management of the soil reduce erosion. The C factor represents the protection against erosion provided by the crop and tillage system, and the P factor represents the protection afforded by the supporting practices of contouring, strip cropping, and terracing.

In spite of its title, the USLE measures soil movement within a field, not soil loss from the field. In many places and many years, very little of the soil moved by sheet and rill erosion leaves the field. Measurements in numerous watershed studies have showed that the amount that actually leaves a watershed ranges from 10 to 100 percent of the eroded soil as estimated by the USLE, with the most common values being around 40 percent. How much is lost depends on the nature of the soil, the slope characteristics of the landscape pattern, and the transport efficiency of the stream system. Damages caused by soil when it leaves a field are discussed in chapter 10 of this report.

The USLE does not estimate all soil moved by water. The USLE was developed through the analysis of data from many years of experiments on standard erosion plots that were about 73 feet long with a slope gradient of about 9 percent. To give results from which useful generalizations could be made, the erosion plots were designed to minimize the effect of factors other than the five that were being studied. The plots, for example, were straight, and the small topographic irregularities that occur in most fields were carefully eliminated. But these irregularities strongly influence erosion, causing erosion in some places and deposition in others. Further research and computer modeling suggest that irregularities in the microtopography of the land may have as much influence on the amount and effect of sheet and rill erosion as slope gradient and slope length.

Wind erosion.--Wind erosion is estimated by the Wind Erosion Equation (WEQ). The equation is E = f(IKCLV). Soil loss, E, is expressed as a

function of the physical and climatic conditions of soil erodibility (I), climate (C), and field length (L) (field length, unlike I and C, can be altered by management) and two management factors, the vegetation density factor (V), and soil (surface) roughness (K). The f indicates that this equation involves relationships that are non-linear.

In wind erosion, the coarser soil particles "jump" along the soil surface (a process known as "saltation"). In doing so, they may damage crops and accumulate as dunes in neighboring fields or roads. The finer particles and aggregates are carried off as dust and may move long distances.

Wind erosion has been studied much less extensively than water erosion, in part because its economic significance was not fully recognized and in part because wind erosion is much more difficult to study and measure. Also, wind erosion is influenced more by variables, such as the moisture content of the soil at the time of a storm, or whether or not the soil's surface has a crust. Most of the research on wind erosion has been done by using wind tunnels, which provide only an imperfect approximation of natural conditions.

Gully erosion.--Estimating ephemeral gully and classic gully erosion is a difficult and lengthy process. Ephemeral gullies begin when sheet and rill runoff converges into gully flow. The soil moved by ephemeral gully erosion is not included in USLE-estimated erosion data because the experimental plots from which the USLE was developed were much shorter than most fields and not long enough to allow flow to concentrate into deeper channels. Studies on the effects and extent of ephemeral gullies have been made, and techniques for estimating erosion from them will soon be developed.

Gully erosion removes large amounts of soil. If the subsoil in a gullied area is deep and has weak structure, the banks of gullies may slough and cave in. As water continues to flow down the gullies, masses of soil break loose and are swept downstream. Processes leading to the formation of gullies are not completely understood; both geological processes and management practices play a part. Predictions can be made only on the basis of detailed studies at specific sites, and available methods are much too expensive and time-consuming for a national inventory. The onsite damage resulting from gully erosion is measured not so much in tons of soil lost as in the loss of arable land. Gully erosion also results in sedimentation downstream, reducing channel capacity and leading to increased flooding.

Erosion/Productivity Impact Calculator (EPIC)

Response to the Resources Conservation Act of 1977 cited the need to study the effects of erosion on soil productivity. As a result a team of Agricultural Research Service (ARS) scientists developed the Erosion/ Productivity Impact Calculator (EPIC) model, first reported operational in May 1985.

EPIC is a production function model which simulates interaction of the soil-climate-plant management processes in agricultural production. The model is composed of physically based submodels capable of simulating plant growth and related processes when constrained by erosion. The components of EPIC include hydrology, weather, erosion-sedimentation, nutrient cycling, plant growth, tillage, soil temperature, plant environment control, and a financial component, which is a simple accounting of costs and returns. Each submodel has subroutines that are linked sequentially and interactively to estimate the change in soil characteristics as the erosion process continues over a given period.

EPIC operates on daily time steps which estimate daily erosion, crop yield, fertilization, irrigation, plant stress, runoff, and many other predictive factors. The model estimates the accumulated impact of soil erosion on inherent soil productivity by reducing the thickness of the root zone and the soil's moisture-holding capacity. EPIC includes in its siumlations the changes in texture and chemical properties as subsoil becomes mixed with topsoil in the plow layer, the loss of nutrients through removal of sediment, accelerated runoff, and changes in toxicity in the root zone. The model is static with respect to management and technology, but is dynamic in its simulation of daily variations in weather.

EPIC was designed to utilize data available from current sources. Its design also allows for expansion and inclusion of the latest research in soil-climate-plant processes. In its present form, EPIC is a point source model with limited reliability on areas greater than 10 square meters (pedon). Future efforts will concentrate on developing a model equation that will make estimates applicable to complex landscapes, even to large watersheds.

At present, EPIC does not estimate or take account of all the possible impacts of erosion on productivity. Some of these are: damage to plants by wind erosion or by deposition; failure of seedlings to emerge, because of crust formation on eroded soils; death of plants affected by drought, where the root cause is that the soil's capacity to absorb and hold water has been reduced by erosion.

Erosion/Productivity Index Simulator (EPIS)

The Erosion/Productivity Index Simulator (EPIS) model was developed to provide a systematic method for analyzing EPIC output. EPIS was used to index 12,000 individual EPIC simulations into values that estimate the effects of erosion at the MLRA, state, and national levels. The EPIS output estimates relative soil productivity among RCA land groups, tillage practices, and crops. EPIS also estimates the additional fertilizer requirements over time due to fertility lost through erosion.

Other Erosion/Productivity Models

USDA has tested two other models to estimate the effects of erosion on productivity that USDA has tested. The yield/soil loss simulator (Y/SL), the first of these models, was developed for the 1980 RCA appraisal. Using regression analysis, a relationship between crop yield and past erosion was computed as a function of soil depth based on expected erosion. The equations in the Y/SL assumed constant technology and management, just as EPIC does. Furthermore, since the data used in the Y/SL system were published over a long period of time, some of the data were not comparable, as those in a regression framework must be, and normalizing procedures were needed.

The Productivity Index (PI) model starts from the hypothesis that the major effect of erosion is to change the soil's micro-environment for root growth, thus affecting crop yields. The PI calculates the relationship between erosion and changes in the soil properties that determine the soil's capacity to support root growth--available water capacity, bulk density (adjusted for permeability), and pH. On most soils, the PI goes down as the lower layers of a soil are incorporated into the plow layer. So far the PI has performed well in tests for the Corn Belt, using corn as the crop. It is being tested in other regions of the country.

Comparison of computer models with the real world is difficult. The primary basis for validation of any erosion/productivity model is how closely that model's projections match the professional judgments of knowledgeable researchers or how closely model assumptions match professionally-accepted "truths." A weaker basis for validation is how well one model's results compare with those of another model; the danger is that both models may be equally wrong.

Interactive Conservation Evaluation (ICE)

The Interactive Conservation Evaluation (ICE) program was designed to provide soil conservationists with an automated evaluation process for assisting land users in evaluating and selecting alternative soil conservation measures for their farming operations. The data for input consists of variables associated with farmland's physical and economic resources and factors involved with the installation of resource management systems. This includes such things as soil series, land use, cost of crop production, interest rate, installation cost of conservation practices, cost share rate, etc. ICE produces results on many alternative resource management systems for each field of a farming operation. These results include a summary of erosion levels, gross and average annual returns, crop yield reductions borne from excessive erosion, and benefits accruing from conservation practices that conserve soil moisture. With these results a land user can evaluate the physical and economic impacts of implementing alternative conservation measures on eroding land and select the alternative that best suits his/her goals.

Water Network Model

The Resources for the Future (RFF) Water Network Model estimates the effects of point and nonpoint pollution on representative water bodies throughout the United States. The network of water bodies covered includes 304 rivers, 175 lakes and reservoirs, 37 bays, 10 segments of Great Lakes shoreline, and 26 segments of ocean shoreline.

The information on pollution loadings is drawn from the RFF Environmental Data Inventory, which estimates discharges of 17 pollutants from approximately 20,000 point sources and an equal number of nonpoint sources. In addition, there are more than a million records describing crop-specific pesticide use at the county level. Point source pollutants enter at one or more of the network's 1,300 nodal points, and nonpoint source pollutants enter evenly between adjacent nodal points. The assignment of nodal points is based on U.S. Geological Survey runoff maps.

Once pollutants enter the water network, the model estimates their transport, dilution, and decay. These are functions of the pollutant's physical characteristics and the characteristics of the receiving water (velocity, flow, channel cross section, slope, and other factors). The model can estimate concentrations of pollutants at any location and for any water body in the system. Usually results are reported at nodal point locations, which often coincide with the locations of USGS monitoring stations, permitting model verification with monitored data.

In principle, concentration estimates can be provided for all 17 pollutants. The current model, however, estimates only the concentrations of dissolved solids, biochemical oxygen demand, dissolved oxygen, total phosphorus, and Kjeldahl nitrogen. Sediment concentration relationships are being developed.

The RFF model provides estimates of water quality in specific bodies of water. It is thus indispensable in analyzing comprehensive national policies affecting water quality. The model can be used to evaluate the effects of various soil and water conservation activities on pollution levels and the offsite impacts of nonpoint pollution.

Wildlife Habitat Assessment Model

The 1985 adaptation of the RCA wildlife appraisal model bases its analysis on actual versus potential species diversity--the number of different species (species richness) and the abundance of each. Since species diversity cannot be precisely determined, the SCS model estimates the potential number of different species that may be present in a particular habitat. Habitat is used as the basis for evaluation because it can be defined and measured and because habitat data are available from the SCS National Resources Inventory.

The appraisal model is based on two assumptions: that the habitat suitable for a particular species satisfies the breeding and feeding needs of that species; and that habitat characteristics directly influence the number of different species and individuals within a region.

To develop a habitat structure index, the acreage of potential wildlife habitat for a specified area of analysis is determined by subtracting the acreage not suitable for habitat. Second, the habitat is divided into seven layers: water column (deep water), water surface (wetland), ground subsurface, ground surface, shrub or midstory, tree bole, and tree canopy. These seven layers are the main components of the landscape used by wildlife species for breeding and feeding.

The model then produces an index which compares existing habitat diversity with that which would be present under natural, undisturbed conditions (index value of 1.00). The index is based on the number of layers present and a rating of the quality of vegetation within each layer. The index value of a given habitat is a measure of how much that environment has been modified by human activities.

Center for Agricultural and Rural Development (CARD) Linear Programming Model

The CARD linear programming model, developed by Iowa State University's Center for Agricultural and Rural Development, analyzes the effects of various practices and conditions on the nation's agricultural land base and selects the least costly method of achieving a given level of production. Constraints on resources available, conservation requirements, and the effects of new technology can be built into the model, which chooses activities that best meet a specific criterion.

Expanded from an earlier version (1980 Appraisal, Part II, pp. 31-33; English, et al.) the model includes livestock production, pasture and range, and private forests. In addition, the crop sector now includes new production cost data and a means for analyzing erosion-productivity-fertilizer relationships estimated by the Erosion Productivity Impact Calculator (EPIC). English, et al. (1986) fully describe the model's methodology, structure, and data sources. For a discussion of its development, see Robertson (1986).

Analysts can use the model to project the response of the nation's agriculture to changes in agricultural policy. For example this model can evaluate farming techniques, changes in prices of agricultural commodities and such agricultural inputs as fertilizer and pesticides, changes in domestic demand and in exports, and environmental policies.

The model allows for regional adjustments in climate, soil, and farm structure. It restricts the availability and use of resources and commodity production, processing, and transportation to levels that are

realistic given the resource base, commodity demands, and infrastructure of a particular region. It uses transportation networks to balance demands and resource interactions among regions.

Analysts have used the results of the CARD model to assess the impact on the resource base of erosion, conservation alternatives, and the costs of production from 1990 to 2030.

National-Interregional Agricultural Projection Model (NIRAP)

The National-Interregional Agricultural Projection (NIRAP) model is used by the Economic Research Service to make long-term projections of the U.S. agricultural sector. The model, a computer simulation of the next 50 years or longer, produces yearly estimates of supply and demand for 31 crops and animal products on a national and state basis. NIRAP allocates production of each commodity to the 50 states on the basis of projected resource availability. Future changes in supply and demand relationships are estimated on the basis of macro-economic variables, such as population growth and technological advances. By quantifying potential levels of production and resource use, NIRAP's projections provide a basic framework for testing alternative future scenarios.

The NIRAP food and fiber demand projections are used in the CARD linear programming model to allocate land and water resources to meet demand in the most cost efficient manner. The CARD model then estimates erosion and other natural resource costs incurred in meeting future demands.

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State Notes

State offices of the USDA Soil Conservation Service prepared brief reports on resource problems that they considered especially significant. Summary statements from these reports are arranged under the following major topics: Land use and management, Erosion, Salinity, Rangeland, Water conservation, Atmospheric deposition, Agricultural nonpoint source pollution, and Wildlife habitat. Within a category, the state notes may be grouped together by farming regions.

CHANGES IN LAND USE: Growth and technology affect all regions

Northeast

Connecticut. A state purchase of development rights program has been established, to help slow the high conversion rate of agricultural lands to nonagricultural land uses. The program is effective on a limited scale, but it is not able to preserve most of the prime farmland. Communities are encouraged to adopt agricultural preservation programs that include local development rights purchase, transfer of development rights, agricultural districts, and other innovative methods. In addition, farmers are searching for higher-value, more competitive agricultural crops such as nurseries and vineyards.

Massachusetts. Conversion of agricultural land to other uses is a major concern. Cropland acreage has declined steadily in the past 17 years to 5.6 percent of the state's land area. In 1977 Massachusetts authorized the Agriculture Preservation Restriction Program, a voluntary plan whereby farmers can be paid the difference between the land's fair market value and its agricultural value. A deed restriction is recorded, prohibiting activities that are detrimental to agricultural land use. The program is popular with farmers. SCS provides technical advice and soils information.

New Hampshire. The Granite State has the second highest population growth rate east of the Mississippi River. About 17,500 acres are developed annually and thousands more are affected by development. Because of the limited agricultural base, about 85 percent of the food consumed is produced outside the state, and prices are 10 to 15 percent higher than in other parts of the country. Through a special effort financed partly by RCA funds, two counties have developed an index that rates soil potential for agricultural uses and for development. These ratings can be used to identify the most important local agricultural lands, choose methods to retain these lands, and determine treatment needs and costs for developing lands not important for farming.

New Jersey. Residential, industrial, highway development, and other uses directly compete with agriculture for land. Over the years, land prices have risen dramatically, and property is still being bought and held for real estate speculation. Although the state has taken initiatives to preserve farmland, other incentives are needed to keep agriculture operating profitably.

New York. Urban land covers nearly 1.8 million acres, about 6 percent of the state. Food and fiber production is losing ground to urban development at an approximate rate of 60,000 acres per year. Experts estimate that for every 1,000 persons added to the population, 200 acres of cropland will be lost to urban and other uses.

Rhode Island. The people of Rhode Island recently approved a $2 million bond referendum for the purchase of development rights on farmland, the second such measure in 3 years. This action indicates strong support for farmland preservation in a state that many believe is totally urban.

Vermont. About 20 percent of the land base consists of soils that are desirable for both agriculture and urban uses. Of these soils about 44 percent are in cropland and pastureland, 42 percent forested (only a fraction have potential for conversion to cropland), 8 percent are developed for urban use, and 6 percent in other uses. Between 1967 and 1977, urban and built-up land increased 53 percent, taking the highest quality land. Today, nearly 1.3 million acres of prime farmland or farmland of statewide importance are threatened by irreversible conversion. SCS is cooperating with the University of Vermont to develop a statewide data base to help plan orderly growth and development.

Other Regions

Alaska. Since 1959 nearly 120 million acres of federal land have been transferred to state and private ownership. Native Alaskans--Eskimos, Indians, Aleuts--have acquired more than 34 million acres under the Alaska Native Claims Settlement Act, and another 10 million acres will be conveyed to them over the next few years. Pressures are mounting to develop lands now used as wildlife habitat, woodland, rangeland, and cropland, for oil and gas exploration and development, transportation corridors, and urban development. Changes carried out without proper precautions could lead to extensive problems with erosion, water quality, and flooding. In preparation, Alaska's major concern is to provide adequate resource inventories, baseline data, and planning assistance.

Florida. Conversion of agricultural land to other uses was one of the major concerns expressed in the 1977 RCA public hearings. SCS provides basic resource data on which sound land use decisions can be made. Important farmlands have been identified by developing soil potential indices for common crops. Soil scientists are explaining published soil surveys and helping counties to digitize soil surveys, develop geographic information systems, incorporate soil survey data into comprehensive plans, and complete land evaluation and site assessment (LESA) systems.

Georgia. Georgia is losing prime farmland at a rate of 25,000 acres per year. Approximately 2.1 million acres of land have been committed to urban uses.

Hawaii. The state legislature established the Hawaii Land Evaluation and Site Assessment (LESA) Commission to formulate a system to identify important agricultural lands. The 17-member commission, which includes a soil and water conservation district official, has prepared a recommendation based on the LESA system introduced earlier by SCS.

After determining the acreage needed to reach Hawaii's agricultural goals for 1990 and 1995, each island's agricultural land requirement was estimated. Based on comments received during a series of public meetings, the commission mapped the final boundaries for important agricultural lands. The State and counties will use the commission's work to assist with decisions on land conversions.

Kentucky. Between 1967 and 1982 Kentucky lost about 800,000 acres of farmland to nonagricultural uses, equal to a loss of 145 acres per day. About 163,000 of these acres were considered prime farmland. In 1982 the state enacted the Agricultural District and Conservation Act to protect agricultural land. The Act authorizes establishment of agricultural districts, places responsibility for the program with the 121 conservation districts, and gives administrative responsibility to the Kentucky Soil and Water Conservation Commission.

Nevada. Conversion of agricultural land is a concern in several counties. In the last 5 years, more than 1,300 acres of land (about percent of it prime farmland) have been converted to residential and other uses. Another 1,200 acres are in the process of conversion.

Puerto Rico. Prime, unique, and important farmlands are rapidly being converted to urban and industrial uses. Urban sprawl is using up limited land resources. Absentee and public ownership are high, making local decisionmaking difficult.

Texas. Urban sprawl is a significant issue around several metropolitan areas. Fertile cropland is being converted to nonrecoverable uses.

Wyoming. SCS is engaged in a program to monitor irreversible land use changes. Nine towns were selected for observation. The most recent aerial photography was purchased for each. The district conservationist in each of the nine towns has delineated the extent of urban encroachment and will do so each year for 10 years.

Wetlands

Louisiana. Conversion of forested wetlands and associated habitats to cropland has become a major resource concern in Louisiana. To date, 527,000 acres of land in capability classes IVw and Vw have been converted to cropland. Current legislation and policy mandate that positive steps be taken to restore these wetlands to uses and cover consistent with their capabilities.

New Hampshire. About 400,000 acres of wetlands exist in the state. Those in rapid growth areas experience increasing pressure for conversion to urban uses. Local ordinances now protect about 90,000 acres in 41 towns.

Pasture Management

New York. Some form of conservation treatment is needed on 1.5 million of the 3.8 million acres of pastureland in the Empire State. A large portion of the land is in transition from pasture to native species not routinely fertilized, overseeded, or irrigated. State and local governments are promoting the use of these idle resources to improve income and the quality of life in rural areas. New intensive-use pasture technology is proving to be culturally and economically sound. Dairy animals, beef, and sheep can be productively maintained on intensive pasture for about 180 a year. Extended use of pasture would greatly reduce pollution from stockpiled manure and would permit sizable acreages of highly erodible marginal cropland, now used to produce silage corn, to be shifted to permanent pasture. Winter feeds could then be grown on the best, least erodible, ground.

Pennsylvania. Demonstration grassland management farms are established in 14 southwestern counties, funded by special Agricultural Conservation Program funds. The Cooperative Extension Service also is actively involved in the program. SCS cooperated with the Pennsylvania Sheep and Wool Producers on a field day and a statewide meeting. Development of the sheep industry could foster the implementation of grassland management systems. In 1 year, the Voisin system of intensive grazing was implemented on 42 farms. SCS is cooperating with Delaware Valley College of Science and Agriculture in funding a demonstration Voisin system on the college farms.

Vermont. About 20 percent, or 5.9 million acres, of the state is in agriculture--the greatest percentage of agricultural land of any New England state. Agriculture and related industries make up 30 percent of the economy. Half of Vermont's 7,000 farms are dairy, accounting for about half the dairy farms in New England. Pasture (448,000 acres) and hayland (487,000 acres) remain the major agricultural land uses.

Forest Land

Georgia. Woodland management needs to be improved. At present, more acres are being cut than are being replanted.

Illinois. Of approximately 3.4 million acres of privately owned forest land, about 638,000 acres need protection from grazing. On these acres soil losses average 13 tons per acre per year. To improve conditions for forest growth and stand composition, almost 1.4 million acres need timber stand improvements and about 250,000 acres need more trees to thicken stands.

Forest Land--continued

New Hampshire. Approximately 70,000 acres, or half of all prime agricultural soils and soils of statewide importance, are wooded. By identifying many prime and important agricultural soils as "important forest soils" and thus focusing the management efforts of landowners and foresters on these soils, multiple objectives are being met. Forest research is meshed with our knowledge of soils into a simple, usable interpretation, and important forest soils groupings are being used by a growing number of landowners, foresters, planners, and town boards.

Vermont. Dramatic land use changes have resulted in an unmanaged succession of northern hardwood climax forests. The resource is low quality, overstocked, and inaccessible. Insect infestation is substantial, causing additional degrading of the forest resource. Commercial forest land exceeds 4.7 million acres. Additionally, noncommercial forest lands, plantations, and reserved lands exceed 107,000 acres.

CROPLAND EROSION: A serious concern throughout most of the nation

Northeast

Connecticut. Cropland erosion exceeds twice the tolerable limit (2T) in many areas. The state is experiencing severe erosion on agricultural lands being used to raise nursery stock. The resulting sediment is a problem in local streams and rivers, on some roads.

New Jersey. Ephemeral gullies, not measurable by the Universal Soil Loss Equation, are a significant type of erosion in New Jersey. Although factors contributing to ephemeral gully erosion have been identified, its extent is not known.

Vermont. Cropland erosion is most severe on acreage used for corn, the major cash crop. SCS is encouraging the use of no-till and other, less erosive, cash crops. Recent legislation may prove to be successful in promoting better land management.

Appalachia

Kentucky. Erosion control is needed on about 46 percent of Kentucky's cropland, which erodes at an annual rate of 9.5 tons per acre. In 1985 farmers used no-till on 2.6 million acres of cropland, reducing erosion by an estimated 14 million tons per year.

Virginia. Historically, erosion has been severe and in some areas the state still exceeds the national average on cropland and pastureland.

SCS has targeted three critical areas for increased technical assistance, six watershed protection projects have been implemented, and statewide efforts encourage the use of conservation tillage. Tax incentive legislation has been passed to assist landowners in buying conservation tillage equipment.

Southeast

Georgia. Erosion exceeds tolerable limits (T) on 47 percent of Georgia's cropland, and the rate is higher than 2T in some areas. The solution in most cases is conversion of the land to other uses. Research is under way to investigate other solutions.

Delta States

Arkansas. Approximately 55 million tons of soil are lost annually through sheet and rill erosion. Rates are greater than T (tolerable) on 41 percent of the cropland and greater than 2T on 11 percent. Ephemeral gullies and mining activities cause additional erosion. The number of acres under conservation tillage has increased from 30,000 in 1981 to approximately 900,000 in 1984. As a result, the average annual rate of sheet and rill erosion has dropped from 6.1 to 5.0 tons per acre.

Louisiana. Sheet and rill erosion is most serious on the silty uplands of the Southern Mississippi. Gully erosion occurs on the slopes. Contributing factors are loessial soils that erode easily, high rainfall, intensive farming practices, and failure to protect the soil.

Mississippi. Erosion is most severe on cropland, with an annual rate exceeding 7.5 tons per acre. Of the land being farmed, 22 percent is adequately protected, 42.2 percent needs erosion control measures, and 35.8 percent needs drainage.

Corn Belt

Illinois. The average erosion rate for Illinois cropland is higher than T, and over half of Illinois cropland erodes at a rate greater than 2T. The total sheet and rill erosion on cropland amounts to an estimated 172 million tons of soil. Not all sediment leaves the field, but what does is generally very high in organic matter, fertile inorganics, and pesticides.

Iowa. Sheet and rill erosion moves 249.8 million tons of soil each year on 26.2 million acres of cropland, or an average of 9.4 tons per acre. Wind erosion brings the erosion rate to 12.5 tons per acre annually.

Missouri. Approximately 53 million acres of cropland in Missouri is considered highly erodible, qualifying that acreage for inclusion in the Conservation Reserve Program.

Cropland erosion--continued

Ohio. Although erosion is a problem on all agricultural land in Ohio, it is most severe on cropland. About 32 percent of cropland erodes at a rate greater than tolerable (T) and 12 percent erodes at rates greater than 2T. Most of the state's erosion occurs in specific areas of highly erodible soils.

Northern Plains

North Dakota. Most of the state's cropland erosion is concentrated in relatively few areas. Forty-two percent of the land is eroding at a rate greater than tolerable (T), and 13 percent is eroding at a rate greater than 2T.

Southern Plains

Oklahoma. Soil erosion, the number one resource concern in the state, affects nearly 8 million acres of agricultural land. Long-term treatment is needed.

Texas. The major agricultural land uses in the state are rangeland (57.8 percent) and cropland (20.2 percent). Wind erosion is a major concern in the western part of the state. Water erosion is a serious problem elsewhere. About one-sixth of cropland acreage is eroding at rates greater than twice the tolerable limit.

Mountain States

Colorado. Soil erosion is the highest priority conservation need. Erosion on farm and ranch land is estimated at more than 200 million tons annually: 112 million from wind, 86 million from water, 18 million from streambank erosion. To combat these losses, several approaches are in use including: 1) a dust-blowing task force representing public agencies and private groups which provides information to state and county decision makers, and 2) a furrow irrigation monitoring program. Plow out of fragile rangeland (over 670,000 acres in the past 8 years) is coming under regulation in some counties.

Idaho. Serious erosion, averaging 14.8 tons per acre per year, occurs in the Palouse region and in the dry cropland of the southeast. Irrigation-induced erosion of Snake River Plain cropland also is a significant problem.

Montana. Wind erosion on cropland is the most significant erosion problem. The average annual rate of wind erosion was 8.3 tons per acre in 1982, and the total erosion rate was 9.9 tons per acre. These figures are twice those recorded in 1977, attributable to drought conditions, a 1.8 million acre increase in cropland, and less protection on the land.

Pacific

California. Although over half of the erosion occurs on rangeland, deserts, and wildlands, erosion control is most economically feasible on the state's cropland. Conservation tillage is being practiced on dry cropland, and a combination of cover crops and surface water disposal systems is being used on very steep strawberry-producing, vineyard, and orchard areas.

Oregon. The Columbia Plateau, the southern extension of the Palouse region, has the highest erosion rate in the state. SCS and ASCS are providing resource management systems to the area. Use of conservation tillage, the most important component of the resource management systems, increased from 50,000 acres in 1981 to 400,000 acres in 1985. In 1985 the five-county region saved more than twice as much soil as the other 31 counties in Oregon combined.

Washington. In the Palouse region, soil losses can be higher than 100 tons per acre per year. Ten percent of the topsoil in the Palouse has already been lost. In 1985 SCS efforts reduced erosion in the state by more than 2 million tons on 660,000 acres.

Other

Puerto Rico. Extensive soil erosion occurs because of a combination of topography, intense rainfall, and poor farming practices.

Targeting erosion control efforts saves more soil

Florida. Since almost all of the seriously eroding croplands are in the northern half of the panhandle, targeting has been very precise. Through data collection, mapping, and computer calculations, erosion reduction work can be concentrated on individual fields with the most serious erosion problems.

Montana. Targeting has been directed to the two major land resource areas with the highest erosion rates. In 1985 more than a third of Montana's cropland was farmed using minimum tillage or no-till systems.

Oregon. The success of targeting in the Columbia Plateau region is shown by the dramatic rise in the amount of soil saved (370,000 tons in 1985) and in the number of acres under conservation tillage (from 50,000 in 1981 to 440,000 in 1985).

Pennsylvania. The Mason-Dixon Erosion Control Project, begun in 1984, has made dramatic gains in a 14-county area of southeastern Pennsylvania. A total of 750,000 tons of soil were saved in 1985 as compared to 382,000 tons in 1984. The per acre rate went from 6.3 tons

of soil saved in 1984 to 8.3 tons of soil saved in 1985. The program is not only reducing erosion, but is improving area water quality by keeping nutrients out of area waterways.

Virginia. For three years, the Piedmont Bright Leaf Erosion Control Project has surpassed its annual goal for protecting cropland from erosion. Acreage of protected cropland has risen from 10,585 before targeting to 29,740 in 1985. Other areas also have been targeted for special projects to reduce cropland and pastureland erosion.

West Virginia. Pastureland acreage far exceeds cropland in the state, so erosion control efforts have been directed mainly at pasture management. In addition to conducting a strong statewide information campaign, SCS has established the eight-county Potomac Headwaters Target Area in the eastern part of the state. Erosion reduction in 1985 in the target area was more than double the goal.

Wyoming. A recently-completed critical erosion map for cropland is being used to develop resource management systems for those cropland areas that need erosion control.

Strategies to increase the effectiveness of erosion control efforts

Arkansas. Technical assistance in applying conservation tillage practices is given to users of highly erodible lands. Field evaluation plantings are being conducted in cooperation with conservation districts to find a suitable winter cover crop for cropland and a grass crop for pastureland.

Georgia. Most highly erodible cropland can best be treated through conversion to pastureland or forest land.

Indiana. A comprehensive state-supported erosion and sediment control program is needed, with the goal of reducing all erosion and sedimentation to tolerable limits or below by the year 2000.

Kansas. Over half the farmers use conservation tillage, and many citizens participate in the state's 24 active conservation tillage councils. In these councils, farmers, conservationists, bankers, and dealers in farm chemicals and farm machinery work together to solve common problems.

Kentucky. Efforts to promote conservation tillage have reduced annual soil loss by about 14 million tons.

Missouri. From July 1984 to June 1985, Missouri used cost-share funds to install 3,762 conservation practices which saved 5.2 million tons of soil on 62,000 acres. In fiscal year 1985, 2,019 miles of terraces were constructed, an all-time record. Such achievements are increasing because of private and governmental commitment to erosion control.

New Mexico. Erosion on both rangeland and cropland are resource concerns. To control rangeland erosion, SCS is assisting land users with grazing management and brush control. Conservation tillage, terrace construction, and conversion of cropland to permanent cover are used to control erosion on cropland.

Oregon. Public information techniques have been extensively and successfully employed in conservation tillage seminars and demonstrations featuring farmers, professional conservationists, and equipment manufacturers. Print and electronic media also have cooperated in telling the conservation tillage story.

Vermont. SCS is working with the University of Vermont to develop field trials for small grains in order to reduce erosion while offering a potential cash crop alternative to current cropping patterns.

West Virginia. A pasture management slide/tape set and brochure have been developed and used widely. District conservationists have worked with local farmers to encourage better pasture management. Erosion reduction results exceeded goals by more than 100 percent in some areas.

Wisconsin. An aggressive program to protect farmland from erosion is summarized in the slogan "T by 2000" for every county in the state. In addition, legislation mandates that conservation measures be in place before a farmer can receive tax advantages.

Erosion on land other than cropland is a problem

Arkansas. Approximately 5 percent of the state's grassland erodes at rates greater than is tolerable. Additional erosion occurs where mining operations are concentrated.

Connecticut. The state is experiencing excessive erosion and sedimentation from highway construction and urbanization. Offsite effects include sediment in local streams and along roadways. The state is taking steps to control such situations. Legislation requires sediment control for highway projects receiving federal funds, and for development sites.

Kentucky. The erosion rate climbs as high as 72.2 tons per acre per year on lands that have been stripmined or used for farmsteads, quarries, pits, and road construction sites.

Louisiana. An inventory of forest land soil erosion revealed that some of the most serious erosion occurs on forest land that has been clear-cut, site-prepared for regeneration, or both. This information will assist resource agencies to develop management systems that protect the resource base, maintain site productivity, and preserve water quality.

Mississippi. Although cropland erosion is the most severe, conservation treatment is needed on 65 percent of pastureland and 58 percent of forest land.

New Hampshire. Erosion of forest land occurs mainly in association with woods roads and logging operations. About 13,000 acres of roads, trails, and landings need treatment, mostly in steep, mountainous areas. Significant progress is being made to solve these problems. Lake waters, especially the centrally located Lakes Region, need protection from erosion caused by development activities. Local ordinances to control excavation and development are generally inadequate or nonexistent. A program to inventory watersheds in Belknap and Carroll Counties will provide data for such local management.

New York. Urban development is occurring rapidly. More soil survey information is needed to enable planners and local governments to identify potential development sites that will have the least adverse effect on high-quality farmlands. Up to 90 percent of the soil erosion in urban areas takes place on land under development. Such urban erosion often causes greater economic and environmental damage than erosion in rural areas, because the resulting sediment generally affects waterways and public structures and must be removed.

Ohio. Erosion rates on abandoned, stripmined land often exceed 100 tons per acre per year. More than 65,000 acres need critical reclamation. Another 3,435 acres of farmland on floodplains has been destroyed by deposition of sediment from the mined land. Flooding has increased in frequency, depth, and extent. Nearly 1,400 miles of streams are contaminated by chemical mine drainage, and 636 miles of waterways contain sediment that is detrimental to crop production.

Vermont. Forest land erosion, especially on roads leading into woodlands, is excessive. A rising demand for forest products makes the need for improved planning and management more urgent. In addition, more than 600 miles of streambank erosion pollutes waterways with sediment. Data are lacking on both the causes of streamback erosion and the most effective measures to control it.

Fragile soils

Iowa. Many soils that have developed in a thin layer of friable material over bedrock or another restrictive layer are considered to be fragile soils. A large number of these soils are located in northeastern Iowa, an area which is very productive in agricultural commodities and dairy products. Since agriculture comprises a large percentage of this area and the state's economy, it is in their best interest to maintain the productivity of these soils.

Kentucky. Corn and soybean acreages have more than doubled during the last 15 years. Much of the increase has been converted from pasture, hay, and other less intensive uses. The trend has also been toward larger fields, which may include areas of land unsuited for row crop production. Average annual soil loss is estimated to be between 5 and 10 tons on about one million acres of row crop fields, and is 10 tons or more per acre on more than 1.5 million acres.

Louisiana. Severe coastal marsh erosion is a major resource concern. This delicately balanced marsh system is being converted from vegetated marshes to open water at an alarming rate. This area has the highest resource degradation rate of any area in the nation. Annually 32,000 acres of productive marshlands are eroded away. This amounts to an 88-acre-per-day loss. Coastal marshes have a very beneficial effect on the state and the nation. More than $10.5 billion is produced annually from the renewable and nonrenewable resources.

New Jersey. Pressures of urbanization compel farmers to grow cultivated crops on many fragile soils. Until recently, such soils were extensively used for hay, pasture, and grains. High fixed costs, a decline in dairy farming, and increased cash-grain farming are causing fragile lands to be used more intensively. In the northwestern and more hilly counties (Hunterdon, Warren, Sussex, and Morris) capability classes IIIe and IVe are being used for the production of soybeans and corn. In the southwestern counties (Salem and Cumberland), extensive areas of Chillum soils are used intensively not only for corn and soybeans but for vegetable crops as well. Chillum soils have a thin, loamy surface soil with gravelly, sandy, and clayey substrata. These soils are being severely damaged by erosion.

New York. Erosion control is needed on 1.8 million acres of nonirrigated cropland or about 32 percent of the cropland in the state. About 1.25 million acres of these soils have rooting depths of less than 30 inches. Soils with limited rooting depths are considered fragile because they are easily damaged by erosion. Soils with a small effective volume will suffer a loss of productivity in less time than deeper soils. About 68 percent of the cropland soils in New York have a small effective volume.

North Dakota. Most soils in the state can be classified as fragile. These soils have developed under arid or semi-arid conditions that produce topsoils less than 15 inches thick. The productive potential of these soils is rapidly depleted by losses due to wind and water erosion.

Ohio. Tolerable soil losses average approximately 3.6 tons per acre per year on all soils. Most cropland is on soils that developed in a thin layer of wind-deposited loess over a substratum of dense compacted glacial till. This productive topsoil, when removed by soil erosion, is not replaced by soil regeneration. The result is a severe loss in soil

productivity. Generally these soils are very erodible. SCS has begun testing the "Larsen Model" (productivity model) in one county on all erodible soil units. Results suggest that productivity declines rapidly under current erosion.

South Dakota. Approximately 1.9 million acres of fragile, highly erodible soils need to be converted from cropland to permanent grass. The Fragile Lands Conversion Pilot Project, conducted by the conservation district in Stanley County and funded by SCS under authority of RCA, has proven to be an effective approach to converting fragile croplands to permanent native grasses. Since 1983 landowners have seeded more than 4,500 acres of highly erodible, thin clay soils to grass. Farmers are paid $20 per year for 3 years and 75 percent of the cost of establishing grass. Landowners in turn agree to maintain the lands in permanent grass for 10 years. The grass, after establishment, can be used for livestock grazing, subject to proper management.

Vermont. A significant acreage of shallow but productive soils has effective rooting depths of 24 to 26 inches. Erosion must be held at tolerable rates or lower on these shallow and sensitive soils for the agricultural industry to remain viable. For corn silage, a dominant crop of the state's dairy industry, the critical rooting depth is 20 inches. Therefore, only 4 to 6 inches remain between good productivity and a point of no economic return.

SALINITY: Yields are affected by saline or sodic conditions

California. Salinity was identified as the state's most serious resource problem in "California's Soil Conservation Report," prepared for the Secretary of the State Resources Agency. About half of the state's nearly 10 million acres of irrigated cropland is affected by salinity or sodicity. About 2.9 million acres are saline/sodic soils, and 1.6 million acres have become saline as a result of application of saline irrigation water. SCS expects this acreage to exceed 5 million acres by the year 2000, unless significant improvements in the treatment of the problem are achieved. Five of the nation's top 10 agricultural counties are seriously affected in the San Joaquin Valley. Salinity accounts for a significant decrease in agricultural productivity. A 1-percent decrease in the productivity of irrigated cropland in California equals about $80 million annually.

Montana. Special multi-county saline seep conservation districts have been formed. The first such district hired a team to identify saline seep and develop treatment plans. That team now works with a statewide program and is funded through state government, local conservation districts, and landowners. Using ARS research, conservation districts and SCS are developing treatment plans that use perennial vegetation to dry out the soil profile and flexible cropping systems which efficiently

utilize soil moisture and allow surface salts to be leached into the soil profile below the root zone. SCS is conducting a saline seep inventory and is cooperating with Montana State University in a research project to use remote sensing to inventory and monitor areas affected by saline seep. Two projects demonstrating saline seep reclamation techniques were funded with RCA grants.

Nevada. Salt in the root zone of soils is a problem on more than 20,000 acres of irrigated land. Irrigation water exceeding the amount required to meet consumptive use must be applied to leach the salts which end up in streams and lakes, reducing water quality. Damaged areas include the Colorado River, wetland areas around Fallon and Yerington, and several irrigated areas. Some monitoring of water tables and salt concentrations has been done to determine the extent of the problem. Observation wells have been installed to determine the location and change in water table levels, the associated effects on crop yields, and how farmers are handling the problem.

Oklahoma. Saline and sodic soil conditions are reducing crop yields and increasing susceptibility to soil erosion on more than 500,000 acres of formerly productive cropland, mainly in western and northwestern regions. Because of adverse effects of salt concentrations or sodium at or near the surface, most affected areas do not support adequate plant growth or produce enough crop residues to protect the soil from severe wind and water erosion. The size of saline seep affected areas is expanding rapidly.

RANGELAND: Cooperative, coordinated efforts protect range resources

Florida. More than 90 percent of the state's 4 million acres of rangeland is in fair or poor condition, producing only half its potential in annual forage. Brush control also is needed on nearly half the rangelands. SCS has begun a demonstration project to conserve water on rangelands by controlling brush. Water use is being monitored on both brush-infested and uninfested rangelands to ascertain how much water is lost to excessive brush.

Idaho. About 57 percent of the state's 6.7 million acres of nonfederal rangeland is in fair and poor condition. More than half is producing less than 50 percent of its potential. A resource conservation and range development program, funded by the state legislature, provides low-interest loans for ranchers to improve practices on seriously degraded grazing land. The Idaho Soil Conservation Commission will administer the program. SCS will provide technical assistance through soil conservation districts.

Kansas. Since 1978 Kansas has developed a number of county and areawide Range-Forage-Livestock programs. Committees identify problems and

Rangeland--continued

management solutions to be promoted and demonstrated. The program is a cooperative effort of many agencies and groups: Kansas State University, the Agricultural Extension Services, Kansas State Board of Agriculture, Kansas Fish and Game Commission, Agricultural Research Service, local conservation districts, local RC&D councils, county livestock associations, local extension councils, and SCS.

Montana. Protection from overgrazing is the most pressing need on the state's rangeland, 30 percent of which needs comprehensive grazing systems. Between 1977 and 1982 the extent of rangeland needing conservation treatment decreased from 64 to 51 percent. This improvement was due at least in part to the work of rancher-run county rangeland committees that promote conservation through local workshops, tours, seminars, and educational programs directed toward ranchers, students, and agricultural loan officers. Montana also has shown leadership in coordinating resource management between federal, state, and private landowners. In 1985, 34 such groups were planning and implementing grazing systems to improve rangeland. The state also provides low-interest loans for rangeland improvement.

Nevada. Because 84 percent of the state's land area is in federal ownership, and because private and federal grazing are interrelated, Nevada has developed an approach called Coordinated Resource Management and Planning. This process, based on the philosophy that problems are best solved at the local level by direct communication among all interested groups and individuals, has been used to develop plans that take into account the rights, obligations, and interests of all resource users and the needs of the resources themselves.

Texas. Brush invasion and expansion are major problems on rangeland, with the need for improved grazing management a second priority. Texas has about 105 million acres of brush, much of which forms dense canopies on natural savannahs. Dense brush uses an estimated 60 million acre-feet of water that could be conserved through brush management and a good grazing management program. Approximately 83 percent of the state's rangelands are in poor or fair condition and need improved grazing management. Each individual ranch needs a custom-made grazing management system that will meet the needs of the range ecosystem, livestock, wildlife, and the rancher.

Utah. Approximately 92 percent of the state's total land area is used for grazing. By targeting the resources of agencies and individual ranchers to areas where problems are greatest, over 1 million acres of rangeland have been improved in the past 5 years. Erosion has been controlled on more than 200,000 acres for an annual savings of more than 700,000 tons of soil, and sediment levels have been significantly reduced in several streams and rivers.

Wyoming. SCS has completed a critical erosion map that identifies areas where rangeland erosion is most severe. This map is being used to develop resource management systems for rangeland, especially in the eastern part of the state where offsite erosion pollutes water and damages streambanks. Conservation districts are promoting conservation education.

WATER CONSERVATION: Special projects address concerns for both quality and quantity of surface and ground water

California. Ten million cropland acres are irrigated. About half of these are in the San Joaquin Valley, 25 percent are in the Sacramento Valley, 7 percent in the Imperial and Coachella Valleys, and the remainder are widely distributed throughout the state. Onfarm irrigation system evaluations over the past three years have shown that about one-third of farmers are irrigating in a highly efficient manner, according to the needs of plants; one-third are overirrigating; and one-third are not supplying enough water at the right times to meet plant needs. The large number (more than 200) of commercial crops grown in the state and the use of irrigation water management as a tool to solve salinity problems require the entire range of irrigation systems.

Colorado. Irrigation water for about 4.3 million acres of cropland, pasture, and hayland comes from both snowmelt and ground water. Both vary in supply; surface sources generally are not adequate. Aquifers, especially the Ogallala and in the San Luis Valley, are being depleted. Approaches to these problems range from a forum providing opportunities to coordinate agency activities (Colorado High Plains Technical Coordinating Committee), and demonstration of new water conservation techniques (Yuma County).

Florida. Water conservation is and will continue to be one of the state's most important concerns. The Florida Water Resources Act of 1972 modified common law doctrines dealing with water use and created water management districts having broad statutory powers for water management. The largest single use of fresh water is for irrigating 2.3 million acres of crops. In 1980 almost 3 billion gallons per day, or 41 percent of the state's total fresh water, were used for irrigation. Funds have been targeted to the Florida Water Conservation Project, in which SCS researchers have inventoried types of irrigation systems and are studying methods of applying and managing irrigation water. Work with soils having a high water table showed they can be managed to supply water to crops by upward flux, reducing the need to pump additional fresh water. A planned Central Florida Water Conservation Study will inventory and evaluate irrigation systems in a six-county area, leading to improved methods to conserve irrigation water on deep, well-drained, sandy soils as well as those that have a high water table.

Kansas. Continuing depletion of the Ogallala Aquifer, which supplies most of the state's irrigation water, threatens farmers in the 46 western counties. In 1983 the National Conservation Program designated this as a water conservation target area and provided funds to assist farmers with water management. A four-member team in a multi-county pilot area has been gathering data, evaluating irrigation systems, and experimenting with new techniques.

Montana. Several irrigation water conservation projects have been planned, including targeting of SCS assistance to about 620,000 acres in seven counties. Workshops and personal contacts with farmers will promote onfarm irrigation water management and automation of irrigation systems. Two small watershed projects are aimed at rehabilitating an existing irrigation system and automating onfarm irrigation systems. Another project in the planning stage will save about 16,000 acre-feet of water annually.

North Carolina. Farmers in eastern North Carolina are installing systems for total water management to improve water quality, to reduce the demand for ground water, to reduce freshwater runoff on primary saline nursery areas, and to increase profits. SCS has funded installation of seven demonstration projects to conserve and store water in the surficial aquifer for use in irrigation. The projects have enabled the agency to apply related research, to train personnel in the concepts of water table management, and to create a close-knit network of cooperation between government agencies, researchers, private industry, and landowners. The number of projects resulting from the demonstrations have far exceeded expectations.

Utah. Most water in Utah is supplied from snowmelt, which occurs during a short period in the spring and then settles to a base flow, even disappearing in some places, during the summer. Generally, high streamflow occurs when crops need water the least, and vice versa. In some places, storage reservoirs have been built to hold the high runoff until it is needed by crops. Where this is not feasible SCS is carrying out a campaign to help landowners improve irrigation methods, distribution systems, and application of management concepts. As a result numerous farmers have adopted more efficient irrigation methods, and in several districts, farmers have become involved in water management scheduling.

ATMOSPHERIC DEPOSITION: Acid precipitation recognized in the Northeast

New Hampshire. Acid rain appears to pose a significant threat to the state's natural environment. Concern is increasing about the effects of acid rain on the forests, soils, and water of the state. The problem exists statewide but appears most critical at the highest elevations. SCS soil scientists have been helping the Environmental Protection

Agency (EPA) complete the 1985 survey of the effects of acid deposition on soils. From the documented sampling points, more knowledge of the effects of acid rain will be obtained.

New York. Acid atmospheric deposition is a grave concern for the 6-million-acre Adirondack Region, one of the most severely affected areas in the world. Damage to some 550 lakes in the Adirondacks is considered catastrophic. About 2 million acres in the Catskills also are affected, though to a lesser extent. Various tree species in these areas are undergoing rapid deterioration. New York was a primary participant in the Environmental Protection Agency's (EPA) pilot study for the National Direct/Delayed Response Acidic Deposition Project. This pilot study developed techniques and protocols for the multimillion-dollar national project.

Vermont. Because Vermont is downwind of major midwestern industrial centers, highly acid precipitation routinely falls throughout the state. Lakes, especially those 2,000 feet above mean sea level, have been found to be sensitive to the detrimental effects of acid precipitation. The resulting decline in lake water quality may lead to a loss of fish populations. More needs to be known about how increased acidity affects the specific lakes that conservation programs are directed at improving.

AGRICULTURAL NONPOINT SOURCE POLLUTION: Chemicals and animal wastes threaten water quality in all regions

Surface water problems

California. The three major sources of nonpoint source pollution in the state are sediment, runoff of irrigation water, and drainage of effluent. Persuading farmers to adopt sediment reducing techniques is difficult, as direct benefits have not been quantified. Irrigation water runoff and drainage of effluent are regulated by legislation, and SCS helps landowners comply with the laws.

Florida. Water pollution is a major public concern. The state has established nonpoint source pollution as part of its Water Quality Management Plan, and districts are establishing best management practices in the 20 top priority watershed sub-basins identified in the plan. Targeting to reduce erosion and sediment in the state's panhandle area also addresses the problem.

Idaho. Most nonpoint source pollution comes from sediment and agricultural chemicals. Since 1981 a state cost-sharing program has helped farmers install practices to control erosion, thus reducing sediment and chemical pollution of surface waters.

Illinois. The Illinois Environmental Protection Agency has made a preliminary water quality assessment of all lakes and water impoundments

over a specified size. More than half were found to have a high potential for problems related to nutrient enrichment and sediment pollution.

Iowa. Most nonpoint pollution problems are related to production of agricultural crops and livestock. Cropland sheet and rill erosion causes an average soil loss of 10 tons per acre per year or a total of 260 million tons annually. Other kinds of erosion (including ephemeral gullies, gullies, streambanks, and nonagricultural land uses) also contribute sediment. Most of Iowa's 22 million acres of corn and soybeans are treated annually with herbicides. Soil insecticides are used on half the corn acreage. An average acre of corn receives 133 lbs. of nitrogen and 60 lbs. of phosphorus. Iowa ranks first in the nation in cash receipts from animal products and also has the highest density of domestic livestock. Ninety percent of all animals are produced in systems with capacity for less than 300 animal units. These small operations are considered nonpoint sources. A project developed to help reduce the offsite costs of erosion contains a three-phase plan to (1) gather data on offsite costs for five areas of concern, (2) identify users and distribute the information gathered, and (3) assist in developing demonstration projects.

New Hampshire. The attractiveness of the Lakes Region has caused and continues to exert great pressure of development. There is widespread concern that overdevelopment be avoided, thus protecting the lakes from sediment overload and other detriments to water quality. SCS is helping provide local governmental units with watershed inventory data on the effects of various land uses on watershed runoff.

New Jersey. Both eutrophication and high bacteria counts result from nutrient enrichment in many waterways. Controlling runoff from areas of high-intensity agriculture and livestock production would reduce the bacteria counts and improve water quality throughout much of the state.

Ohio. Lake Erie receives half of all sediment deposited in the Great Lakes System. Phosphorus attached to the sediment causes eutrophication and degradation of water quality. The Lake Erie Phosphorus Reduction Task Force has determined that proper land management is the best way to reduce phosphorus transport. Demonstration projects have been set up, and water quality training is being provided to field personnel, but staffing is insufficient to meet the need.

Pennsylvania. Livestock and poultry production have increased dramatically since 1960, resulting in increased production of animal wastes. Not only is the amount far greater than needed for crops, but when it is applied to cropland, the runoff pollutes waterways that flow into the Chesapeake Bay. A state cost-sharing program has been started in the most severely affected watershed.

Utah. The state is primarily concerned with nonpoint source pollution as it affects fish and wildlife. Water that is usable by fish and wildlife is generally acceptable for other uses.

Virginia. Contamination of lakes, rivers, and streams by intensive use has mandated restrictions on specific uses for many waterways. Pollution abatement efforts are targeted mainly at the Chesapeake Bay, but also at the Chowan River and other important watersheds. Best management practices have been installed on more than 60,000 acres.

Washington. The Puget Sound area has a unique and nationally important fisheries resource which is being threatened by sediments, animal wastes, and intensive urban activities. The Puget Sound Water Quality Authority recently was set up to develop a comprehensive plan to protect and enhance the water quality of the Sound.

Nonpoint source pollution of ground water or of both ground water and surface water

Arkansas. Most cropland is in the eastern part of the state, and surface waters in those areas contain agricultural pollutants. In other areas, livestock and poultry production are major industries. Wastes from these animals have potential for contaminating of ground water.

Connecticut. In addition to the increasing number of wells found contaminated by agricultural chemicals, sedimentation and animal waste problems are increasing. Connecticut's resources inventory program has been used to identify sources, solutions, and costs of problems due to animal wastes and excessively eroding cropland. SCS and state officials are using such data to develop new and better approaches to problem-solving, but more data is needed.

Delaware. The large poultry industry produces a correspondingly large amount of poultry waste, much of which is used on cropland. This use must be properly managed to avoid contaminating underground aquifers.

Maryland. Legislation has resulted in a plan to control agricultural nonpoint source pollution through the implementation of best management practices. The goal is to have conservation plans in place on critical farms within five years and on all farms within 10 years. The initiative provides for cost-sharing grants and technical personnel to implement the program.

Minnesota. Identification of sources, nature, volume, and costs of nonpoint source pollution is needed. Increasingly high concentrations of organic wastes are being found in domestic wells, and pesticides have been detected in ground water. Conflicts exist because the application of conservation practices to reduce erosion and runoff into surface

waters may increase the rate of chemical infiltration into ground water. Work is continuing on development and improvement of predictive water quality computer models and on interagency efforts to improve water quality.

New York. Pollution from point sources has been significantly reduced, but nutrient pollution persists as a result of soil erosion and runoff of animal wastes and chemicals. Targeted activities are reducing nonpoint impacts. Agricultural chemicals also have been detected in ground water. Research on the ways in which agricultural chemicals move through particular types of soils will provide information on best management practices to prevent such infiltration. Accelerated land treatment and resource management systems also are needed.

Vermont. Land runoff from agriculture accounts for more than half of all nonpoint source pollutants entering surface waters. Agricultural chemicals also have been found in ground water. A state assessment has identified watersheds needing accelerated land treatment and recommended watershed protection projects and other remedial approaches.

Wisconsin. Although soil conservation is practiced extensively, agricultural chemicals and animal wastes from dairy farms are a serious threat to the state's waters. Ground water in some sections contains agricultural chemicals at levels that pose a hazard to human health. Wisconsin has an active program in nonpoint source identification and treatment.

WILDLIFE HABITAT: Recognition of wildlife values heightens interest in conservation efforts

Connecticut. A method for evaluating 13 inland wetland functions has been developed for citizens and public officials to use in analyzing wildlife trends and formulating policy. The information provided by the evaluations also can be helpful in addressing such concerns as water conservation and drainage.

Illinois. Farmland-associated wildlife populations have fallen steadily since the mid-1950's as fields have become larger and agricultural practices more intensive. Birds and wildlife that inhabit the forest interior have declined as forests have become fragmented and total woodland acreage has decreased. Sedimentation and nonpoint pollution have degraded water quality in the state, reducing numbers of wetland plants, fish, and waterfowl.

Iowa. Agricultural land use changes, such as larger fields and a fairly restricted variety of crops, have had dramatic effects on Iowa's fish and wildlife populations. Some of the highest ring-necked pheasant population levels were recorded during the Conservation Reserve Program of the late 1950's and early 1960's when almost two million birds were

harvested annually. In 1985 less than one million birds were harvested --a direct result of land use changes that affected this ground-nesting bird.

Missouri. Areas that have experienced the most excessive erosion also have undergone the most severe losses in upland wildlife habitat. Using Missouri's newly developed wildlife habitat appraisal guide to evaluate current conditions and monitor changes, SCS field staff and state biologists have worked with landowners to improve wildlife habitat on 300,000 acres targeted for conservation treatment. Preliminary results are highly positive.

New Hampshire. The state is attempting to reestablish the wild turkey and to increase the deer population. Turkey habitat encompasses both woodland and cropland, and both need improvement for the turkey population to succeed. SCS is working with state agencies and landowners to establish winter food and shelter plantings. Increased timber harvesting has destroyed deer areas and reduced deer populations. Habitat for other kinds of wildlife also is disappearing as cropland is converted to other uses. The New Hampshire Fish and Game Department is inventorying deeryards in an effort to increase the number of deer from the present 13,000 to an optimum 40,000.

New Jersey. Since the 1950's, New Jersey has lost at least 20 percent of its wetland resources to urbanization and intensive cropping. The legislature is formulating a bill to recognize, regulate, and preserve inland freshwater wetland. Fee hunting and leasing are becoming increasingly important as a source of income to farmers. Farmers need help in developing resource management systems that emphasize wildlife management practices along with other conservation practices.

Vermont. Eighty percent of the state is forested but much of the forest is even-aged stands of timber that provide little habitat diversity. Current farming practices emphasize maximum crop production and economic return and minimize wildlife habitat. SCS is working with the state and private landowners to create more whitetail deer habitat on private lands.

Wyoming. Overgrazing of riparian zones by livestock is the most serious threat to fish and wildlife habitat in Wyoming. Rangeland targeting activities will improve some areas. However, the problem is statewide. Wyoming's water law does not recognize fish and wildlife as a beneficial use of water, and no legislation exists to protect riparian areas. Nevertheless, protection of riparian areas in the arid West has extremely beneficial effects in terms of reduced erosion and sediment delivery and increased forage production, fish and wildlife resources, esthetic quality, water quality, and ground water resources.

Appendix I: Land Use Data

The following pages present definitions and basic statistics on land use not presented elsewhere in this report. Much of the information was collected for the 1982 National Resources Inventory (NRI). Some data from other sources also are included.

The 1982 NRI was conducted on nonfederal land by the USDA Soil Conservation Service. The data collection methods are described in the "Methods" chapter of this report.

The total surface area of the United States (including the Caribbean and Hawaii but excluding Alaska) is 1,940,060,100 acres, according to the 1982 NRI. Of this, about 77 percent is owned by private citizens, by businesses and industries, and by states, counties, cities, and other units of nonfederal government. About 21 percent is administered by the federal government. About 2 percent is large areas of water of more than 40 acres (defined as water by the Bureau of the Census).

The status of federal land is described in the report prepared by the USDA Forest Service under the terms of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA).

Figure 15-1 shows the acres of nonfederal land in each of the 10 USDA farming regions. Figure 15-2 shows distribution of nonfederal and federal land among the 10 USDA farming regions.

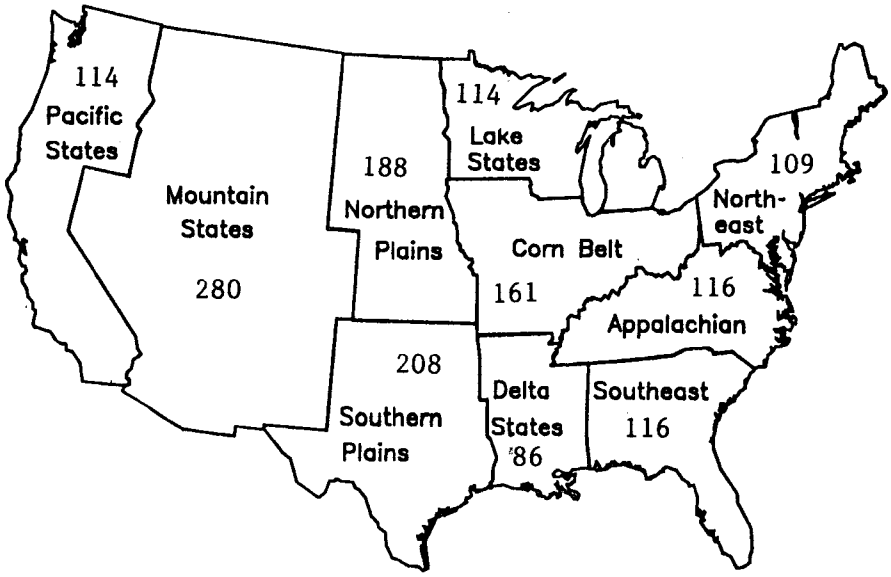

Figure 15-1.--Acreage of nonfederal land in the 10 USDA farming regions, million acres (1982 NRI).

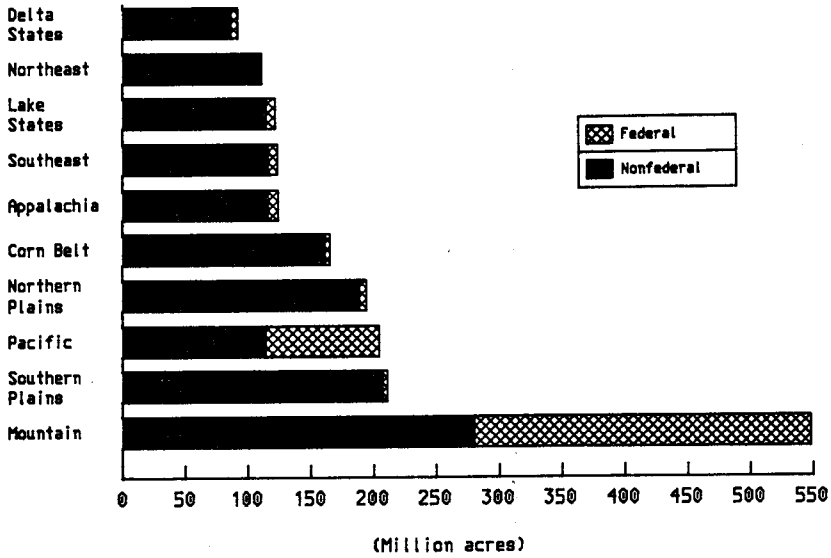

Figure 15-2.--Federal and nonfederal land in the farming regions (1982 NRI).

Adjusted Land Use Data

Data gathered on nonfederal land by SCS and those compiled by the USDA Forest Service on federal land are not compatible because the two agencies use different definitions for some plant communities that include grasses, shrubs, and trees. The two agencies are attempting to resolve these differences so that data collected by the two agencies can be combined to present a comprehensive study of all the nation's soil and water resources. Table 15-1 shows the acreage of both federal and nonfederal land according to the definitions currently agreed to. Definitions shown, except "transition land," also are used in the 1982 NRI. The table includes data for Alaska that are not included in the NRI.

Table 15-1.--Use of federal and nonfederal land in the United States

	Nonfederal land	Federal land	Total
	(1,000 acres)		
Crop and pasture land	529,851		529,851
Rangeland	441,466	328,887	770,353
Transition land	35,603		35,603
Forest land	409,284	276,417	685,701
Other land	159,776	73,504	233,280
Total	1,575,980	678,808	2,254,788

CROPLAND--Land used for the production of adapted crops for harvest, alone or in rotation with grasses and legumes. Adapted crops include row crops, small grain, hay, nursery crops, orchard and vineyard crops, and other similar specialty crops.

PASTURELAND--Land used primarily for the production of adapted, introduced, or native species in a pure stand, grass mixture, or a grass-legume mixture. Cultural treatment in the form of fertilization, weed control, reseeding, or renovation is usually a part of pasture management in addition to grazing management.

RANGELAND--Land on which the climax vegetation (potential natural plant community) is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing and browsing. It includes natural grasslands, savannas, many wetlands, some deserts, tundra, and certain forb and shrub communities. It also includes areas seeded to native or adapted introduced species that are managed like native vegetation.

TRANSITION LAND--Land that meets the definition of forest land based on cover characteristics but where the predominant vegetation is grasses or forage plants that are used for grazing. The Soil Conservation Service has classified most of these lands as rangeland; the Forest Service has classified these lands as forest land. In most instances, these lands are noncommercial timberland ecosystems such as pinyon-juniper, chaparral, and post oak. Transition land is an interim category; the Forest Service and Soil Conservation Service will resolve classification differences and show all such land as rangeland or forest land in future reports. Some of the area in noncommercial timberland ecosystems is classified as forest and range land in this report.

FOREST LAND--Land at least 10 percent stocked by forest trees of any size, or formerly having had such tree cover and not currently developed for nonforest use. The minimum area for classification of forest land is 1 acre and must be at least 100 feet wide. Forest land is distinguished from rangeland in transition vegetation types if the tree canopy cover exceeds 10 percent. Forest lands include cutover areas temporarily unstocked as well as young stands and plantations established for forestry purposes which do not yet have 10 percent crown cover.

OTHER LAND--A category of land cover and land use that includes farmsteads, other land in farms, stripmines, quarries, gravel pits, borrow pits, permanent snow and ice, small built-up areas, and all other land that does not fit into any other land cover or land use category.

Source: USDA Forest Service and Soil Conservation Service.

Cropland

Nearly 28 percent of all nonfederal land is used as cropland. About two-thirds of cropland is planted to four crops (fig. 15-3). Table 15-2 15-2 shows the average yield per acre on irrigated and nonirrigated land for some major crops. Actual yields vary widely on different soils, and average yields vary among regions.

Table 15-2.--Irrigated and nonirrigated yield per acre for specified crops, 1978-1982

Crop		Average yield per acre 1978 Irrigated	1978 Non irrigated	1982 Irrigated	1982 Non irrigated
Corn for grain or seed	(bushels)	114.3	94.9	122.1	106.0
Corn for silage	(ton, green)	17.7	12.6	19.3	13.0
Sorghum for grain	(bushels)	71.3	48.1	78.0	53.6
Wheat for grain	(bushels)	71.3	48.1	78.0	53.6
Barley for grain	(bushels)	54.7	28.5	64.3	31.8
Rice	(cwt)	44.5	-	47.9	-
Soybeans for beans	(bushels)	29.6	28.1	34.1	30.7
Dry edible beans, excluding dry limas	(cwt)	16.8	10.6	17.2	12.3
Cotton	(bales)	1.2	0.7	1.7	0.9
Irish potatoes	(cwt)	295.0	185.6	310.2	183.2
Sugar beets for sugar	(tons)	21.4	18.5	22.8	17.9
Alfalfa hay	(tons, dry)	3.9	2.6	4.1	2.7
Tame hay other than alfalfa, small grain and wild	(tons, dry)	2.0	1.7	2.0	1.8
Wild hay	(tons, dry)	1.3	1.1	1.4	1.2

Source: Dept. of Commerce, Census of Agriculture - 1982 U.S. Summary, Table 40; and 1978 Irrigation, Table 15.

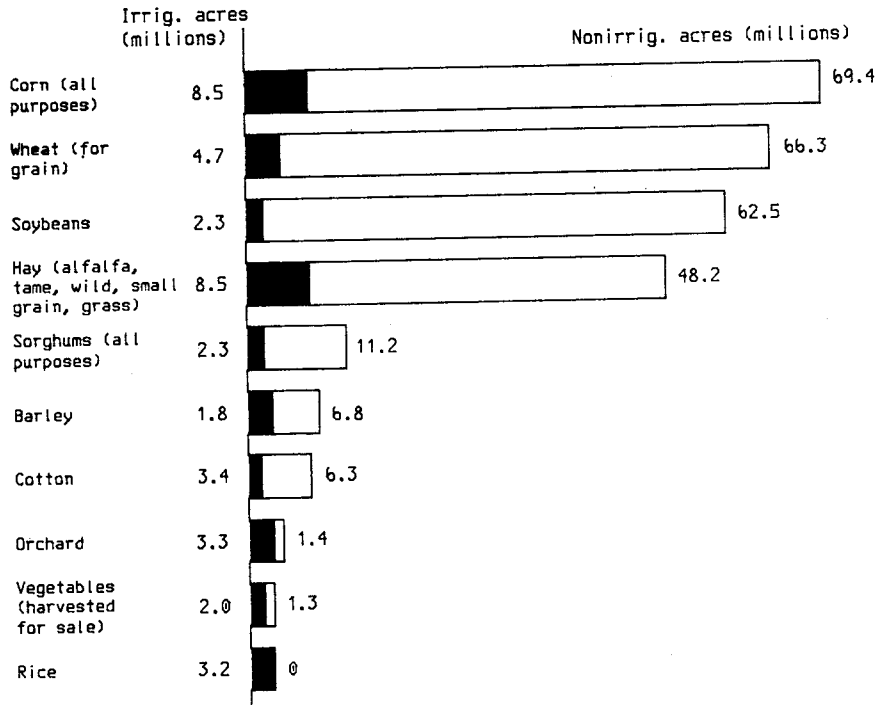

Figure 15-3.--Acreage of major crops, irrigated and nonirrigated, (Census of Agriculture, 1982).

Cropland is not evenly distributed across the nation (fig. 15-1 and table 15-3). Texas has more acres of cropland than any other state; Iowa has the highest percentage of its land in crops (74 percent). Cropland is an important land use in all regions, making up more than 10 percent of the nonfederal land in all regions except the Mountain States.

Table 15-2 shows the crop value per acre, for selected crops, on irrigated and nonirrigated land in each region. Receipts are larger on irrigated land because yields are higher or quality is higher or because different crops are grown. For the nation as a whole, crop sales average about $145 per acre from nonirrigated land and about $280 per acre from irrigated land. Net profits average about $25 per acre higher on irrigated farms than on nonirrigated farms. For some regions, the value of returns on irrigated land shown in the table is low because high-return vegetable and orchard crops are not included.

Table 15-3.--Acres of cropland

Region	Irrigated	Non-irrigated	Total
		(Million acres)	
Northeast	0.3	16.9	17.2
Southeast	3.1	15.1	18.2
Delta States	5.2	16.8	22.0
Pacific States	12.2	10.4	22.6
Appalachian	0.4	22.3	22.7
Mountain States	14.8	28.4	43.2
Lake States	1.1	42.8	43.9
Southern Plains	10.5	34.4	44.9
Corn Belt	1.2	91.2	92.4
Northern Plains	11.2	82.1	93.3

Source: 1982 NRI.

Table 15-4.--Crop value per acre, irrigated and nonirrigated land, by farming region

Region	Irrigated	Nonirrigated
Northeast	380	230
Southeast	300	175
Delta States	255	170
Pacific States	400	160
Appalachian	305	200
Mountain States	220	100
Lake States	320	185
Southern Plains	280	135
Corn Belt	315	220
Northern Plains	240	110

Source: 1985 RCA Appraisal water data work group, April 1985, unpublished.
Composite acreage of selected crops: corn, sorghum, wheat, oats, barley, soybeans, cotton, and hay.
Vegetables, orchards, rice, and pasture are excluded.

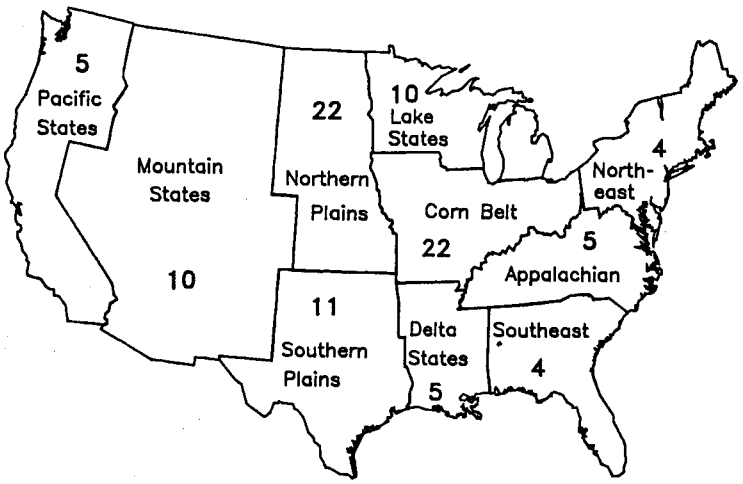

Figure 15-4.--Percentage distribution of the nation's cropland among farming regions (1982 NRI).

Most cropland is in land capability class II or higher, therefore it has some limitations to use. (Refer to Chapter 3 for an explanation of land capability classes.) Figures 15-5 and 5-6 show the major limitations to use of cropland in the nation and in each farming region. As the figures show, susceptibility to erosion is the main limitation on more than half of the nation's cropland. In addition, erosion is also a hazard on some land where the primary limitations are considered to be wetness, climate, or characteristics of the root zone. Erosion is a hazard on 52 percent of the cropland soils in subclass w, about 70 percent of those in subclass s, and 89 percent of those in subclass c. Climatic conditions are considered the major limitation to use of only a small portion of the nation's cropland. There are, however, millions of acres of cropland where climatic conditions are similar to those of soils assigned to the c subclass but where other factors are considered the dominant limitation. A climatic limitation--periodic drought --affects crop production and management on most of the cropland in the western United States.

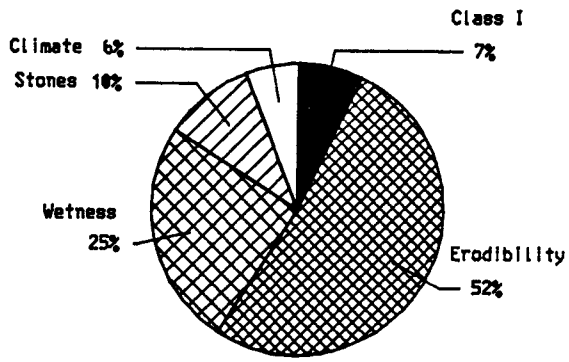

Figure 15-5.--Major limitations to use of cropland (1982 NRI).

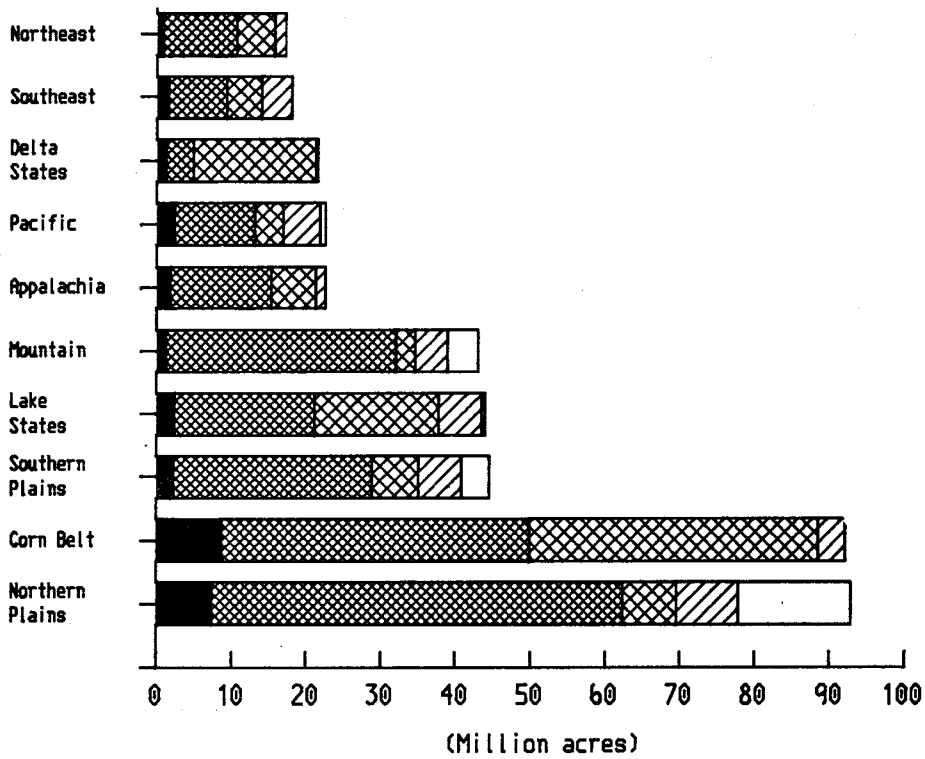

Figure 15-6.--Major limitations to use of cropland, by farming region (1982 NRI).

Rangeland and Pastureland

About 43 percent of nonfederal land (excluding Alaska) is producing forage (fig. 15-7). Forage land includes pastureland, rangeland, grazed forest land, and hayland.

The distribution of pastureland and rangeland is tied primarily to climate and soils. A relatively distinct climatic line exists along the 96th meridian (fig. 15-8 and 9). East of the meridian, lands that are unsuitable for cultivation because of soil limitations generally yield the highest returns if established to well-managed pasture. West of the meridian, most grassland is rangeland because native plants survive better and produce more forage than introduced species will unless the land is irrigated.

Pastureland

Pastureland is land that supports introduced or domestic forage plants that respond significantly to management. Native pasture is land on which the natural potential or climax vegetation is trees, but which is used primarily for production of native herbaceous forage plants. In this report, "pastureland" includes both pastureland and native pasture.

Soils in capability classes I through VI are considered suitable for use as pastureland. On these soils, management techniques can be properly applied for high production of introduced species. Soils in capability classes VII and VIII have limitations that prevent adequate management of introduced species. About 10 million acres of land in those two classes are currently used as pasture.

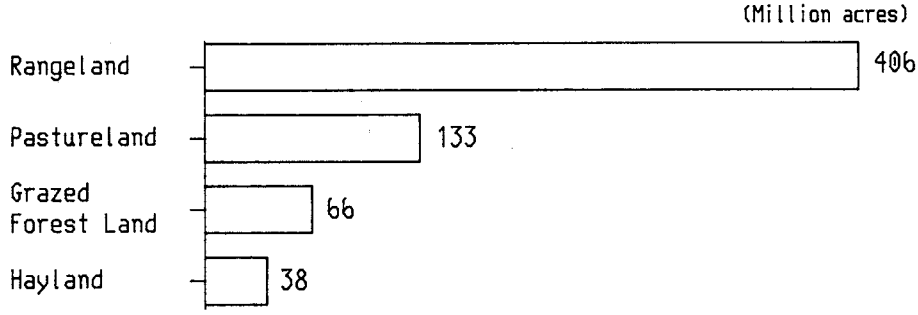

Figure 15-7.--Acreage producing forage, by type of forage land, million acres, (1982 NRI).

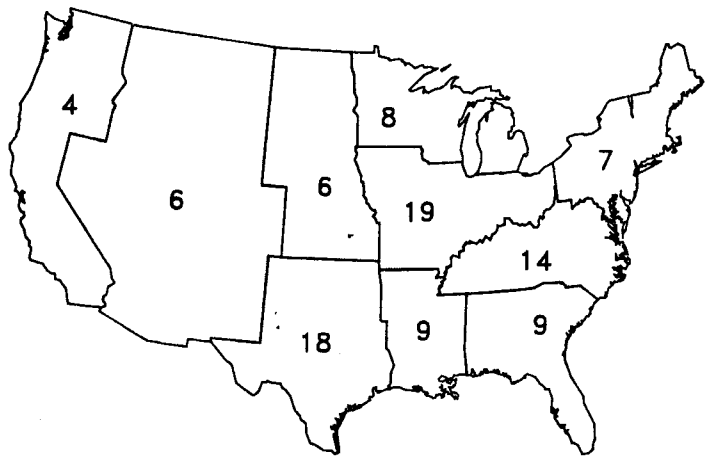

Figure 15-8.--Percentage distribution of pastureland in farming regions (1982 NRI).

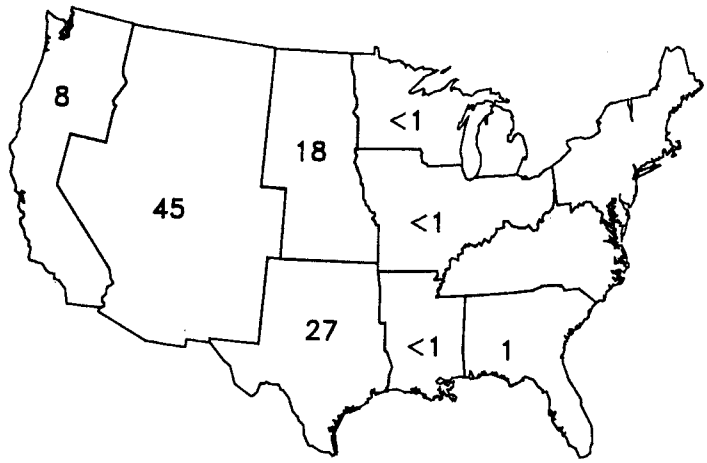

Figure 15-9.--Percentage distribution of nonfederal rangeland in farming regions (1982 NRI).

Figure 15-10 shows major limitations to the use of nonfederal pastureland. About 26 million acres of pastureland are affected to some degree by wetness. Wetness affects species adaptation, grazing management, and operations such as fertilizing. About 18.8 million acres of pastureland have limitations in the root zone. Limitations in the root zone affect productivity, species adaptation, and use of equipment.

On some steep slopes, erosion is a hazard. Runoff can be a serious problem in pastures. Studies indicate that there is substantial runoff from many pastures in midsummer when the moisture supplies are limited. Much of this water loss is caused by overgrazing or by soil compaction.

There are three pastureland condition ratings: good, fair, and poor (fig. 15-11). "Good" means that the best suited plants are being used. There is a moderate to high level of fertility and good to excellent management of grazing. Grazing is at an intensity that results in maximum plant production and vigor. "Fair" means that a moderate level of management is being used. The plants are adapted to the climate and soils but are not necessarily the best for the designated use. Grazing is at an intensity that limits production. Erosion is minimal. Fertilization is irregular and unplanned. A continuous grazing system is in use. "Poor" indicates that the pasture is not properly used or the level of management is low or that the plants are not well suited to the climate and soil. The soil has a low fertility level and evidence of erosion. Brush may be a problem.

Pasture condition ratings are not applicable on land in native plants that are not routinely fertilized, overseeded, or irrigated.

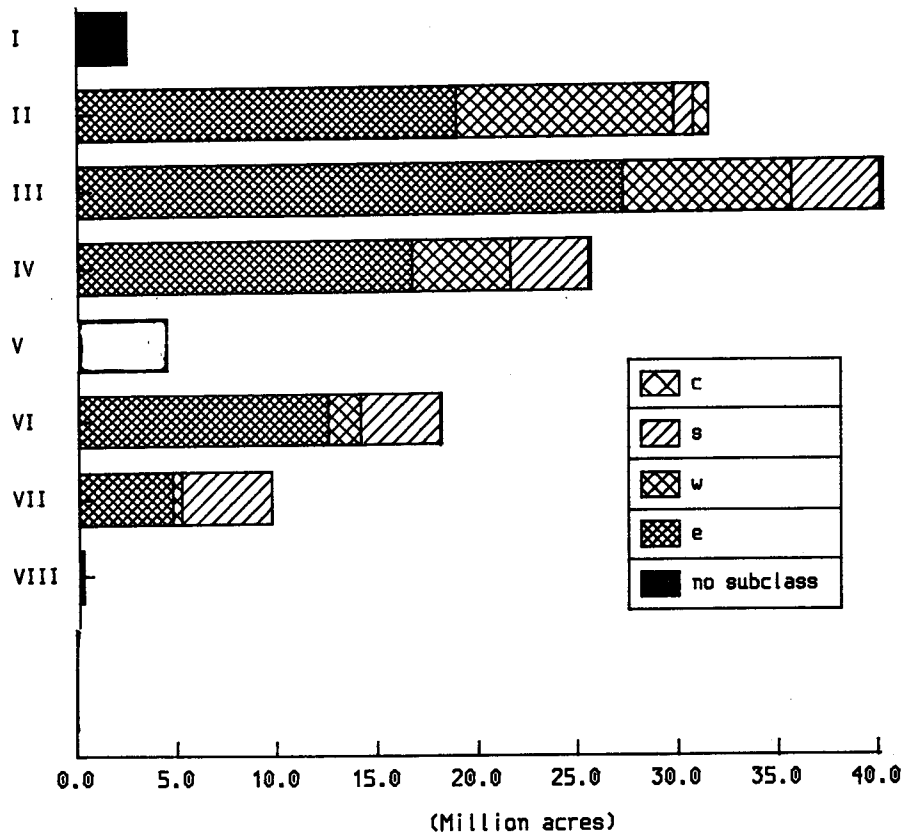

Figure 15-10.--Major limitations to use of nonfederal pastureland (1982 NRI).

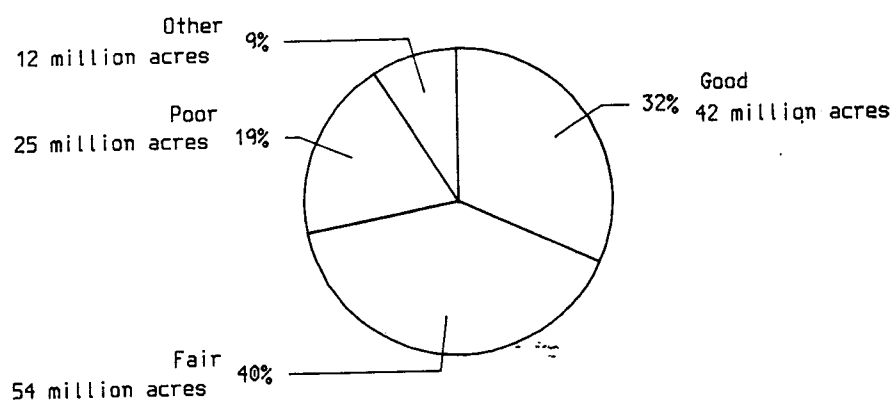

Figure 15-11.--Condition of nonfederal pastureland (1982 NRI).

Rangeland

Rangeland quality is judged by comparing the present vegetation to the climax vegetation for the site. The climax plant community for a site is the combination of species that has evolved over time and is best suited to exploit the soil, moisture, temperature, and other environmental conditions of that site. It is the most productive natural plant community the site is capable of supporting.

The amount of forage provided by the climax community varies widely; average annual production may range from a low of 200 pounds of air-dry material per acre in the arid Southwest to more than 12,000 pounds per acre on marsh sites in the Gulf Coast area.

The degree to which the kinds and proportions of plants in the existing plant community resemble those of the presumed climax vegetation for the site is called range condition. There are four range condition classes: excellent, good, fair, and poor. Excellent condition means that more than 75 percent of the present plant community is climax; good, 50 to 75 percent; fair, 26 to 50 percent; and poor, less than 25 percent (fig. 15-12). Range condition ratings are not applicable on land seeded to non-native grasses. Range condition is discussed in more detail in chapter 6 of this report.

Grazing by domestic livestock is the dominant use of most rangeland. In fact, grazing is the only feasible means of harvesting the production on most areas. About 93 percent of nonfederal rangeland was grazed by livestock in 1982. This included 24 percent temporarily deferred from grazing during the data-gathering period. Fifty-one percent was judged to be lightly to properly grazed, and 18 percent was overgrazed. Rangeland is considered to be overgrazed when more than 50 percent of the annnual growth of management species is removed by grazing animals. Red meat, wool and mohair, and milk are the principal end products of range grazing. Leather, pharmaceuticals, and many other by-products of animal slaughter are also valuable derivatives of range vegetation.

Rangelands provide many other benefits:

- Habitat for many species and large numbers of wildlife.
- A large reservoir for moisture storage. Proper range management enhances infiltration and storage of rainfall and snowmelt. Some of this soil moisture returns to the surface through seeps and springs, feeding rivers and streams.
- Sites for recreation.
- Firewood and several specialty wood products are harvested from shrubby range plants; other range shrubs are popular urban landscape materials.

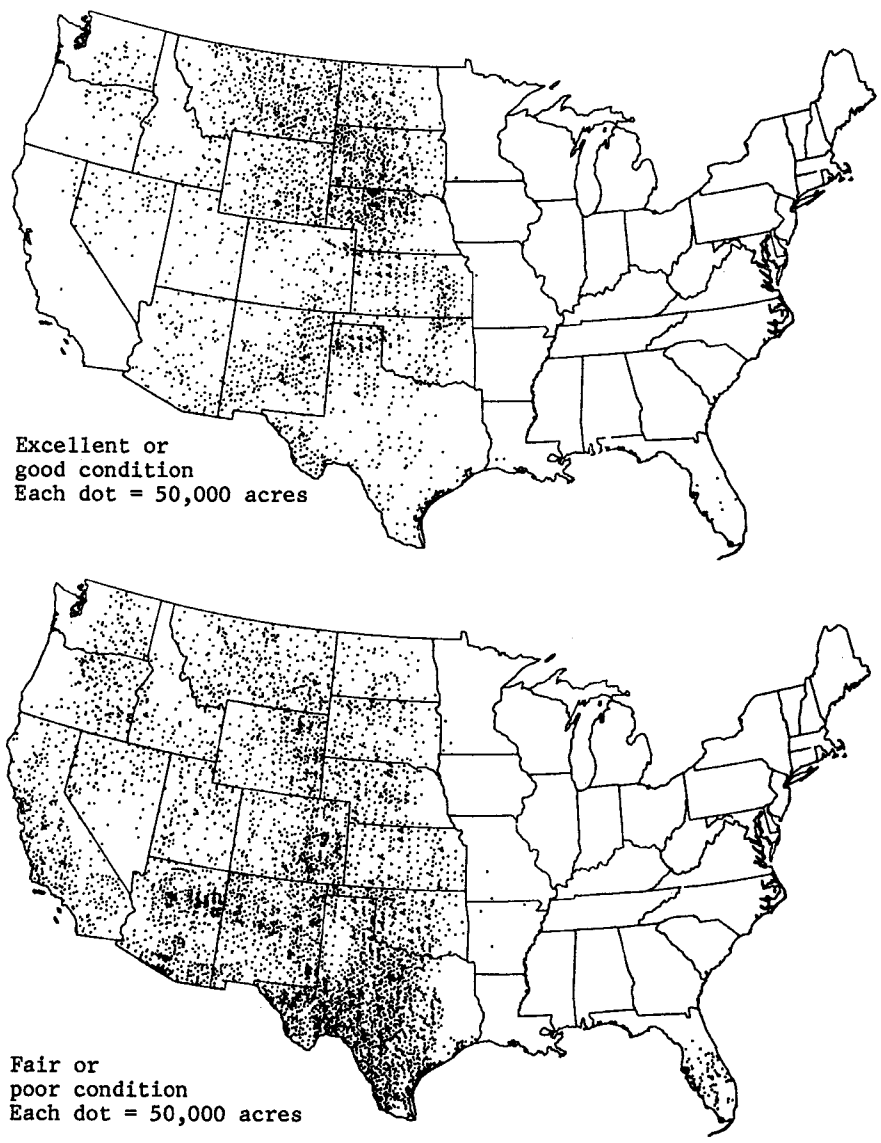

Figure 15-12.--Range condition on nonfederal rangeland (1982 NRI).

Forest land

Nonfederal forests grow on 394 million acres (fig. 15-13). Nonfederal forest land provides wood, water, wildlife habitat, herbage, and recreation. Seventeen percent is grazed. Nonfederal forest land is mainly under private or corporate ownership, but some is state and municipal land.

A wide variety of major forest-cover types occurs within each geographic region (table 15-5). In the Pacific and Mountain regions, Douglas-fir, ponderosa pine, fir-spruce, and hemlock-Sitka spruce are dominant cover types. In the North, oak-hickory, maple, beech, birch, spruce-fir, and elm-ash-cottonwood are the chief cover types. In the South, oak-hickory, loblolly-shortleaf pine, oak-pine, and oak-gum-cypress dominate. These forest-cover types are defined by the USDA Forest Service.

Table 15-5.--Major forest-cover types on nonfederal forest land, by geographic area

North	South	Rocky Mountain and Pacific Coast
White-red-jack pine	White-red-jack pine	Douglas-fir
Spruce-fir	Longleaf-slash pine	Ponderosa pine
Loblolly-shortleaf pine	Loblolly-shortleaf pine	Western white pine
Oak-pine	Oak-pine	Fir-spruce
Oak-hickory	Oak-hickory	Hemlock-Sitka spruce
Oak-gum-cypress	Oak-gum-cypress	Larch
Elm-ash-cottonwood	Elm-ash-cottonwood	Lodgepole pine
Maple-beech-birch		Redwood
Aspen-birch		

Source: USDA Forest Service.

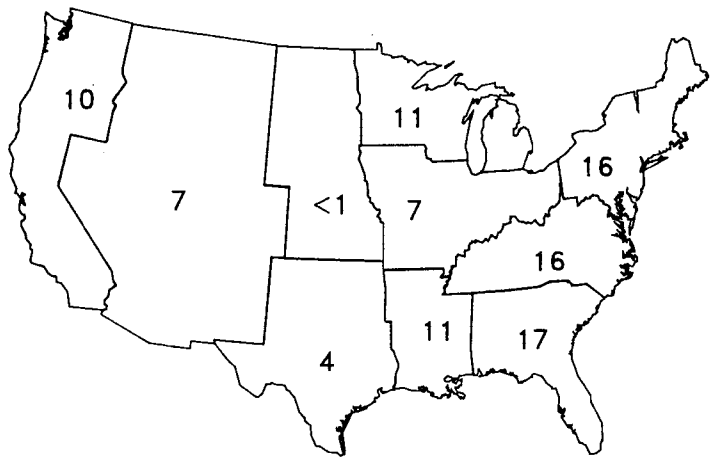

Figure 15-13.--Acreage of nonfederal forest land in each farming region (1982 NRI).

Prime farmland

Prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation and favorable temperature and growing season. The soils have acceptable acidity or alkalinity, acceptable salt and sodium content, and few rocks. They are permeable to water and air. They are not excessively eroded. They are flooded less often than once in 2 years during the growing season and are not saturated with water for a long period of time; that is, the water table is maintained at a sufficient depth during the growing season to allow cultivated crops common to the area to be grown. The slope ranges mainly from 0 to 5 percent. To be classified as prime, land must meet the criteria and must be available for use in agriculture. Land committed to some nonagricultural use is not classified as prime farmland.

In 1982, there were about 342 million acres of prime farmland in the nation (fig. 15-14). Figure 15-15 shows use of prime farmland in the nation.

Table 15-6 shows states with the largest acreages of prime farmland used as cropland and other agriculture uses.

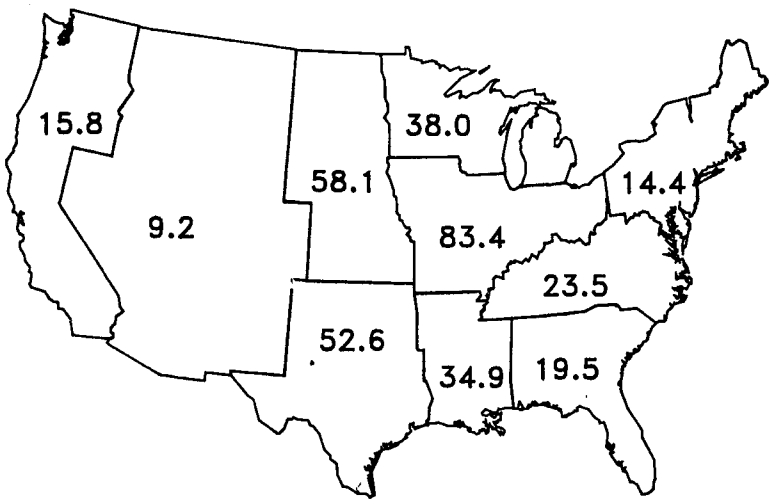

Figure 15-14.--Distribution of prime farmland among farming regions, millions of acres (1982 NRI).

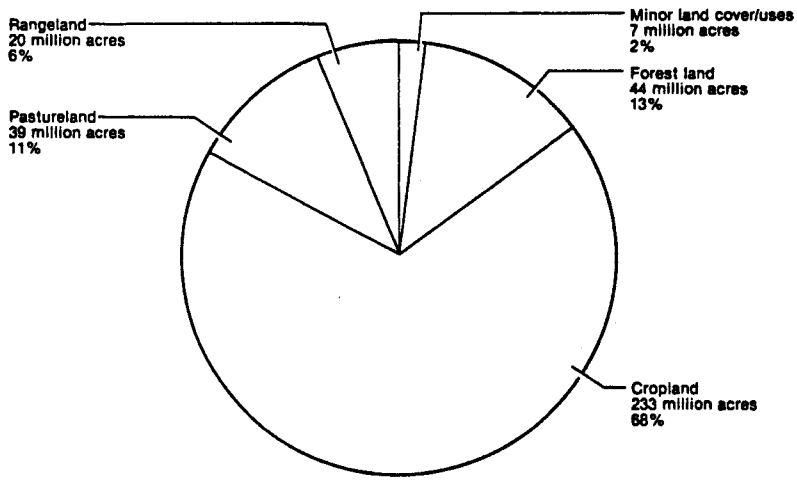

Figure 15-15.--Use of prime farmland (1982 NRI).

Table 15-6.--States with largest percentage of cropland defined as prime farmland, top ten states

	CROPLAND that is prime farmland (1,000 acres)	Percent of total cropland
Texas	19,230	57.7
Illinois	19,089	77.2
Kansas	19,007	65.3
Iowa	16,684	63.1
Minnesota	16,051	69.7
North Dakota	12,683	46.9
Indiana	11,191	81.2
Nebraska	19,600	96.7
Missouri	9,863	65.8
Ohio	9,764	78.4

Source: 1982 NRI.

Table 15-7.--Prime farmland used as cropland, pastureland, rangeland, forestland; top ten states

PASTURELAND that is prime farmland (1,000 acres)		RANGELAND that is prime farmland (1,000 acres)		FORESTLAND that is prime farmland (1,000 acres)	
Texas	5,526	Texas	10,198	Louisiana	5,488
Missouri	3,761	Kansas	4,665	Mississippi	3,088
Oklahoma	3,337	Oklahoma	3,015	Minnesota	2,993
Arkansas	2,226	Nebraska	692	Alabama	2,750
Mississippi	1,781	North Dakota	602	Arkansas	2,675
Louisiana	1,592	South Dakota	414	Georgia	2,673
Tennessee	1,570	Missouri	74	Virginia	2,649
Kentucky	1,506	Minnesota	73	North Carolina	2,179
Alabama	1,497	Idaho	56	Wisconsin	2,118
Kansas	1,345	California	45	Pennsylvania	1,413

Source: 1982 NRI.

Appendix II: Water Supply and Use Data

This appendix reports data on water supply and water use on which the analyses in earlier chapters of this report were based.

The Hydrologic Cycle. About 40,000 billion gallons of water per day (bgd) pass over the conterminous United States as water vapor. Of this about 4,200 bgd fall as precipitation onto the conterminous United States. If spilled evenly over the nation's surface, this would represent an average annual precipitation of 30 inches. About two-thirds (2,800 bgd) of the 4,200 bgd returns to the atmosphere through transpiration by plants, evaporation from water and wet surfaces, and absorption of vapors. The remaining 140 bgd replenish ground water and surface water supplies (fig. 16-1).

People withdraw 360 bgd from replenishable supplies and 20 bgd from ground water in excess of natural recharge. An estimated 105 bgd are consumptively used--that is, they return to the atmosphere, or are incorporated into products, or percolate beyond the area of reuse. The rest flows beyond the nation's boundaries or returns by streamflow or subsurface flow to the oceans.

Overall, these numbers indicate no water shortages at the national level. But in many areas water is in short supply, is not available when it is needed, or is of poor quality.

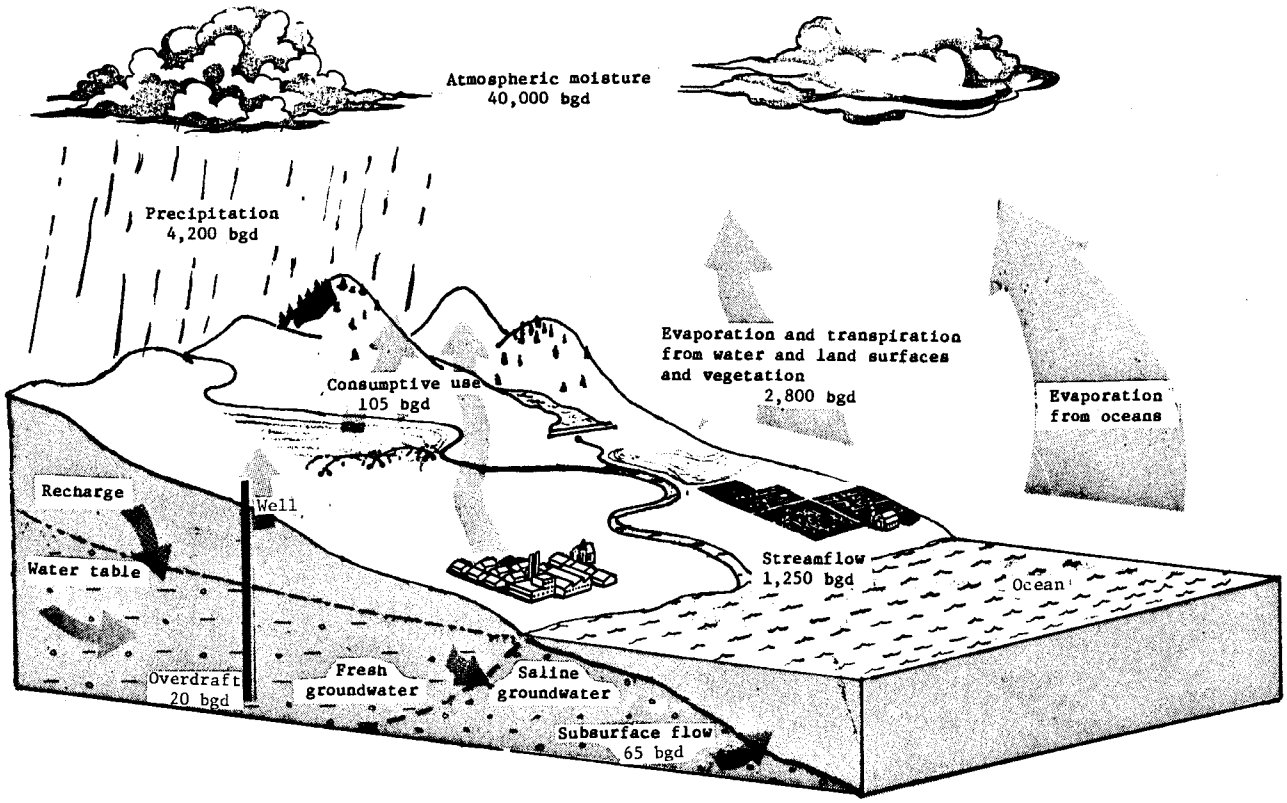

Figure 16-1.--Hydrologic cycle of the conterminous United States.

Water continuously circulates from the oceans, to the atmosphere, to the land, from where it returns to the atmosphere by evaporation or transpiration or to the oceans by streamflow. Many human activities--especially those of agriculture--affect the distribution of water on land and in the atmosphere by directly consuming or using water by altering the land and vegetation, or by influencing the climate.

Water Supply

Precipitation is the source of almost all our water. Some localities add to the supplies provided by precipitation by drawing upon water that has accumulated in aquifers over hundreds of years, water transferred from other river basins, and desalted ocean water.

The 30 inches of average annual precipitation falling on the United States actually ranges from less than 4 inches in parts of the Great Basin and Lower Colorado regions to more than 200 inches in some parts of the coastal area of the Pacific Northwest.

About 1,000 bgd of precipitation run off the land directly into streams, rivers, lakes, and reservoirs. These surface waters evaporate, move into the ground, flow through the drainage system to the sea, or are diverted for offstream uses.

About 400 bgd of precipitation soak into the ground below the root zone and move downward to recharge ground water supplies. Ground water comes to the land surface in springs or seeps, emerges as streamflow, enters the ocean as subsurface flow, or is withdrawn by pumping.

Ground water

Ground water is the water that saturates sediment and permeable rock strata beneath the earth's surface. The amount of fresh ground water is much greater than the amount of fresh water in streams and lakes. The ground water within one-half mile of the earth's surface in the conterminous United States amounts to more than 130 billion acre-feet, or enough to fill Lake Michigan 33 times (fig. 16-2).

About 44 billion acre-feet of water are of acceptable quality and close enough to the land surface to be tapped with conventional wells (appendix table 16-1). Ground water is

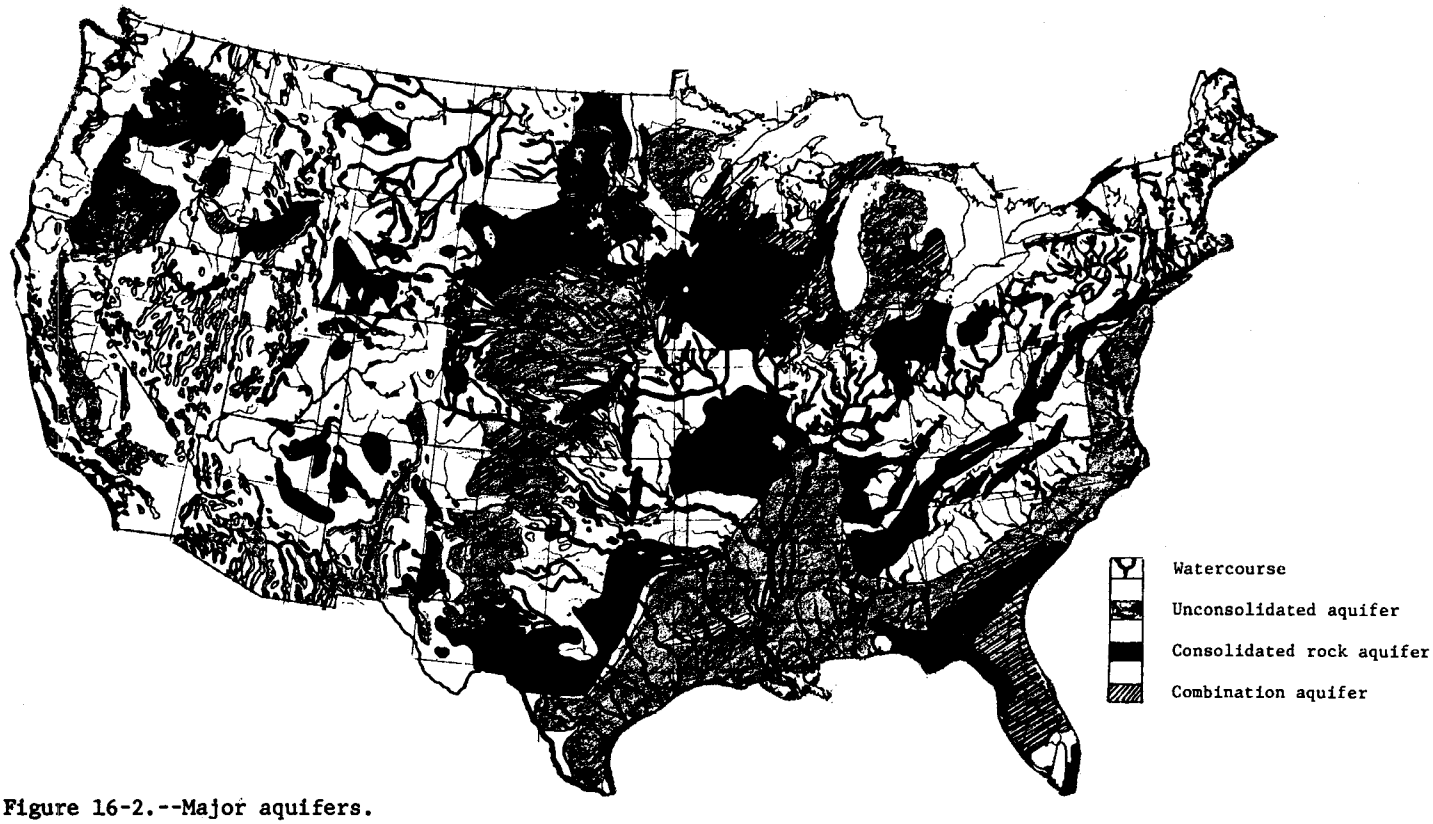

Figure 16-2.--Major aquifers.

More than 80 percent of all the water pumped from wells in the United States comes from gravel or sand aquifers. If the aquifer is adjacent to a watercourse, infiltration from the river normally replaces the water withdrawn from wells. Consolidated rock aquifers may yield enough water for modest-scale irrigation or for industrial uses.

available in at least small amounts nearly everywhere, but the quantity of water wells yield varies greatly. Most ground water development occurs in areas where wells yield more than 50 gallons of fresh water per minute.

Surface water

Surface water is water flowing in streams and rivers and stored in lakes, wetlands, and reservoirs. The total area of inland water in the conterminous United States, excluding the Great Lakes, bays, and estuaries, is 48.3 million acres.

In an average year, 1.4 billion acre-feet (1.23 trillion gallons per day) flow through streams and rivers of the conterminous United States into the oceans. These flows comprise runoff from precipitation (fig. 16-3), discharges from ground water seeps and springs, and return flows from human activities. Without human intervention, outflows would be a direct function of precipitation, the long-term recharge of the ground water system would be balanced by long-term discharge, and overdrafts would not occur. Natural outflows would average 1,640 million acre-feet per year (1.33 trillion gallons per day).

Water supply and use across the nation are described in terms of water resource regions (fig. 16-4). There are 21 regions, 18 of which are in the conterminous United States. Each water resource region is made up of drainage basins of tributaries or coastal drainage areas of a group of streams called subregions. Each subregion consists of watersheds of a few thousand acres to several hundred thousand acres.

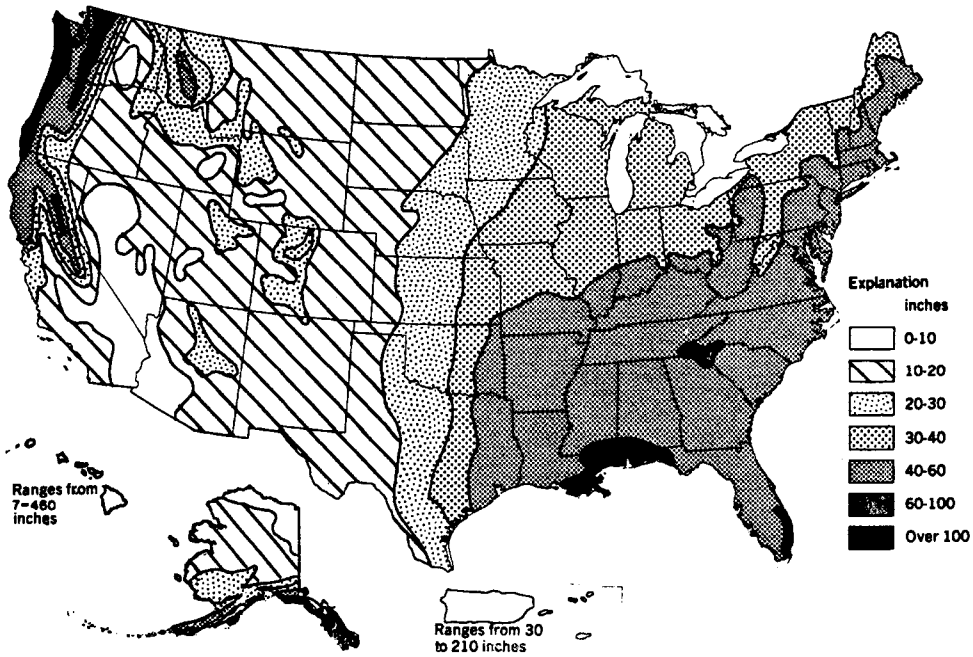

Figure 16-3.--Average annual precipitation in the United States.

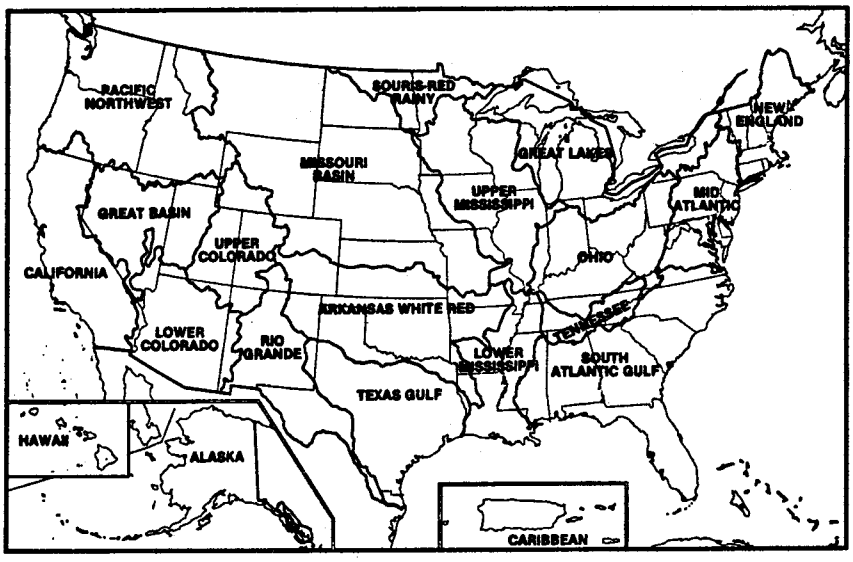

Figure 16-4.--Water resources regions.

There is great contrast between the quantity of water flowing out of a water resource region during an average year and that in a wet year or a dry year, between average seasonal flows and those of exceptional seasons, and between monthly high and low flows. Both annual and seasonal streamflows vary least in the Northeast. Annual streamflow in the Southwest ranges from less than 30 percent to more than 200 percent of mean annual streamflow. Monthly streamflows are even more erratic.

Weather conditions and, consequently, precipitation, runoff, and streamflows fluctuate widely from year to year (fig. 16-5). In very dry years, the total yearly flows from the conterminous United States may be less than 770 million acre-feet (675 bgd)--about 55 percent of the average (1,233 bgd). In very wet years, the total yearly flows may exceed 2,180 million acre-feet (1,955 bgd).

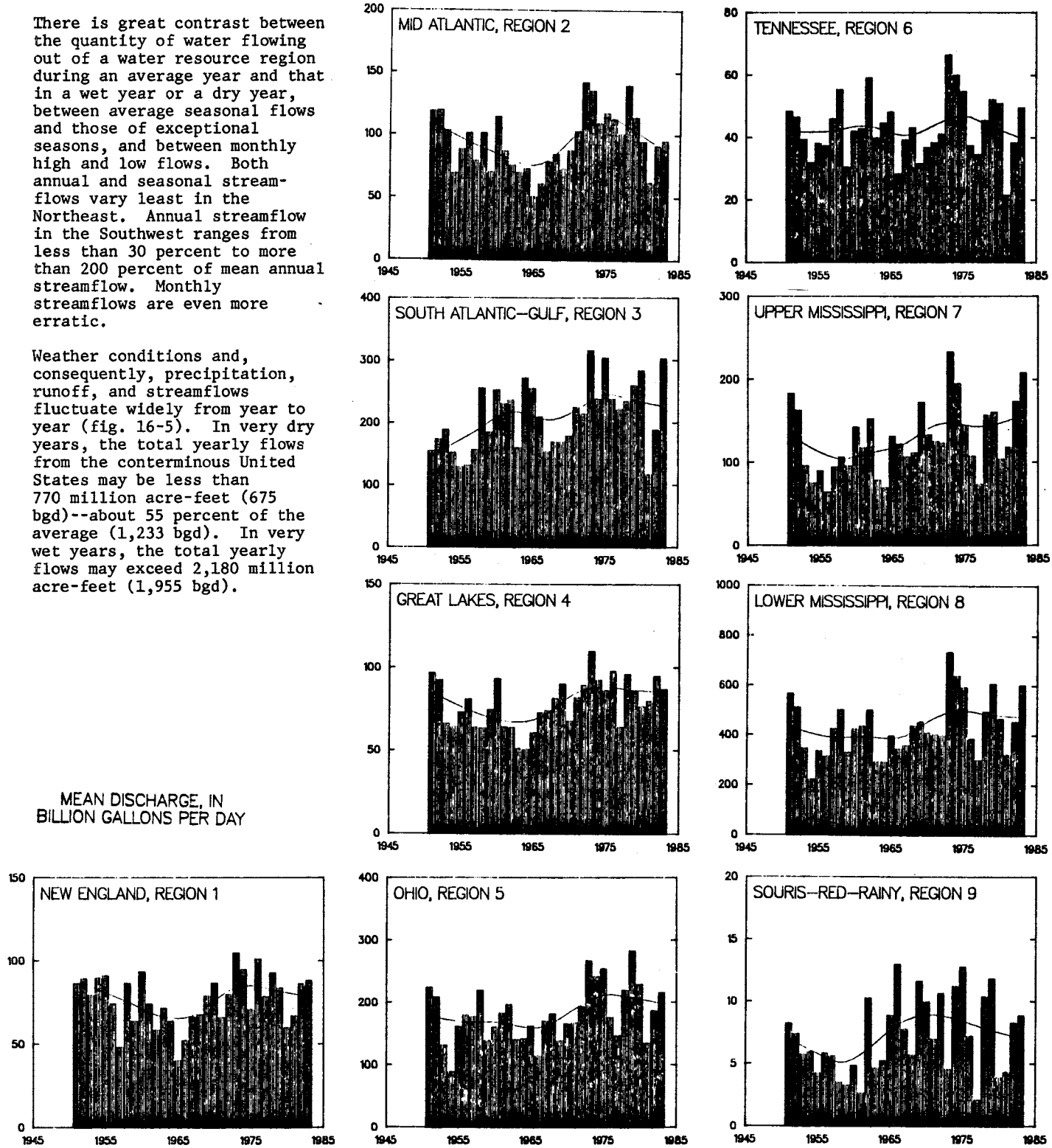

Figure 16-5.--Yearly streamflows, by water resources region, for water years 1950-1982 mean discharge in billion gallons per day (US Geological Survey).

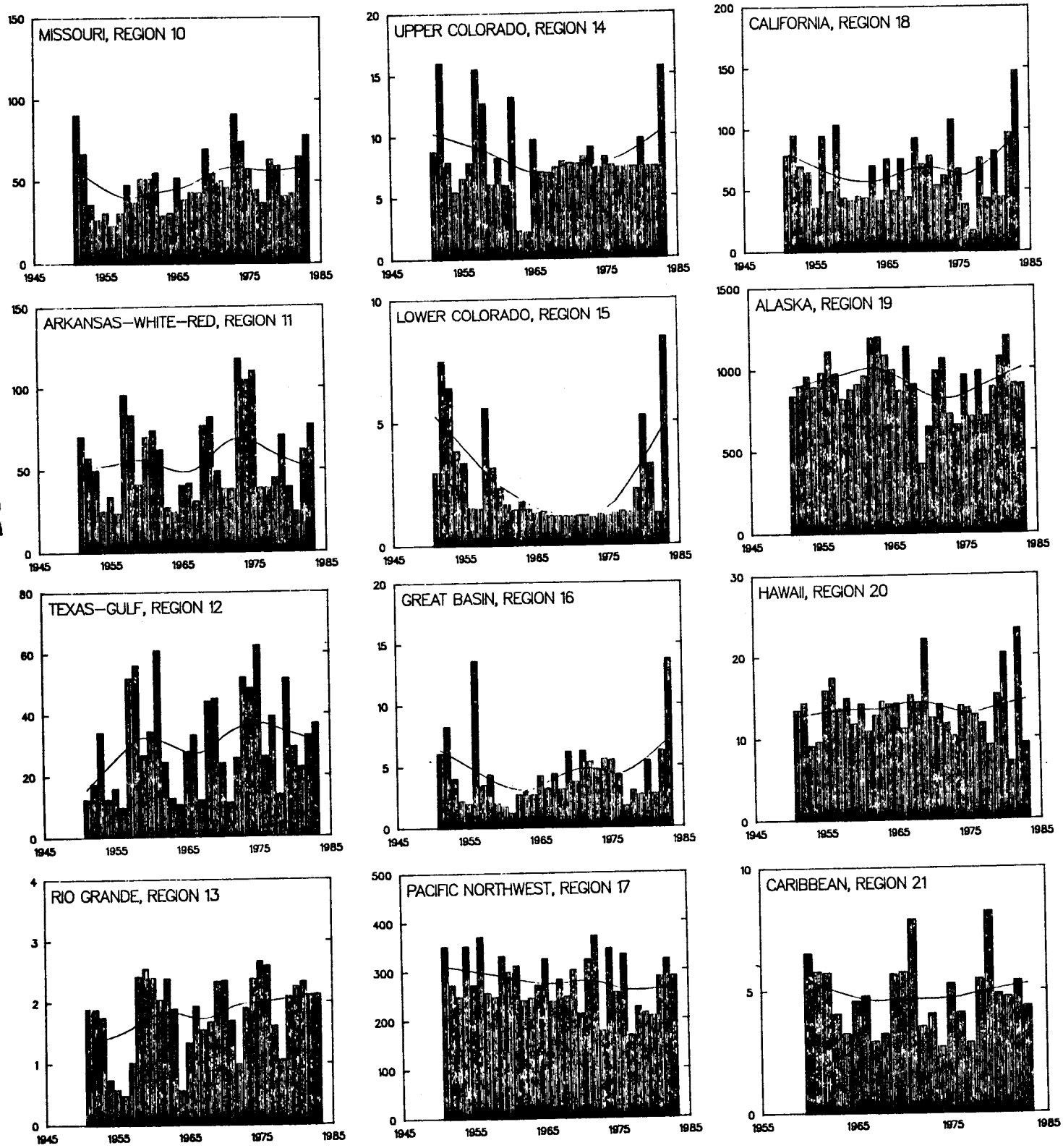

Figure 16-5 continued. Yearly streamflows, by water resources region, for water years 1950-1982 mean discharge in billion gallons per day (US Geological Survey).

Seasonal flows also vary across the nation. Seasonal variation is relatively small in the Northeast. In the midcontinent area, summer storms from May to October produce more than twice the precipitation that occurs during the rest of the year. Thunderstorms provide inland areas with precipitation in summer, hurricanes bring rain to coastal areas in fall, and cyclonic storms occur in winter in the Southeast. In western mountain areas, the heaviest precipitation occurs as snow in winter. In the Southwest, up to 75 percent of the annual runoff occurs during a few weeks in spring when snow melts. During summer, much of California has virtually no precipitation. Coastal Alaska receives precipitation mainly late in fall. The interior receives it mainly in summer. In both Hawaii and the Caribbean, fall is the wet season and early spring the dry. Figure 16-6 shows the normal distribution of monthly flows and the size of high and low monthly flows relative to average monthly flows.

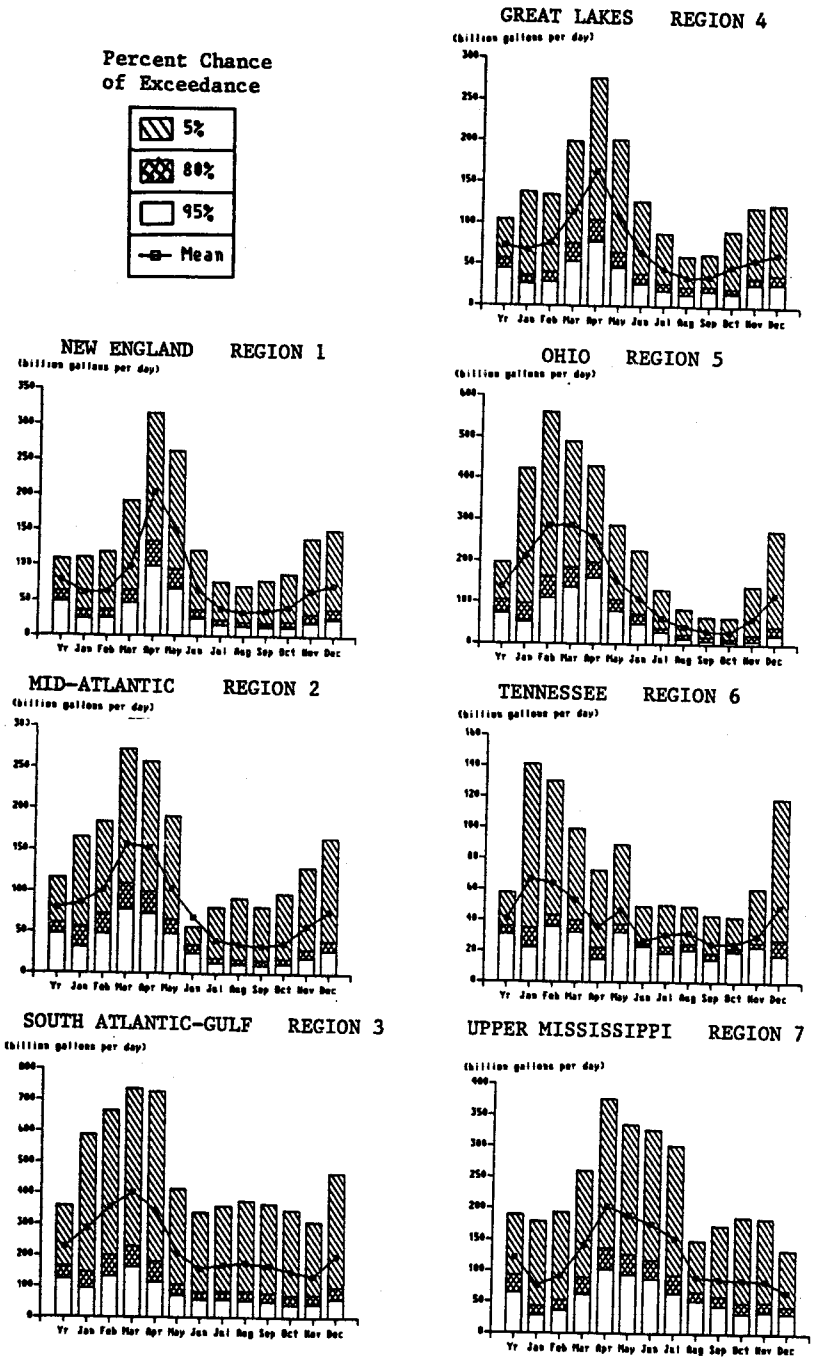

Figure 16-6.--Regional streamflow frequency analysis (Second National Water Assessment).

A 5-percent exceedance flow will be exceeded in only about 5 years of a 100-year period and thus represents a year with very high streamflows. A 95-percent exceedance flow will be exceeded in about 95 years of a 100-year period.

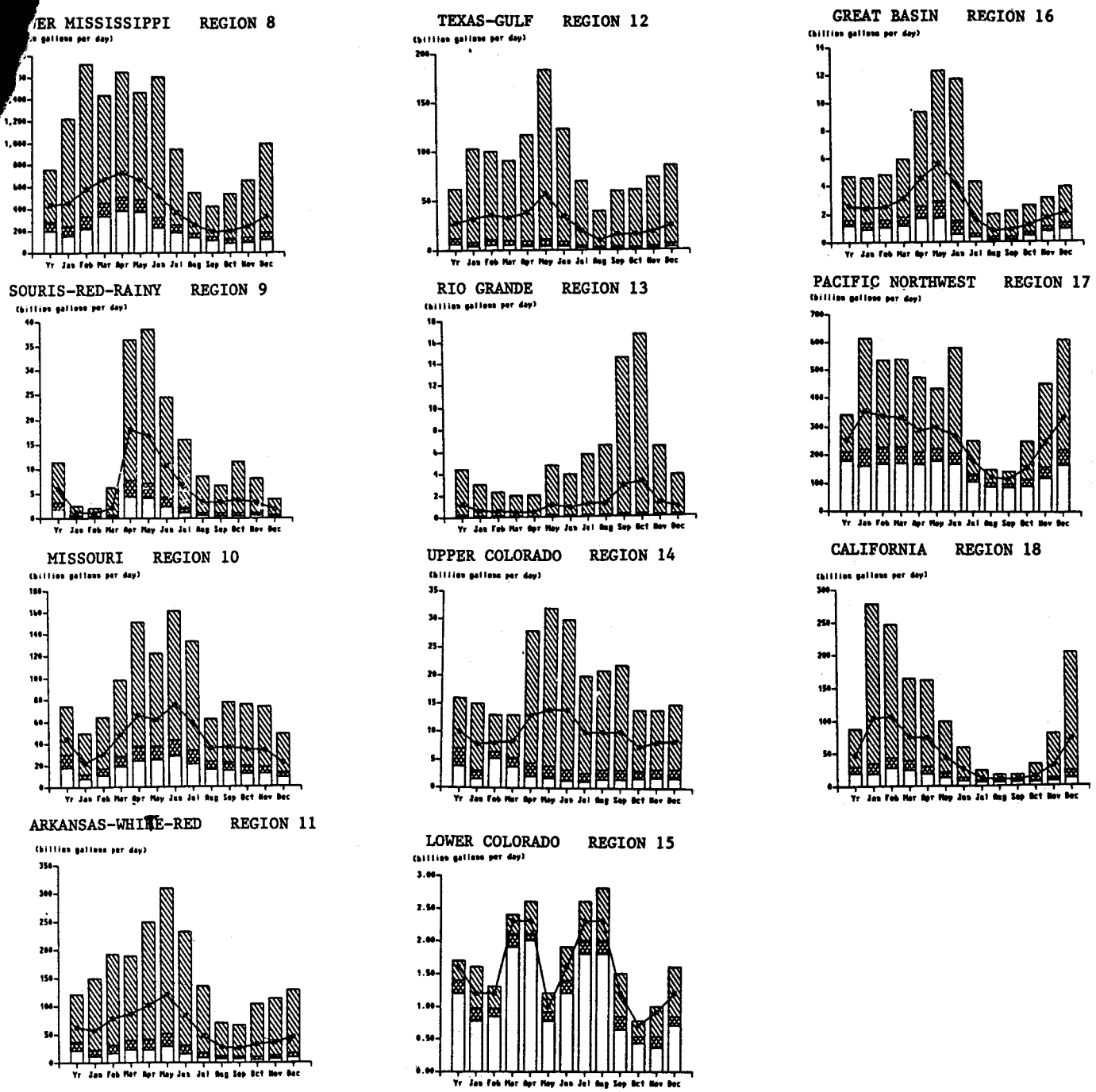

Figure 16-6.--Regional streamflow frequency analysis (cont.).

WHAT USES DO WE MAKE OF WATER SUPPLIES?

Water is used offstream and instream. Offstream water is withdrawn or diverted from a ground or surface source to its place of use. Instream water is used where it naturally flows.

Offstream Uses

An estimated 309 billion gallons of water per day (bgd) of fresh water are withdrawn from ground and surface water sources (table 16-1). About 105 bgd are consumptively used--that is, are returned to the atmosphere or incorporated into the plant or animal tissue or commodity produced, or percolate beyond the area of reuse. The rest of the withdrawals (204 bgd) return to the water supply and are available for downstream uses. An additional 72 bgd of saline water are withdrawn from the oceans, primarily for industry. Only 2 bgd are consumptively used. Seventy bgd are returned to the oceans and estuaries.

Of the freshwater withdrawals, 213 bgd are from surface water sources and 96 bgd are from ground water sources (fig. 16-7).

Water sources vary by region (fig. 16-8). Saline water withdrawals are greatest in the Mid-Atlantic Region. Surface water is the dominant source in the north-central regions. California is the big user of ground water.

Nonagricultural Water Use.--Table 16-2 shows nonagricultural water uses, by region.

o Domestic Water Use.--The 91 million households in the United States use an average of 230 gallons of water per household daily. Domestic water use is affected by availability, source, system ownership, quality and reliability of supplies, outdoor uses, and cost.

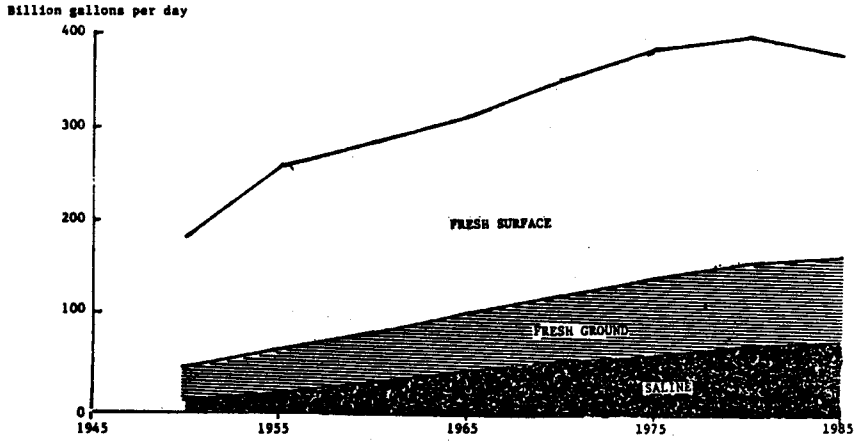

Figure 16-7.--Fresh and saline water withdrawals since 1950, United States (1950-75, USGS; 1975-85, SCS).

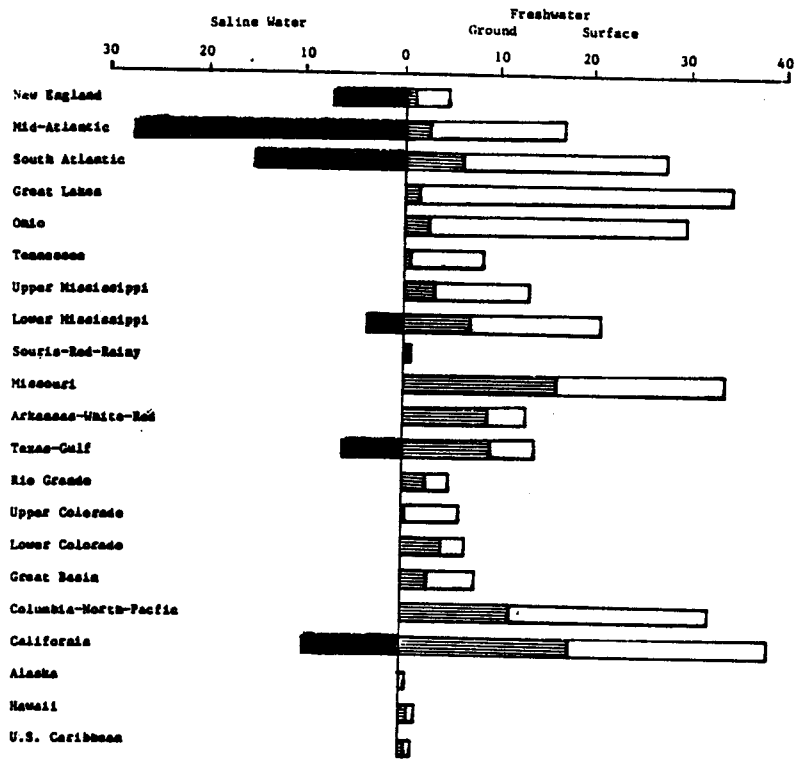

Figure 16-8.--Sources of water withdrawals, by region, 1985.

Domestic per capita water use is smallest in the Northeast and largest in the West. Most of the regional differences are in the amount needed for outdoor uses, such as cleaning windows and vehicles, watering lawns and gardens, and recreational uses. The amount used indoors is about the same from region to region, except for the amount used to cool the house.

About 23 percent of central-system withdrawals and 60 percent of self-supplied withdrawals are consumptively used.

The 83 percent of the U.S. population that receives its domestic water from public systems and private companies accounts for 87 percent of

Table 16-1.--Offstream water uses for the United States, 1982

Type of use	Withdrawals	Consumption
	(billion gallons per day)	
Domestic	21.1	5.8
Commercial and public use	12.0	3.7
Industrial uses: steam, electric, minerals, manufacturing, etc.	144.1	15.9
Agriculture	131.6	79.9
Irrigation	129.4	78.0
Livestock	2.2	1.9
Subtotal, freshwater	308.8	105.3
Subtotal, saline	72.0	2.2

Source: SCS analysis based on USGS Circular 1001.

Table 16-2.--Nonagricultural offstream water use, by water resource region, 1982

Water resource region	Withdrawal				Consumption			
	Domestic	Commercial Public & public land	Indus-trial	Total	Domestic	Commercial Public & public land	Indus-trial	Total
	(millions of gallons per day)							
New England	996	535	2912	4443	272	112	213	597
Mid-Atlantic	3052	1519	11580	16151	826	347	961	2134
South Atlantic	2613	1157	19652	23422	801	267	2354	3422
Great Lakes	2379	1171	29859	33409	666	273	2107	3046
Ohio	1710	814	26561	29085	514	183	1650	2347
Tennessee	336	160	7804	8300	105	35	461	601
Upper Mississippi	1189	562	10249	12000	341	130	620	1091
Lower Mississippi	638	302	13760	14700	182	72	1043	1297
Souris-Red-Rainy	62	30	71	163	20	8	27	55
Missouri	937	653	6738	8328	256	292	533	1081
Arkansas-White-Red	719	421	2412	3552	201	112	750	1063
Texas-Gulf	1128	587	2480	4195	291	134	2008	2433
Rio Grande	249	161	279	689	65	55	241	361
Upper Colorado	66	179	742	987	18	127	185	330
Lower Colorado	389	276	680	1345	95	94	550	739
Great Basin	209	463	742	1414	52	376	221	649
Pacific-Northwest	920	1000	4079	5999	259	361	542	1162
California	2817	1920	3040	7777	679	716	1288	2680
Contiguous U.S.	20,408	11,908	143,640	175,959	5,641	3,693	15,753	25,088
Alaska	105	56	170	294	8	13	43*	63
Hawaii	172	93	130	338	52	28	88	152
U.S. Caribbean	376	184	185	613	61	30	5	77
Nation	21,061	12,241	144,125	177,204	5,762	3,764	15,890	25,380

Source: SCS analysis based on USGS Circular 1001.

domestic withdrawals and 72 percent of domestic consumption. Groundwater makes up 35 percent of centrally-supplied domestic water withdrawals.

About 17 percent of the population obtains its water from individual wells, springs, ponds or catchments. Groundwater makes up 97 percent of the 2.7 bgd of self-supplied domestic water withdrawals.

More and more people are hooking into central systems (tables 16-3, 16-4). Domestic water withdrawals are projected to increase to 32 bgd and consumption to 8 bgd by 2030.

o Commercial and Public Uses.--Commercial establishments and public water uses (which include control system delivery losses and water for municipal parks and swimming pools, street cleaning, and fire-fighting) are in areas served by central systems. An estimated 9.8 bgd are withdrawn and 2.2 bgd are consumed by the establishments and uses.

Public lands are maintained to preserve natural and historic resources and to provide outdoor recreation. About two-thirds of the 2.2 bgd withdrawn for public land are consumptively used. Water for the land and facilities at the site commonly is self-supplied.

o Industrial Water Use.--Two-thirds of industrial withdrawals are for producing energy--mostly for steam electric generation. Thermoelectric plants use different techniques to dispose of cooling water. Many plants return the warmed water directly to receiving waters. Others use cooling towers and ponds to reduce withdrawals and thermal pollution. As a result of advanced cooling technologies, withdrawals are expected to increase at a much slower rate than consumption.

Manufacturing and mining industries withdraw an estimated 47 bgd and consumptively use 11.8 bgd. Water uses by steel, chemical, paper, mining, petroleum refining, and other industries vary widely. Manufacturers and miners are expected to continue to increase recycling or improve treatment of used water. Consequently, withdrawals per unit of production value are expected to decline further and consumption per unit of production value is to remain about the same.

Agricultural Water Use.--Table 16-5 summarizes agricultural water use. See also chapter 8.

o Livestock.--Of the 2,164 million gallons of water per day (mgd) used for production of red meat, poultry and eggs, and milk, 1,200 mgd are from groundwater and 964 mgd from surface water. Most of the withdrawals are consumptively used--perhaps 10 to 15 percent of the livestock water withdrawals return to water supplies.

In 1983, an average of 1,600 million gallons of water per day (mgd) were used to produce 17.8 million tons carcass weight of beef, mutton, and pork; 460 mgd to produce 1,400 million hundred-weight of milk; and 104 mgd to produce 5,676 million dozens of eggs and 15,750 million pounds of live-weight poultry. Water withdrawals for horses, domesticated reindeer, goats, rabbits, household pets, and animals raised for fur or for scientific purposes, aquaculture, and fish and wildlife are not included.

Table 16-3.--U.S. urban and rural population, by type of water-supply system, 1980

	Total	Urban	Rural
	----------(1,000)----------		
Central systems	189,392	158,033	31,359
Self-supplied systems	37,154	9,018	28,136
With pressure (bathroom)	30,605	5,979	24,626
With limited or no pressure	6,549	3,039	3,510
Incomplete plumbing facilities	5,095	3,039	2,056
No plumbing facilities	1,454	0	1,454
Total population	226,546	167,051	59,495

Source: 1980 Census of Housing.

Table 16-4.--Population served by central and self-supplied systems, selected years

	1969	1975	1980	1985
	(million people)			
Central	166	179	189	202
Self-supplied	38	37	37	34
With pressure	30	31	31	
Lacks full pressure	8	6	6	
Total	204	216	226	236

Source: SCS.

Drinking water accounts for 60 percent of the livestock water use. The amount of drinking water required by livestock depends on the animal and its environment, including the species, size, age, sex, and production of the animal; amount and content of the feed; the animal's access to water; and the air temperature. Other livestock water uses include dairy sanitation, cleaning and waste disposal, cooling, on-farm processing, and water losses including evaporation from stockwater ponds.

o Irrigation.--About 40 percent of all freshwater withdrawals are for agricultural irrigation. Irrigators in the United States pump an average 66.9 million gallons of ground water per day and divert 62.2 million gallons of surface water per day. Crops evaportranspire 61 million gallons per day.

Vegetative water use is affected by both natural and management factors. Important natural factors include precipitation, humidity, temperature, solar radiation, wind movement, and length of growing season. Irrigation water use is described in chapter 7 of this report.

Some additional land could be irrigated in the future, should the need arise. There are an estimated 56 million acres of potentially irrigable land, that is, potential cropland or nonirrigated cropland in proximity to water supplies. An estimated 23 million acres are in the West and 33 million acres in the East. Figure 16-9 shows the acreage of potentially irrigable land in each water resources region.

Instream Uses

Instream uses generally do not reduce supplies. Lakes, reservoirs, wetlands, streams, and rivers provide habitat for fish and wildlife, flows for recreation and waste assimilation, waterways for navigation, supplies for hydroelectric power generation and treaty and compact obligations, and surfaces for esthetic purposes. Waters can serve several instream uses simultaneously.

Recreation.--Water-related outdoor recreation activities can be divided into two types: water-dependent activities, which require a substantial supply of accessible water, and water-enhanced, where the presence of water is desirable but not necessary. Only about one-fifth of the 108 million acres of surface water is accessible and usable for recreation. The other 87 million acres are inaccessible, polluted, or otherwise restriced from recreational use. As of 1975, about 8 million more acres of water were needed for recreation.

Fish and Wildlife.--Many fish and wildlife species are sensitive to changes in their riverine, wetland, or coastal environments. A riverine ecosystem is a watercourse containing flowing water at

Table 16-5.--Livestock and irrigation water use in 1982, by water resource regions

Region	Livestock		Irrigation		Total Agriculture	
	Withdrawal	Consumption	Withdrawal	Consumption	Withdrawal	Consumption
	(million gallons per day)					
New England	18	16	27	19	45	35
Mid-Atlantic	69	62	238	164	307	226
South Atlantic	166	150	3,543	2,439	3,709	2,589
Great Lakes	85	76	471	326	556	402
Ohio	127	114	96	67	223	181
Tennessee	31	28	18	12	49	40
Upper Mississippi	283	254	536	394	819	648
Lower Mississippi	54	49	5,692	3,916	5,746	3,965
Souris-Red-Rainy	33	29	159	101	192	130
Missouri	502	452	24,425	14,884	24,927	15,336
Arkansas-White-Red	237	214	8,474	5,892	8,711	6,106
Texas-Gulf	191	172	8,825	6,110	9,016	6,282
Rio Grande	38	34	3,931	2,627	3,969	2,573
Upper Colorado	29	26	4,601	2,404	4,630	2,430
Lower Colorado	53	47	4,782	2,997	4,835	3,044
Great Basin	33	30	5,722	3,066	5,755	3,096
Pacific Northwest	88	79	25,711	12,323	25,799	12,402
California	117	105	30,912	19,585	31,029	19,690
Contiguous U.S.	2,153	1,938	128,163	77,327	130,316	79,265
Alaska	1	1	1	1	1	1
Hawaii	3	2	837	480	840	482
U.S. Caribbean	8	7	417	233	425	240
National total	2,164	1,947	129,417	78,040	131,581	79,987

Source: SCS.

least part of the year and supporting a biotic community of aquatic plants and animals. Beyond the stream channel, the ecosystem generally includes a zone of riparian vegetation dependent upon surface or subsurface flow and a flood plain that is formed by the kinetic energy of the stream during periods of high flow.

There are about 666 thousand miles of perennial streams, 116.9 million acres of open flood plain (land in pasture, range, or forest), and 48.4 million acres of surface water that provide riparian and aquatic habitats.

Instream flow requirements for fish and wildlife are those amounts of water flowing through a stream channel that support aquatic life at an acceptable level. Habitat conditions may be categorized as optimum, good survival for most aquatic life forms, and short-term survival habitat. Generally, optimum habitat. requires more than 75 percent of the total streamflow in the humid area and 50 percent in the subhumid and semi-arid areas. Good survival habitat requires more than 60 percent of the total streamflow in the humid area and 30 percent in the subhumid and semi-arid areas.

Hydropower.--Hydroelectric power plants produce power without consuming fuel and without polluting water and air. They capture energy by releasing water. Hydroelectric generation supplied 321 billion kilowatt hours in 1984--about 13.3 percent of the electric power generated and 5 percent of the nation's total energy production. Hydroelectricity provides base loads in the Pacific Northwest, where much of the hydropower generation occurs. It generally provides only peak loads in the rest of the nation.

Because of low operating costs and advances in low-head flow generation and rewinding generators, interest has renewed in the potential for hydro-electric power generation.

Navigation.--Carriers moved 357 billion ton-miles on inland navigable waterways in 1983. More than 25,000 miles of navigable waterways are used to transport commodities. Domestic waterborne traffic increased from 829 million tons in 1965 to 1 billion tons in 1974, peaked in 1979, and dropped back to 1 billion tons in 1983. Domestic waterborne commerce accounted for 16 percent of the net tonnage carried commercially. The instream flow required for navigation depends on the size and depth of the channel and the number and operation of the locks. Even though 50 percent more waterborne freight is expected by the turn of the century, water supplies for navigation should be adequate.

Preservation.--In certain natural or historical areas, surface flows, groundwater levels, and high water quality must be maintained. In some locations, minimum water flow is needed to meet commitments in treaties and compacts, to meet local or state health standards, and to support established esthetic values.

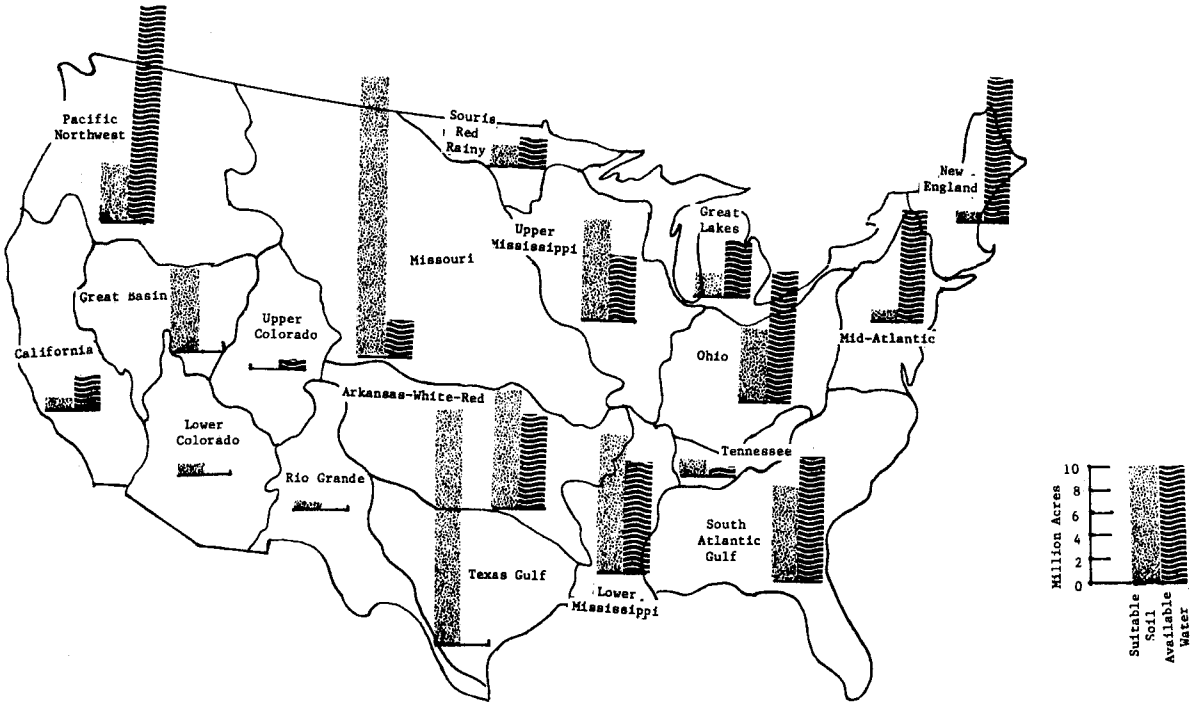

Figure 16-9.--Potentially irrigable land, by water resources region (1982 NRI).

Table A1-1.--National average yield projections, First and Second RCA Appraisals

Crop	Units	2000 RCA1	2000 RCA2	Increase (percent)	2030 RCA1	2030 RCA2	Increase (percent)
Barley	bu	53	79	50	58	88	52
Corn	bu	107	158	48	144	198	38
Corn silage	ton	14	22	62	15	27	74
Cotton	bale	1.1	1.9	73	1.4	1.9	36
Legume hay	ton	3.2	4.4	38	3.8	4.2	11
Oats	bu	64	69	8	68	86	26
Sorghum	bu	57	98	73	67	127	89
Sorghum silage	ton	15	17	18	14	19	39
Soybeans	bu	36	57	60	45	69	54
Wheat	bu	35	61	72	42	70	65

Source: CARD.

Table A3-1.--Land cover/use of nonfederal rural land in 1982, by land capability class and subclass

Class and subclass	Cropland	Pastureland	Range-land	Forest land	Minor land cover/use	Total
	1,000 acres					
I	30,219.1	2,562.4	514.9	1,930.4	803.2	36,030.0
IIe	91,363.1	18,924.6	9,748.3	23,836.2	3,951.0	147,823.2
IIw	64,951.8	10,816.9	2,536.2	16,122.7	1,879.8	96,307.4
IIs	17,187.0	1,996.8	1,313.3	3,043.0	462.9	24,003.0
IIc	17,758.5	762.5	3,149.5	611.1	395.0	22,676.6
II, totals	191,260.4	32,500.8	16,747.3	43,613.0	6,688.7	290,810.2
IIIe	82,720.3	27,237.0	37,886.7	32,152.9	3,165.3	183,162.2
IIIw	33,291.7	8,388.1	3,975.1	20,734.9	2,872.9	69,262.7
IIIs	12,498.1	4,397.1	2,348.8	8,457.4	670.7	28,372.1
IIIc	5,164.6	201.8	2,178.1	45.8	119.2	7,709.5
III, totals	133,674.7	40,224.0	46,388.7	61,391.0	6,828.1	288,506.5
I-III	355,154.2	75,287.2	63,650.9	106,934.4	14,320.0	615,346.7
IVe	32,479.2	16,648.3	42,815.4	30,574.2	1,641.0	124,158.1
IVw	7,191.3	4,908.3	4,312.1	15,720.7	1,138.5	33,270.9
IVs	6,821.9	3,951.8	4,509.6	11,296.5	650.9	27,230.7
IVc	470.4	79.4	1,448.0	50.2	18.1	2,066.1
IV, totals	46,962.8	25,587.8	53,085.1	57,641.6	3,448.5	186,725.8
I-IV	402,117.0	100,875.0	116,736.0	164,576.0	17,768.5	802,072.5
V	2,356.7	4,456.6	5,896.6	18,971.8	1,976.2	33,657.9
VIe	9,928.6	12,466.4	96,356.9	48,429.3	1,314.4	168,495.6
VIw	1,181.0	1,628.5	4,461.0	9,247.8	3,757.8	20,276.1
VIs	2,801.3	3,967.1	32,000.2	29,693.2	811.3	69,273.1
VIc	193.7	49.5	6,293.6	435.3	79.9	7,052.0
VI, totals	14,104.6	18,111.5	139,111.7	87,805.6	5,963.4	265,096.8
VIIe	1,303.6	4,644.6	53,948.8	55,033.8	1,850.6	116,781.4
VIIw	298.6	467.9	2,441.3	8,195.9	3,096.6	14,500.3
VIIs	1,123.2	4,497.3	79,400.3	55,916.6	3,259.7	144,197.1
VIIc	64.3	29.4	5,034.1	25.3	147.4	5,300.5
VII, totals	2,789.7	9,639.2	140,824.5	119,171.6	8,354.3	280,779.3
VIII	34.5	228.3	3,344.9	3,188.4	20,351.4	27,147.5
V-VIII	19,285.5	32,435.6	289,177.7	229,137.4	36,645.3	606,681.5
NA	0.0	0.0	0.0	0.0	5,222.7	5,222.7
Total	421,402.5	133,310.6	405,913.7	393,713.4	59,636.5	1,413,976.7 1/

1/ To this total may be added the following acreages of lands that are not assigned to a capability classification:

Urban (small communities) and other built-up land	46,627.7
Rural transportation	26,933.2
Small water areas	10,118.0
Total from table	1,413,976.7
Grand total	1,497.655.6

One unit = 1,000 acres.

Source: 1982 NRI.

Table A3-2.--Land cover/use of federal and nonfederal land, by farming region

Farming region and state	Cropland	Pastureland	Rangeland	Forest land	Other land	Total nonfederal	Federal land	Census water	Grand total
	(1,000 acres)								
NORTHEAST									
Connecticut	244.7	114.0	0	1,828.3	921.5	3,108.5	9.1	94.1	3,211.7
Delaware	519.1	35.2	0	347.6	301.6	1,203.5	33.3	71.7	1,308.5
Maine	953.4	569.0	0	16,770.3	1,409.0	19,701.7	135.0	1,452.9	21,289.6
Maryland	1,794.4	534.1	0	2,425.3	1,360.1	6,113.9	157.9	422.7	6,694.5
Massachusetts	297.2	201.6	0	2,970.1	1,454.2	4,923.1	89.0	289.8	5,301.9
New Hampshire	157.8	124.5	0	4,085.1	665.8	5,033.2	727.1	178.0	5,938.3
New Jersey	809.4	239.6	0	1,848.4	1,737.5	4,634.9	144.5	204.5	4,983.9
New York	5,912.1	3,871.8	0	16,516.9	3,782.9	30,083.7	237.1	1,108.3	31,429.1
Pennsylvania	5,896.3	2,592.6	0	15,300.3	4,270.5	28,059.7	668.0	269.5	28,997.2
Rhode Island	27.2	35.9	0	405.5	202.9	671.5	3.8	100.6	775.9
Vermont	648.4	500.7	0	4,086.5	383.6	5,619.2	315.4	218.3	6,152.9
Subtotal	17,260.0	8,819.0	0	66,584.3	16,489.6	109,152.9	2,520.2	4,410.4	116,083.5
LAKE STATES									
Michigan	9,443.1	2,911.0	0	15,359.7	5,654.4	33,368.2	3,087.1	1,002.1	37,457.4
Minnesota	23,024.1	3,589.8	198.5	13,956.3	6,688.6	47,457.3	3,372.6	3,187.3	54,017.2
Wisconsin	11,456.8	3,394.2	0	13,392.8	4,820.2	33,064.0	1,799.9	1,074.0	35,937.9
Subtotal	43,924.0	9,895.0	198.5	42,708.8	17,163.2	113,889.5	8,259.6	5,263.4	127,412.5
CORN BELT									
Illinois	24,727.4	3,157.3	0	3,429.4	3,823.1	35,137.2	492.8	430.8	36,060.8
Indiana	13,781.3	2,211.9	0	3,639.9	2,880.4	22,513.5	488.6	156.5	23,158.6
Iowa	26,440.7	4,536.1	0	1,756.2	2,910.6	35,643.6	171.6	201.0	36,016.2
Missouri	14,998.4	12,573.0	167.8	10,985.6	3,258.5	41,983.3	2,093.6	529.3	44,606.2
Ohio	12,447.1	2,713.9	0	6,380.2	4,350.8	25,892.0	346.1	212.8	26,450.9
Subtotal	92,394.9	25,192.2	167.8	26,191.3	17,223.4	161,169.6	3,592.7	1,530.4	166,292.7
NORTHERN PLAINS									
Kansas	29,118.3	2,240.9	16,908.9	626.2	2,890.4	51,784.7	584.5	288.3	52,657.5
Nebraska	20,276.7	2,125.3	23,095.7	732.1	2,219.6	48,449.4	638.6	419.3	49,507.3
North Dakota	27,039.2	1,271.9	10,948.4	438.2	2,736.0	42,433.7	1,879.0	936.8	45,249.5
South Dakota	16,947.2	2,703.0	22,783.6	561.6	2,766.4	45,761.8	2,824.4	767.8	49,354.0
Subtotal	93,381.4	8,341.1	73,736.6	2,358.1	10,612.4	188,429.6	5,926.5	2,412.2	196,768.3
APPALACHIA									
Kentucky	5,934.2	5,879.8	0	10,158.2	2,305.8	24,278.0	1,124.8	459.2	25,862.0
North Carolina	6,694.8	1,980.2	0	16,728.5	3,707.1	29,110.6	2,115.9	2,481.7	33,708.2
Tennessee	5,592.1	5,355.6	0	11,529.1	2,503.1	24,979.9	1,343.1	648.9	26,971.9
Virginia	3,396.9	3,392.0	0	13,625.3	2,648.4	23,062.6	2,347.4	680.6	26,090.6
West Virginia	1,093.1	1,869.1	0	10,422.5	945.2	14,329.9	1,104.0	74.2	15,508.1
Subtotal	22,711.1	18,476.7	0	62,463.6	12,109.6	115,761.0	8,035.2	4,344.6	128,140.8

Table A3-2.--Land cover/use of federal and nonfederal land, by farming region--continued

Farming region and state	Cropland	Pastureland	Rangeland	Forest land	Other land	Total nonfederal	Federal land	Census water	Grand total
	(1,000 acres)								
SOUTHEAST									
Alabama	4,510.3	3,816.6	0	20,633.3	2,593.2	31,553.4	904.4	633.3	33,091.1
Florida	3,556.8	4,273.2	3,803.9	12,430.1	7,464.2	31,528.2	3,129.2	2,887.3	37,544.7
Georgia	6,568.4	2,976.6	0	21,883.6	3,649.5	35,078.1	2,067.9	556.1	37,702.1
South Carolina	3,578.7	1,208.0	0	11,025.5	2,361.0	18,173.2	1,149.8	589.1	19,912.1
Subtotal	18,214.2	12,274.4	3,803.9	65,972.5	16,067.9	116,332.9	7,251.3	4,665.8	128,250.0
DELTA STATES									
Arkansas	8,101.5	5,793.8	164.6	14,339.8	1,820.8	30,220.5	3,113.7	705.4	34,039.6
Louisiana	6,408.9	2,368.5	241.3	12,895.0	5,188.8	27,102.5	1,104.3	2,354.2	30,561.0
Mississippi	7,415.3	3,975.2	0	15,242.7	1,924.3	28,557.5	1,618.3	345.4	30,521.2
Subtotal	21,925.7	12,137.5	405.9	42,477.5	8,933.9	85,880.5	5,836.3	3,405.0	95,121.8
SOUTHERN PLAINS									
Oklahoma	11,568.1	7,137.9	15,059.6	6,538.7	2,478.4	42,782.7	1,191.6	797.4	44,771.7
Texas	33,319.6	17,042.8	95,353.1	9,323.6	9,726.2	164,765.3	2,998.3	2,992.7	170,756.3
Subtotal	44,887.7	24,180.7	110,412.7	15,862.3	12,204.6	207,548.0	4,189.9	3,790.1	215,528.0
MOUNTAIN									
Arizona	1,206.3	79.3	30,948.2	4,760.2	3,609.4	40,603.4	32,056.3	300.3	72,960.0
Colorado	10,602.7	1,259.7	24,222.5	4,030.1	2,581.3	42,696.3	23,611.2	310.7	66,618.2
Idaho	6,390.1	1,274.2	6,732.9	3,977.1	1,075.1	19,449.4	33,445.0	586.8	53,481.2
Montana	17,196.9	3,036.0	37,837.0	5,228.0	2,649.2	65,947.1	27,106.9	1,055.2	94,109.2
Nevada	859.7	304.4	7,907.8	356.6	730.0	10,158.5	60,188.7	411.7	70,758.9
New Mexico	2,412.7	163.3	40,981.9	4,733.9	2,955.2	51,247.0	26,419.8	152.4	77,819.2
Utah	2,038.7	490.3	8,489.3	3,234.6	2,450.2	16,703.1	35,818.5	1,813.9	54,335.5
Wyoming	2,587.4	754.8	26,915.1	987.1	1,558.1	32,802.5	29,315.0	480.5	62,598.0
Subtotal	43,294.5	7,362.0	184,034.7	27,307.6	17,608.5	279,607.3	267,961.4	5,111.5	552,680.2
PACIFIC									
California	10,517.7	1,392.5	18,124.6	15,217.8	9,217.9	54,470.5	45,552.3	1,549.1	101,571.9
Oregon	4,356.4	1,965.9	9,392.0	11,889.2	1,728.6	29,332.1	32,121.5	673.0	62,126.6
Washington	7,793.4	1,344.6	5,637.0	12,690.3	2,626.4	30,091.7	12,474.3	1,042.7	43,608.7
Subtotal	22,667.5	4,703.0	33,153.6	39,797.3	13,572.9	113,894.3	90,148.1	3,264.8	207,307.2
OTHER									
Hawaii	333.2	974.0	0.0	1,473.5		3,770.6	341.5	29.2	4,141.3
Caribbean	408.3	955.0	0.0	516.6		2,219.4	104.1	10.3	2,333.8
Subtotal	741.5	1,929.0	0.0	1,990.1		5,990.0	445.6	39.5	6,475.1
TOTAL	421,402.5	133,310.6	405,913.7	393,713.4	141,986.0	1,497,655.6	404,166.8	38,237.8	1,940,060.1

Source: 1982 NRI.

Table A3-3a.--Capability classification of nonfederal rural land (1982), by state: Cropland

State	Land capability class								
	I	II	III	IV	V	VI	VII	VIII	Total
	(1,000 acres)								
Alabama	327.6	2,228.7	1,193.5	544.5	45.0	121.6	49.4	0.0	4,510.3
Arizona	771.3	201.6	199.0	28.1	0.0	6.0	0.3	0.0	1,206.3
Arkansas	585.0	2,524.2	4,266.4	663.6	28.4	23.4	10.5	0.0	8,101.5
California	2,093.7	3,268.7	3,331.9	1,442.8	1.8	200.8	170.1	7.9	10,517.7
Colorado	205.6	1,841.1	3,564.5	3,632.9	80.6	1,219.0	59.0	0.0	10,602.7
Connecticut	26.5	114.4	49.1	26.4	0.0	20.2	8.1	0.0	244.7
Delaware	80.6	250.3	176.7	9.7	1.1	0.7	0.0	0.0	519.1
Florida	66.6	505.5	1,944.5	736.6	9.5	115.2	178.9	0.0	3,556.8
Georgia	726.5	4,136.4	876.6	635.3	96.3	69.3	28.0	0.0	6,568.4
Hawaii	31.0	98.8	95.6	67.1	0.0	14.0	26.7	0.0	333.2
Idaho	110.8	1,983.9	2,524.6	1,281.1	54.3	359.1	74.7	1.6	6,390.1
Illinois	3,971.5	14,514.1	4,493.8	1,205.9	64.3	423.3	54.5	0.0	24,727.4
Indiana	668.7	10,051.5	1,916.1	941.6	13.5	179.8	9.5	0.6	13,781.3
Iowa	3,085.6	13,645.9	7,296.0	1,726.8	71.4	456.2	158.8	0.0	26,440.7
Kansas	3,212.1	13,942.5	8,750.6	2,371.4	78.7	731.3	31.7	0.0	29,118.3
Kentucky	647.6	2,772.4	1,578.9	547.5	0.7	301.3	85.8	0.0	5,934.2
Louisiana	371.5	1,781.2	3,651.6	482.6	114.7	6.3	1.0	0.0	6,408.9
Maine	57.2	537.1	216.1	120.6	0.0	20.8	1.6	0.0	953.4
Maryland	137.5	898.1	503.8	151.4	13.0	66.4	24.2	0.0	1,794.4
Massachusetts	21.5	122.4	81.7	27.6	12.1	31.4	0.5	0.0	297.2
Michigan	22.7	5,545.8	3,019.0	604.8	38.3	169.5	43.0	0.0	9,443.1
Minnesota	2,051.5	14,074.5	4,749.4	1,856.0	34.1	200.3	58.3	0.0	23,024.1
Mississippi	317.8	3,132.2	2,571.5	901.1	192.9	208.2	91.6	0.0	7,415.3
Missouri	732.5	6,613.1	6,162.7	1,082.5	38.5	299.3	69.8	0.0	14,998.4
Montana	0.0	516.3	11,711.1	3,409.1	83.3	1,188.5	288.6	0.0	17,196.9
Nebraska	2,498.2	7,962.9	5,400.6	3,133.4	41.5	1,214.3	23.1	2.7	20,276.7
Nevada	1.1	402.2	137.9	84.8	53.4	104.8	75.5	0.0	859.7
New Hampshire	14.3	42.8	59.7	20.9	0.8	9.4	9.9	0.0	157.8
New Jersey	54.7	423.3	196.1	74.2	22.4	20.0	17.8	0.9	809.4
New Mexico	212.1	552.9	809.6	549.6	0.4	251.9	36.2	0.0	2,412.7
New York	220.6	2,381.3	2,571.7	579.8	56.5	91.3	10.9	0.0	5,912.1
North Carolina	508.1	3,087.9	2,230.5	625.4	2.3	178.5	62.1	0.0	6,694.8
North Dakota	0.0	16,534.3	6,613.4	2,289.7	271.1	1,229.3	94.6	6.8	27,039.2
Ohio	262.6	8,503.7	3,013.3	492.1	8.5	149.2	17.7	0.0	12,447.1
Oklahoma	1,242.9	4,301.6	3,866.7	1,639.3	108.4	398.0	11.2	0.0	11,568.1
Oregon	159.1	1,226.1	1,986.6	721.4	72.0	147.3	43.9	0.0	4,356.4
Pennsylvania	191.9	2,344.7	2,181.0	805.0	15.4	251.1	106.4	0.8	5,896.3
Rhode Island	7.6	15.4	2.0	0.7	0.5	1.0	0.0	0.0	27.2
South Carolina	505.5	1,945.6	821.2	246.7	2.7	45.2	11.8	0.0	3,578.7
South Dakota	1,660.4	8,493.8	3,934.9	2,011.0	74.0	757.2	15.9	0.0	16,947.2
Tennessee	371.0	2,643.0	1,436.5	711.6	47.3	305.8	76.9	0.0	5,592.1
Texas	1,014.6	14,378.4	13,981.0	2,685.7	345.7	798.9	115.3	0.0	33,319.6
Utah	44.2	603.1	684.3	473.8	28.4	134.1	69.3	1.5	2,038.7
Vermont	22.8	213.5	244.2	128.5	4.4	31.1	2.9	1.0	648.4
Virginia	278.2	1,781.7	791.6	345.1	12.5	137.0	50.8	0.0	3,396.9
Washington	146.8	1,280.6	3,775.6	2,099.4	11.1	381.9	95.3	2.7	7,793.4
West Virginia	34.2	425.1	262.5	190.3	10.7	99.6	68.5	2.2	1,093.1
Wisconsin	418.5	6,032.7	2,658.5	1,621.3	36.4	593.8	90.3	5.3	11,456.8
Wyoming	0.9	314.8	1,040.7	891.1	57.8	254.8	27.3	0.0	2,587.4
Caribbean	25.9	68.3	49.9	45.0	0.0	87.2	131.5	0.5	408.3
Total	30,219.1	191,260.4	133,674.7	46,962.8	2,356.7	14,104.6	2,789.7	34.5	421,402.5

Source: 1982 National Resources Inventory.

Table A3-3b.--Capability classification of nonfederal rural land (1982), by state: Pastureland

State	Land capability class								
	I	II	III	IV	V	VI	VII	VIII	Total
	(1,000 acres)								
Alabama	53.4	1,234.7	1,004.8	818.8	119.4	337.9	247.6	0.0	3,816.6
Arizona	18.2	7.2	10.1	13.3	22.1	6.0	2.4	0.0	79.3
Arkansas	74.4	1,123.9	2,424.4	913.1	113.8	672.3	471.9	0.0	5,793.8
California	68.7	148.0	490.1	436.8	31.1	105.3	99.8	12.7	1,392.5
Colorado	0.7	54.8	242.3	446.9	116.3	359.9	38.8	0.0	1,259.7
Connecticut	4.1	30.0	18.7	11.6	1.5	30.2	17.9	0.0	114.0
Delaware	3.0	13.5	12.6	3.6	0.6	0.7	1.2	0.0	35.2
Florida	11.3	227.3	1,516.8	2,132.2	64.7	151.6	146.8	22.5	4,273.2
Georgia	47.6	1,081.3	751.9	679.7	98.8	199.6	117.7	0.0	2,976.6
Hawaii	0.0	20.7	157.1	138.4	0.0	143.5	458.0	56.3	974.0
Idaho	8.2	152.2	306.1	408.0	134.1	168.2	92.0	5.4	1,274.2
Illinois	142.3	1,158.2	671.3	421.8	26.4	557.5	175.1	4.7	3,157.3
Indiana	46.5	921.8	408.0	391.3	11.7	314.1	113.1	5.4	2,211.9
Iowa	102.7	1,263.7	1,253.4	812.4	117.8	538.1	448.0	0.0	4,536.1
Kansas	47.8	607.2	907.5	263.1	52.1	297.5	62.5	3.2	2,240.9
Kentucky	294.6	1,216.4	1,369.4	936.8	7.5	1,280.3	774.8	0.0	5,879.8
Louisiana	74.2	677.2	1,192.0	209.0	159.9	49.2	7.0	0.0	2,368.5
Maine	7.4	219.6	146.1	114.0	0.0	62.7	15.4	3.8	569.0
Maryland	18.7	180.0	128.1	86.8	10.0	71.9	38.6	0.0	534.1
Massachusetts	1.8	62.3	45.0	14.7	6.3	39.3	31.7	0.5	201.6
Michigan	7.8	692.4	1,041.3	520.6	152.9	406.9	79.7	9.4	2,911.0
Minnesota	41.2	1,132.2	814.2	660.0	186.7	503.1	237.3	15.1	3,589.8
Mississippi	81.2	1,600.5	880.4	413.3	89.3	459.1	449.2	2.2	3,975.2
Missouri	180.6	3,043.0	4,625.3	2,230.0	32.4	1,460.6	1,001.1	0.0	12,573.0
Montana	0.0	90.6	1,210.0	813.3	75.9	743.9	89.8	12.5	3,036.0
Nebraska	60.6	401.0	577.5	558.7	19.7	457.7	46.2	3.9	2,125.3
Nevada	0.0	54.7	104.7	58.8	13.8	31.2	41.2	0.0	304.4
New Hampshire	1.0	24.6	43.9	12.9	0.0	24.4	17.7	0.0	124.5
New Jersey	3.1	94.9	70.6	27.6	7.7	16.7	19.0	0.0	239.6
New Mexico	6.3	25.7	36.9	34.9	4.6	47.8	7.1	0.0	163.3
New York	52.6	894.2	1,675.8	624.4	148.2	289.9	186.7	0.0	3,871.8
North Carolina	5.8	502.8	502.9	425.9	16.4	314.8	208.8	2.8	1,980.2
North Dakota	0.0	353.7	310.1	246.4	74.3	262.8	24.6	0.0	1,271.9
Ohio	31.1	762.8	712.1	592.5	6.9	433.2	175.3	0.0	2,713.9
Oklahoma	202.0	2,204.9	1,543.7	1,072.3	371.5	1,318.2	422.8	2.5	7,137.9
Oregon	19.3	414.5	508.1	451.6	97.4	353.9	118.7	2.4	1,965.9
Pennsylvania	43.5	616.2	916.7	533.3	8.7	183.2	291.0	0.0	2,592.6
Rhode Island	4.5	9.0	7.1	3.0	1.7	6.7	3.9	0.0	35.9
South Carolina	19.9	450.8	460.8	169.4	3.9	72.0	31.2	0.0	1,208.0
South Dakota	133.4	1,027.8	597.4	485.0	59.7	366.7	33.0	0.0	2,703.0
Tennessee	233.7	1,227.1	1,177.9	1,028.1	4.4	1,039.4	641.6	3.4	5,355.6
Texas	324.0	4,137.3	6,657.5	2,542.3	1,770.0	1,483.0	128.7	0.0	17,042.8
Utah	0.0	74.3	123.1	113.1	18.4	40.6	118.6	2.2	490.3
Vermont	3.0	87.1	136.2	94.5	7.5	76.2	95.2	1.0	500.7
Virginia	33.7	757.7	829.8	791.4	22.8	498.7	456.7	1.2	3,392.0
Washington	9.1	251.7	454.2	359.5	30.1	209.3	30.7	0.0	1,344.6
West Virginia	9.8	213.5	243.4	328.3	9.3	500.1	556.6	8.1	1,869.1
Wisconsin	17.0	874.0	605.9	670.1	106.9	810.0	286.8	23.5	3,394.2
Wyoming	0.0	28.1	187.4	345.8	21.4	147.9	20.1	4.1	754.8
Caribbean	12.6	53.7	113.4	128.5	0.0	167.7	459.6	19.5	955.0
Total	2,562.4	32,500.8	40,224.0	25,587.8	4,456.6	18,111.5	9,639.2	228.3	133,310.6

Source: 1982 National Resources Inventory.

Table A3-3c.--Capability classification of nonfederal rural land (1982), by state: Rangeland

State	Land capability class								
	I	II	III	IV	V	VI	VII	VIII	Total
	(1,000 acres)								
Alabama	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arizona	0.0	0.0	1.5	54.5	0.0	12,188.5	18,479.8	223.9	30,948.2
Arkansas	0.0	2.5	15.3	20.1	0.0	35.8	90.9	0.0	164.6
California	3.0	117.5	1,074.6	3,180.9	11.6	4,426.7	8,367.2	943.1	18,124.6
Colorado	0.0	205.2	1,458.5	5,535.6	203.3	11,279.8	5,128.4	411.7	24,222.5
Connecticut	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Delaware	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Florida	0.0	6.1	999.5	2,165.2	83.3	140.0	401.1	8.7	3,803.9
Georgia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hawaii	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Idaho	0.0	14.7	507.3	1,026.7	99.2	2,309.9	2,706.0	69.1	6,732.9
Illinois	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iowa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kansas	127.5	2,457.1	3,784.9	1,693.2	438.0	7,226.1	1,156.1	26.0	16,908.9
Kentucky	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Louisiana	1.0	0.7	24.2	16.2	2.0	0.0	160.5	36.7	241.3
Maine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maryland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Massachusetts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Michigan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Minnesota	2.5	72.2	18.6	20.7	2.4	57.8	24.3	0.0	198.5
Mississippi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Missouri	0.0	69.4	21.6	12.2	6.2	14.6	43.8	0.0	167.8
Montana	0.0	15.1	8,758.3	7,766.7	148.9	12,225.6	8,590.4	332.0	37,837.0
Nebraska	36.1	689.1	1,233.2	2,694.9	564.5	13,761.3	4,060.7	55.9	23,095.7
Nevada	0.0	10.5	3.2	6.5	35.5	1,977.7	5,850.1	24.3	7,907.8
New Hampshire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Jersey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Mexico	0.0	11.3	604.7	2,576.8	2.2	16,415.3	21,069.5	302.1	40,981.9
New York	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Carolina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Dakota	0.0	1,718.0	1,886.1	1,418.3	508.2	3,690.2	1,686.7	40.9	10,948.4
Ohio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oklahoma	118.9	1,303.1	2,337.4	2,686.2	498.4	5,744.0	2,357.0	14.6	15,059.6
Oregon	1.6	87.8	488.9	782.2	144.3	2,823.6	5,021.6	42.0	9,392.0
Pennsylvania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhode Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
South Carolina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
South Dakota	78.1	2,592.8	3,110.3	3,722.5	313.6	9,331.5	3,634.8	0.0	22,783.6
Tennessee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Texas	146.1	7,334.4	17,568.1	11,945.8	2,659.8	20,668.4	34,867.3	163.2	95,353.1
Utah	0.1	5.7	105.0	290.4	33.8	2,164.4	5,796.2	93.7	8,489.3
Vermont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Virginia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Washington	0.0	26.4	688.3	983.0	5.2	1,350.5	2,523.2	60.4	5,637.0
West Virginia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wisconsin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wyoming	0.0	7.7	1,699.2	4,486.5	136.2	11,280.0	8,808.9	496.6	26,915.1
Caribbean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	514.9	16,747.3	46,388.7	53,085.1	5,896.6	139,111.7	140,824.5	3,344.9	405,913.7

Source: 1982 National Resources Inventory.

Table A3-3d.--Capability classification of nonfederal rural land (1982), by state: Forest land

State	Land capability class								
	I	II	III	IV	V	VI	VII	VIII	Total
	(1,000 acres)								
Alabama	153.9	2,336.6	2,706.6	3,774.7	1,777.7	2,675.6	7,194.7	13.5	20,633.3
Arizona	0.0	0.0	0.0	114.6	0.0	2,620.1	2,025.5	0.0	4,760.2
Arkansas	96.9	1,682.0	3,754.4	2,057.2	1,270.4	2,115.4	3,363.5	0.0	14,339.8
California	5.0	30.3	424.5	2,196.7	0.0	5,638.5	6,553.8	389.0	15,217.8
Colorado	0.0	1.6	5.1	89.3	23.3	1,142.7	2,660.8	107.3	4,030.1
Connecticut	14.7	134.3	85.4	70.3	81.9	408.8	1,012.3	20.6	1,828.3
Delaware	4.9	47.1	244.3	18.2	0.0	2.7	30.4	0.0	347.6
Florida	19.4	945.6	3,633.0	4,430.1	1,101.7	865.7	1,378.1	56.5	12,430.1
Georgia	139.8	3,581.7	3,401.4	5,499.1	3,400.2	3,116.0	2,738.0	7.4	21,883.6
Hawaii	0.0	10.3	78.1	156.3	0.0	71.0	786.8	371.0	1,473.5
Idaho	0.0	5.8	79.9	595.3	4.1	955.5	2,289.5	47.0	3,977.1
Illinois	65.9	843.0	540.5	416.1	90.3	829.4	636.1	8.1	3,429.4
Indiana	77.9	1,017.3	473.5	540.5	37.3	598.4	886.3	8.7	3,639.9
Iowa	29.2	245.1	264.3	192.6	146.8	247.5	629.1	1.6	1,756.2
Kansas	33.7	176.0	71.3	23.0	71.7	150.2	94.0	6.3	626.2
Kentucky	141.0	413.7	733.9	868.5	9.2	1,586.7	6,405.2	0.0	10,158.2
Louisiana	42.1	1,825.1	5,218.4	1,596.9	2,237.6	685.1	1,231.8	58.0	12,895.0
Maine	11.8	1,172.3	1,166.0	1,404.0	74.5	6,730.9	5,326.6	884.2	16,770.3
Maryland	25.6	392.0	742.0	256.6	141.8	403.6	456.2	7.5	2,425.3
Massachusetts	16.0	163.4	209.0	107.9	219.5	477.4	1,774.2	2.7	2,970.1
Michigan	8.2	1,920.0	2,940.7	2,671.2	1,789.1	4,535.7	1,441.1	53.7	15,359.7
Minnesota	29.7	3,343.3	2,105.1	2,964.8	553.6	2,015.4	2,915.6	28.8	13,956.3
Mississippi	98.3	2,676.6	1,939.2	1,941.7	1,577.2	2,344.7	4,655.3	9.7	15,242.7
Missouri	140.5	829.1	1,866.8	1,602.1	25.0	1,876.5	4,640.7	4.9	10,985.6
Montana	0.0	5.5	85.3	322.4	28.5	2,468.8	2,275.4	42.1	5,228.0
Nebraska	10.9	75.1	36.6	37.4	22.1	244.1	283.0	22.9	732.1
Nevada	0.0	0.0	0.0	0.0	0.0	21.7	334.3	0.6	356.6
New Hampshire	5.4	118.7	349.9	312.1	6.2	1,749.9	1,470.3	72.8	4,085.1
New Jersey	44.7	382.1	322.3	245.4	155.5	137.3	523.3	37.8	1,848.4
New Mexico	0.0	0.0	0.0	13.1	0.0	1,389.2	3,331.6	0.0	4,733.9
New York	103.2	1,693.1	3,868.0	2,324.7	642.6	3,715.8	4,116.4	53.1	16,516.9
North Carolina	90.4	2,788.1	4,030.4	2,797.7	657.7	2,497.4	3,794.8	72.0	16,728.5
North Dakota	0.0	109.6	86.7	36.2	3.9	144.6	52.9	4.3	438.2
Ohio	34.5	1,067.8	1,354.2	1,132.6	16.1	1,332.8	1,439.7	2.5	6,380.2
Oklahoma	25.0	376.1	346.0	614.8	394.1	1,462.3	3,320.4	0.0	6,538.7
Oregon	17.2	176.7	481.7	866.1	0.0	6,478.8	3,826.1	42.6	11,889.2
Pennsylvania	62.1	1,644.2	2,481.1	1,510.0	24.9	3,442.0	5,974.8	161.2	15,300.3
Rhode Island	5.9	36.2	31.4	28.2	27.9	175.6	100.3	0.0	405.5
South Carolina	87.0	2,063.0	3,997.4	1,750.7	102.5	1,661.6	1,362.5	0.8	11,025.5
South Dakota	5.0	21.7	22.1	17.7	0.0	199.4	295.7	0.0	561.6
Tennessee	90.6	1,024.1	1,612.0	1,348.3	131.7	2,065.5	5,245.1	11.8	11,529.1
Texas	4.6	1,856.8	2,749.6	1,512.8	1,266.3	1,813.1	120.4	0.0	9,323.6
Utah	0.0	0.0	8.2	12.2	0.0	660.4	2,459.0	94.8	3,234.6
Vermont	3.1	111.1	365.9	365.6	45.5	1,489.2	1,642.7	63.4	4,086.5
Virginia	144.9	3,262.8	2,222.4	1,834.9	336.1	2,150.1	3,651.0	23.1	13,625.3
Washington	0.7	411.1	1,895.4	3,255.3	49.3	4,280.3	2,744.0	54.2	12,690.3
West Virginia	18.0	214.8	451.8	916.5	10.4	1,559.1	7,120.9	131.0	10,422.5
Wisconsin	22.7	2,380.8	1,896.5	2,745.5	411.9	4,055.1	1,752.7	127.6	13,392.8
Wyoming	0.0	0.0	2.3	34.1	5.7	447.0	474.7	23.3	987.1
Caribbean	0.0	1.4	10.4	19.6	0.0	71.0	354.0	60.2	516.6
Total	1,930.4	43,613.0	61,391.0	57,641.6	18,971.8	87,805.6	119,171.6	3,188.4	393,713.4

Source: 1982 National Resources Inventory.

Table A3-4.-- Nonfederal land with high or medium potential for conversion to cropland

Farming region and state	Pastureland		Rangeland		Forest land		Total	
	High	Medium	High	Medium	High	Medium	High	Medium
	(1,000 acres)							
NORTHEAST								
Connecticut	26.8	41.9	0.0	0.0	40.9	181.3	67.7	223.2
Delaware	11.4	13.7	0.0	0.0	23.6	205.0	35.0	218.7
Maine	60.9	164.4	0.0	0.0	80.9	423.9	141.8	588.3
Maryland	70.4	129.1	0.0	0.0	48.9	258.2	119.3	387.3
Massachusetts	20.4	64.2	0.0	0.0	14.6	98.7	35.0	162.9
New Hampshire	22.1	18.9	0.0	0.0	6.9	93.5	29.0	112.4
New Jersey	15.7	42.9	0.0	0.0	33.1	129.4	48.8	172.3
New York	285.6	1,381.0	0.0	0.0	61.5	738.8	347.1	2,119.8
Pennsylvania	342.9	793.6	0.0	0.0	198.3	1,065.2	541.2	1,858.8
Rhode Island	2.0	4.4	0.0	0.0	0.0	21.1	2.0	25.5
Vermont	64.0	118.8	0.0	0.0	36.7	136.6	100.7	255.4
Subtotal	922.2	2,772.9	0.0	0.0	545.4	3,351.7	1,467.6	6,124.6
LAKE STATES								
Michigan	438.8	856.0	0.0	0.0	237.6	1,465.1	676.4	2,321.1
Minnesota	686.2	1,119.0	10.9	37.1	401.0	2,060.3	1,098.1	3,216.4
Wisconsin	531.4	805.1	0.0	0.0	202.2	1,265.4	733.6	2,070.5
Subtotal	1,656.4	2,780.1	10.9	37.1	840.8	4,790.8	2,508.1	7,608.0
CORNBELT								
Illinois	469.3	860.9	0.0	0.0	142.2	480.6	611.5	1,341.5
Indiana	420.2	638.8	0.0	0.0	229.8	578.4	650.0	1,217.2
Iowa	783.7	1,457.7	0.0	0.0	45.9	219.7	829.6	1,677.4
Missouri	2,367.1	4,690.6	47.8	32.4	270.7	1,216.0	2,685.6	5,939.0
Ohio	388.8	718.5	0.0	0.0	249.4	829.4	638.2	1,547.9
Subtotal	4,429.1	8,366.4	47.8	32.4	938.0	3,324.1	5,414.9	11,722.9
NORTHERN PLAINS								
Kansas	416.3	878.3	1,139.4	3,217.1	15.5	68.7	1,571.2	4,164.1
Nebraska	378.9	777.4	645.6	3,724.0	19.3	58.0	1,043.8	4,559.4
North Dakota	230.5	422.1	467.5	1,935.6	17.7	84.5	715.7	2,442.2
South Dakota	581.8	1,204.0	689.1	3,688.6	1.3	4.9	1,272.2	4,897.5
Subtotal	1,607.5	3,281.8	2,941.6	12,565.2	53.8	216.1	4,602.9	16,063.1
APPALACHIA								
Kentucky	969.4	1,608.6	0.0	0.0	150.0	522.4	1,119.4	2,131.0
North Carolina	275.7	707.5	0.0	0.0	1,150.3	4,155.6	1,426.0	4,863.1
Tennessee	1,040.5	1,450.2	0.0	0.0	402.0	1,044.4	1,442.5	2,494.6
Virginia	233.0	823.7	0.0	0.0	278.4	1,996.8	511.4	2,820.5
West Virginia	112.1	547.4	0.0	0.0	24.5	605.4	136.6	1,152.8
Subtotal	2,630.7	5,137.4	0.0	0.0	2,005.2	8,324.5	4,635.9	13,461.9

Table A3-4.-- Nonfederal land with high or medium potential for conversion to cropland--continued

Farming region and state	Pastureland		Rangeland		Forest land		Total	
	High	Medium	High	Medium	High	Medium	High	Medium
	1,000 acres							
SOUTHEAST								
Alabama	814.5	1,477.3	0.0	0.0	498.7	2,287.3	1,313.2	3,764.6
Florida	419.5	1,658.9	86.5	1,009.3	185.4	1,020.7	691.4	3,688.9
Georgia	546.5	979.3	0.0	0.0	774.5	2,438.9	1,321.0	3,418.2
South Carolina	120.1	416.2	0.0	0.0	117.0	1,070.1	237.1	1,486.3
Subtotal	1,900.6	4,531.7	86.5	1,009.3	1,575.6	6,817.0	3,562.7	12,357.9
DELTA STATES								
Arkansas	438.5	1,745.9	2.5	7.3	251.3	979.0	692.3	2,732.2
Louisiana	446.0	743.6	0.7	11.0	390.2	1,733.5	836.9	2,488.1
Mississippi	630.2	1,129.8	0.0	0.0	400.0	1,333.1	1,030.2	2,462.9
Subtotal	1,514.7	3,619.3	3.2	18.3	1,041.5	4,045.6	2,559.4	7,683.2
SOUTHERN PLAINS								
Oklahoma	733.1	2,134.3	727.6	2,514.9	42.6	364.9	1,503.3	5,014.1
Texas	1,390.3	4,666.0	2,490.0	11,273.7	35.4	449.6	3,915.7	16,389.3
Subtotal	2,123.4	6,800.3	3,217.6	13,788.6	78.0	814.5	5,419.0	21,403.4
MOUNTAIN								
Arizona	42.3	32.0	329.7	1,703.3	0.0	2.2	372.0	1,737.5
Colorado	84.1	232.6	277.1	1,775.7	1.6	17.7	362.8	2,026.0
Idaho	118.1	417.0	114.4	386.9	23.7	139.9	256.2	943.8
Montana	438.2	1,023.2	753.4	3,668.8	2.2	47.3	1,193.8	4,739.3
Nevada	16.4	77.1	46.5	169.9	0.0	0.0	62.9	247.0
New Mexico	19.1	32.1	177.9	947.8	0.0	0.1	197.0	980.0
Utah	28.2	142.1	39.0	191.6	0.0	3.3	67.2	337.0
Wyoming	96.2	313.8	185.8	1,444.3	0.5	2.7	282.5	1,760.8
Subtotal	842.6	2,269.9	1,923.8	10,288.3	28.0	213.2	2,794.4	12,771.4
PACIFIC								
California	210.7	423.7	318.0	1,123.0	23.8	86.3	552.5	1,633.0
Oregon	244.3	503.5	67.4	612.5	11.1	177.0	322.8	1,293.0
Washington	177.3	512.6	147.6	539.1	109.3	1,574.2	434.2	2,625.9
Subtotal	632.3	1,439.8	533.0	2,274.6	144.2	1,837.5	1,309.5	5,551.9
OTHER								
Hawaii	29.4	58.2	0.0	0.0	12.2	24.3	41.6	82.5
Puerto Rico	62.1	147.2	0.0	0.0	0.4	39.5	62.5	186.7
Subtotal	91.5	205.4	0.0	0.0	12.6	63.8	104.1	269.2
TOTAL	18,350.9	41,205.0	8,764.4	40,013.9	7,263.1	33,798.8	34,378.8	115,017.9

This table does not include data on land in minor cover types and uses.
Source: 1982 NRI.

Table A3-5.--Cropland and land with potential for conversion to cropland, by land capability class and subclass, 1982 NRI

Class and subclass	Potential for conversion to cropland					Cropland in 1982	Total
	High	Medium	Low	Zero	Total		
	(1,000 acres)						
I	1,731.3	1,512.4	2,025.6	541.6	5,810.9	30,219.1	36,030.0
IIe	9,842.2	18,856.7	22,525.4	5,235.8	56,460.1	91,363.1	147,823.2
IIw	4,999.0	8,569.1	14,338.8	3,448.7	31,355.6	64,951.8	96,307.4
IIs	1,157.2	2,457.3	2,559.9	623.6	6,816.0	17,187.0	24,003.0
IIc	1,038.5	1,670.0	1,780.5	429.1	4,918.1	17,758.5	22,676.6
II, totals	17,036.9	31,571.1	41,204.6	9,737.2	99,549.8	191,260.4	290,810.2
IIIe	7,602.4	30,626.1	50,253.2	11,960.2	100,441.9	82,720.3	183,162.2
IIIw	2,784.1	8,571.2	19,419.3	5,196.4	35,971.0	33,291.7	69,262.7
IIIs	848.6	3,922.9	8,999.9	2,102.6	15,874.0	12,498.1	28,372.1
IIIc	356.7	771.6	1,187.1	229.5	2,544.9	5,164.6	7,709.5
III, totals	11,591.8	43,891.8	19,859.5	19,488.7	154,831.8	133,674.7	288,506.5
I-III	30,360.0	76,975.3	123,089.3	29,767.5	260,192.5	355,154.2	615,346.7
IVe	1,983.0	16,477.1	54,427.5	18,791.3	91,678.9	32,479.2	124,158.1
IVw	656.8	4,927.6	15,484.5	5,010.7	26,079.6	7,191.3	33,270.9
IVs	492.6	3,862.5	12,149.9	3,903.8	20,408.8	6,821.9	21,280.7
IVc	42.2	517.3	876.3	159.9	1,595.7	470.4	2,066.1
IV, totals	3,174.6	25,784.5	82,938.2	27,865.7	139,763.0	46,962.8	186,725.8
I-IV	33,534.6	102759.8	206,027.9	57,633.2	399,955.5	402,117.0	802,072.5
V	319.5	2,368.3	16,329.5	12,283.9	31,301.2	2,356.7	33,657.9
VIe	427.8	6,803.4	70,117.6	81,218.2	158,567.0	9,928.6	168,495.6
VIw	180.9	1,059.7	9,405.8	8,448.7	19,095.1	1,181.0	20,276.1
VIs	360.6	2,645.9	30,671.7	32,793.6	66,471.8	2,801.3	69,273.1
VIc	208.9	565.5	4,181.7	1,902.2	6,858.3	193.7	7,052.0
VI, totals	1,178.2	11,074.5	114,376.8	124,362.7	250,992.2	14,104.6	265,096.8
VIIe	4.3	84.2	284.3	115,105.0	115,477.8	1,303.6	116,781.4
VIIw	0.0	0.0	0.0	14,201.7	14,201.7	298.6	14,500.3
VIIs	95.7	416.7	561.6	141,999.9	143,073.9	1,123.2	144,197.1
VIIc	201.9	936.8	3,105.9	991.6	5,236.2	64.3	5,300.5
VII, totals	301.9	1,437.7	3,951.8	272,298.2	277,989.6	2,789.7	280,779.3
VIII	0.0	0.0	0.0	27,113.0	27,113.0	34.5	27,147.5
V-VIII	1,799.6	14,880.5	134,658.1	436,057.8	587,396.0	19,285.5	606,681.5
NA	0.0	0.0	0.0	5,222.7	5,222.7	0.0	5,222.7
Total	35,334.2	117,640.3	340,686.0	498,913.7	992,574.2	421,402.5	1,413,976.7

Source: 1982 NRI.

Table A4-1.--Estimated average annual erosion (1982) on nonfederal rural land (except small built-up land) by state

State	Wind erosion		Sheet and rill erosion	
	1,000 tons	tons/acre	1,000 tons	tons/acre
Alabama	0.0	0.0	90,880.4	3.1
Arizona	142,878.6	3.6	27,513.8	0.7
Arkansas	356.3	0.0	54,540.1	1.9
California	254,679.9	5.1	157,520.0	3.2
Colorado	116,517.5	2.8	119,998.7	2.9
Connecticut	0.0	0.0	1,255.3	0.5
Delaware	1,125.0	1.1	1,132.8	1.1
Florida	4,244.9	0.2	10,995.9	0.4
Georgia	0.0	0.0	51,294.8	1.6
Hawaii	0.0	0.0	14,876.6	4.1
Idaho	19,436.3	1.0	38,210.4	2.0
Illinois	0.0	0.0	200,778.7	6.3
Indiana	8,910.8	0.4	98,903.8	4.8
Iowa	70,346.1	2.1	272,022.4	8.1
Kansas	89,181.4	1.8	112,905.1	2.3
Kentucky	0.0	0.0	147,596.9	6.5
Louisiana	0.0	0.0	32,183.9	1.3
Maine	0.0	0.0	3,856.4	0.2
Maryland	456.2	0.1	12,055.1	2.4
Massachusetts	0.0	0.0	1,462.4	0.4
Michigan	15,805.5	0.5	26,934.7	0.9
Minnesota	90,129.8	2.0	63,506.3	1.4
Mississippi	0.0	0.0	82,249.7	3.1
Missouri	0.0	0.0	205,628.1	5.2
Montana	144,309.6	2.2	70,513.0	1.1
Nebraska	41,821.2	0.9	139,011.2	3.0
Nevada	44,157.7	4.5	7,142.1	0.7
New Hampshire	0.0	0.0	1,079.7	0.2
New Jersey	322.0	0.1	5,973.9	1.8
New Mexico	152,405.7	3.0	55,191.2	1.1
New York	0.0	0.0	23,809.5	0.9
North Carolina	0.0	0.0	60,691.4	2.3
North Dakota	85,969.2	2.1	120,580.9	2.9
Ohio	2,805.9	0.1	86,277.0	3.8
Oklahoma	39,985.3	1.0	73,057.1	1.8
Oregon	11,918.3	0.4	67,809.3	2.4
Pennsylvania	0.0	0.0	84,245.3	3.4
Rhode Island	0.0	0.0	209.2	0.4
South Carolina	0.0	0.0	14,539.1	1.1
South Dakota	45,261.1	1.0	117,392.1	2.6
Tennessee	0.0	0.0	80,762.2	3.5
Texas	535,194.5	3.4	237,958.0	1.5
Utah	64,289.8	4.0	33,070.9	2.0
Vermont	0.0	0.0	2,830.3	0.5
Virginia	721.6	0.0	47,777.8	2.3
Washington	18,201.5	0.6	53,810.6	1.9
West Virginia	0.0	0.0	45,927.7	3.4
Wisconsin	16,544.5	0.5	62,520.7	2.0
Wyoming	10,367.5	0.3	69,610.2	2.2
Caribbean	0.0	0.0	23,361.5	12.1
Total	2,028,343.7	1.4	3,416,454.2	2.4

Source: 1982 NRI.

Table A4-2.--Estimated average annual erosion on all 1982 cropland, by state

State	Wind erosion		Sheet and rill erosion	
	1,000 tons	tons/acre	1,000 tons	tons/acre
Alabama	0.0	0.0	32,183.1	7.1
Arizona	3,941.2	3.3	582.7	0.5
Arkansas	356.3	0.0	39,362.1	4.9
California	11,206.4	1.1	12,138.8	1.2
Colorado	98,750.8	9.3	22,876.0	2.2
Connecticut	0.0	0.0	694.0	2.8
Delaware	940.5	1.8	1,042.0	2.0
Florida	3,329.7	0.9	7,190.2	2.0
Georgia	0.0	0.0	41,713.7	6.4
Hawaii	0.0	0.0	2,115.0	6.4
Idaho	18,438.0	2.9	32,132.0	5.0
Illinois	0.0	0.0	172,432.0	7.0
Indiana	8,878.8	0.6	75,791.8	5.5
Iowa	70,206.8	2.7	247,791.8	9.4
Kansas	80,203.8	2.8	79,830.1	2.7
Kentucky	0.0	0.0	56,537.3	9.5
Louisiana	0.0	0.0	29,310.2	4.6
Maine	0.0	0.0	1,988.6	2.1
Maryland	433.3	0.2	8,890.3	5.0
Massachusetts	0.0	0.0	620.8	2.1
Michigan	15,309.9	1.6	20,982.5	2.2
Minnesota	90,053.9	3.9	57,706.3	2.5
Mississippi	0.0	0.0	55,268.1	7.5
Missouri	0.0	0.0	146,452.9	9.8
Montana	143,337.1	8.3	26,614.1	1.6
Nebraska	27,036.9	1.3	105,035.4	5.2
Nevada	7,916.7	9.2	64.1	0.1
New Hampshire	0.0	0.0	191.1	1.2
New Jersey	95.8	0.1	4,577.3	5.7
New Mexico	12,601.0	5.2	3,110.6	1.3
New York	0.0	0.0	17,413.3	3.0
North Carolina	0.0	0.0	45,667.2	6.8
North Dakota	83,805.6	3.1	52,379.7	1.9
Ohio	2,795.5	0.2	46,587.3	3.7
Oklahoma	38,672.4	3.3	25,034.1	2.2
Oregon	7,365.9	1.7	17,299.2	4.0
Pennsylvania	0.0	0.0	31,171.1	5.3
Rhode Island	0.0	0.0	66.7	2.5
South Carolina	0.0	0.0	12,931.6	3.6
South Dakota	45,043.7	2.7	44,537.9	2.6
Tennessee	0.0	0.0	55,896.4	10.0
Texas	437,970.3	13.1	87,413.8	2.6
Utah	5,175.7	2.5	1,543.1	0.8
Vermont	0.0	0.0	831.1	1.3
Virginia	633.5	0.2	21,008.8	6.2
Washington	16,468.8	2.1	37,194.6	4.8
West Virginia	0.0	0.0	2,810.0	2.6
Wisconsin	16,263.9	1.4	51,141.3	4.5
Wyoming	1,921.2	0.7	2,542.0	1.0
Caribbean	0.0	0.0	4,694.7	11.5
Total	1,249,155.4	3.0	1,843,388.8	4.4

Source: 1982 NRI.

Table A4-3a.--Annual sheet and rill erosion on cropland, and the amount of erosion in excess of T, by erosion interval, 1982

Erosion interval (tons/acre)	Total acres (millions)	Cumulative percentage of acreage	Sheet & rill erosion (million tons)	Cumulative percentage of erosion	Erosion in excess of T (million tons)	Cumulative percentage of erosion in excess of T
> T+20	11.6	2.7	502.1	27.2	454.1	50.5
T+19 to T+20	0.8	2.9	19.0	28.3	15.7	52.2
T+18 to T+19	0.9	3.1	19.6	29.3	16.1	54.0
T+17 to T+18	1.0	3.4	21.2	30.5	17.1	55.9
T+16 to T+17	1.1	3.6	22.6	31.7	18.1	57.9
T+15 to T+16	1.2	3.9	23.8	33.0	18.7	60.0
T+14 to T+15	1.4	4.3	26.1	34.4	20.3	62.3
T+13 to T+14	1.5	4.6	26.6	35.9	20.4	64.5
T+12 to T+13	1.8	5.0	29.4	37.4	22.1	67.0
T+11 to T+12	2.0	5.5	30.8	39.1	22.7	69.5
T+10 to T+11	2.3	6.1	34.2	41.0	24.6	72.2
T+9 to T+10	2.4	6.6	32.8	42.8	22.8	74.8
T+8 to T+9	3.1	7.4	39.2	44.9	26.4	77.7
T+7 to T+8	3.5	8.2	40.8	47.1	26.3	80.6
T+6 to T+7	4.3	9.2	45.6	49.6	27.9	83.7
T+5 to T+6	5.2	10.5	49.8	52.3	28.5	86.9
T+4 to T+5	6.5	12.0	56.2	55.3	29.2	90.2
T+3 to T+4	8.6	14.0	65.0	58.8	29.9	93.5
T+2 to T+3	11.1	16.7	73.1	62.8	27.4	96.5
T+1 to T+2	14.8	20.2	83.1	67.3	21.5	98.9
T to T+1	21.2	25.2	96.9	72.6	9.8	100.0
< T	315.1	100.0	505.6	100.0	0.0	100.0
Total	421.4		1,843.4		899.4	

Source: 1982 NRI.

Table A4-3b.--Annual wind erosion on cropland, and the amount of erosion in excess of T, by erosion interval, 1982

Erosion interval (tons/acre)	Total acres (millions)	Cumulative percentage of acreage	Wind erosion (million tons)	Cumulative percentage of erosion	Erosion in excess of T (million tons)	Cumulative percentage of erosion in excess of T
> T+20	9.1	2.2	456.5	36.5	414.0	56.9
T+19 to T+20	0.6	2.3	14.7	37.7	11.9	58.6
T+18 to T+19	0.6	2.4	12.9	38.8	10.4	60.0
T+17 to T+18	0.7	2.6	15.1	40.0	11.9	61.6
T+16 to T+17	0.9	2.8	18.4	41.4	14.3	63.6
T+15 to T+16	0.9	3.0	17.6	42.8	13.5	65.5
T+14 to T+15	1.0	3.2	18.4	44.3	13.9	67.4
T+13 to T+14	1.1	3.5	19.4	45.9	14.5	69.4
T+12 to T+13	1.4	3.8	23.1	47.7	17.0	71.7
T+11 to T+12	1.4	4.2	22.9	49.5	16.4	74.0
T+10 to T+11	1.6	4.5	24.8	51.5	17.3	76.3
T+9 to T+10	1.7	5.0	24.4	53.5	16.5	78.6
T+8 to T+9	2.0	5.4	26.2	55.6	16.9	80.9
T+7 to T+8	3.2	6.2	39.2	58.7	24.2	84.3
T+6 to T+7	3.1	6.9	34.7	61.5	20.4	87.1
T+5 to T+6	4.1	7.9	41.1	64.8	22.3	90.1
T+4 to T+5	4.5	9.0	40.3	68.0	19.9	92.9
T+3 to T+4	5.4	10.2	43.5	71.5	18.7	95.5
T+2 to T+3	6.4	11.8	45.5	75.1	15.9	97.6
T+1 to T+2	8.4	13.8	50.8	79.2	12.5	99.4
T to T+1	9.8	16.1	48.0	83.1	4.6	100.0
< T	353.6	100.0	211.6	100.0	0.0	100.0
Total	421.4		1,249.2		727.1	

Source: 1982 NRI.

Table A4-4.--Nonfederal cropland eroding at rates greater than T

Farming region and state	Cropland (1,000 acres)	Acres eroding in excess of T: Sheet & rill (1,000 acres)	Sheet & rill Percent	Wind (1,000 acres)	Wind Percent
NORTHEAST					
Connecticut	244.7	55.2	23	0.0	*
Delaware	519.1	53.0	10	91.3	18
Maine	953.4	268.2	28	0.0	*
Maryland	1,794.4	589.4	33	13.3	*
Massachusetts	297.2	36.0	12	0.0	*
New Hampshire	157.8	9.3	6	0.0	*
New Jersey	809.4	384.3	48	0.0	*
New York	5,912.1	1,616.6	27	0.0	*
Pennsylvania	5,896.3	2,214.1	38	0.0	*
Rhode Island	27.2	8.4	31	0.0	*
Vermont	648.4	65.7	10	0.0	*
Subtotal	17,259.9	5,300.2		104.6	
Regional average			31		*
LAKE STATES					
Michigan	9,443.0	1,204.4	13	920.9	10
Minnesota	23,024.0	3,023.2	13	7,078.8	31
Wisconsin	11,456.7	3,120.1	27	895.5	8
Subtotal	43,923.9	7,347.7		8,895.1	
Regional average			17		20
CORN BELT					
Illinois	24,727.3	10,227.3	41	0.0	*
Indiana	13,781.2	4,687.4	34	556.8	4
Iowa	26,440.6	12,261.0	46	5,572.7	21
Missouri	14,998.3	7,223.7	48	0.0	*
Ohio	12,447.0	3,704.4	30	95.4	*
Subtotal	92,394.8	38,104.0		6,224.9	
Regional average			41		7
NORTHERN PLAINS					
Kansas	29,008.2	4,475.6	15	4,990.6	17
Nebraska	20,276.6	4,620.7	23	1,461.6	7
North Dakota	27,039.1	2,579.1	10	6,261.2	23
South Dakota	16,947.1	2,391.6	14	2,911.3	17
Subtotal	93,381.3	14,066.9		15,624.6	
Regional average			15		17
APPALACHIA					
Kentucky	5,934.2	2,412.7	41	0.0	*
North Carolina	6,694.8	2,476.4	37	0.0	*
Tennessee	5,592.1	2,806.9	50	0.0	*
Virginia	3,396.9	1,191.5	35	28.7	*
West Virginia	1,093.1	123.4	11	0.0	*
Subtotal	22,711.0	9,010.8		28.7	
Regional average			40		*
SOUTHEAST					
Alabama	4,510.3	2,558.8	57	0.0	*
Florida	3,556.8	375.9	11	294.3	8
Georgia	6,568.4	3,072.7	47	0.0	*
South Carolina	3,578.7	699.1	20	0.0	*
Subtotal	18,241.1	6,706.5		294.3	
Regional average			36		2
DELTA STATES					
Arkansas	8,101.5	3,276.1	40	0.0	*
Louisiana	6,408.9	2,171.0	34	0.0	*
Mississippi	7,415.2	3,009.9	41	0.0	*
Subtotal	21,925.6	8,456.9		0.0	
Regional average			38		*
SOUTHERN PLAINS					
Oklahoma	11,568.0	1,395.5	12	2,399.7	21
Texas	33,319.5	4,898.5	15	15,518.7	47
Subtotal	44,887.6	6,294.0		17,918.4	
Regional average			14		40

Table A4-4.--Nonfederal cropland eroding at rates greater than T--continued

Farming region and state	Cropland (1,000 acres)	Acres eroding in excess of T			
		Sheet & rill		Wind	
		(1,000 acres)	Percent	(1,000 acres)	Percent
MOUNTAIN					
Arizona	1,206.3	0.0	*	187.1	16
Colorado	10,602.6	1,072.3	10	5,407.8	51
Idaho	6,390.1	2,454.2	38	1,221.6	19
Montana	17,196.8	1,714.3	10	8,330.5	48
Nevada	859.7	0.0	*	79.1	9
New Mexico	2,412.7	118.1	5	653.6	27
Utah	2,038.7	109.2	5	283.4	14
Wyoming	2,587.4	207.4	8	96.7	4
Subtotal	43,294.4	5,675.5		16,259.9	
Regional average			13		38
PACIFIC					
California	10,517.6	503.7	5	423.8	4
Oregon	4,356.4	1,577.4	36	637.2	15
Washington	7,793.4	2,503.1	32	1,039.6	13
Subtotal	22,667.4	4,548.2		2,100.6	
Regional average			20		9
OTHER					
Hawaii	333.2	102.0	31	0.0	*
Puerto Rico	408.3	177.5	44	0.0	*
Subtotal	741.5	279.5		0.0	
Average			38		*
TOTAL	421,402.4	105,826.5	25	67,451.4	16

* = less than 1 percent.

Source: 1982 NRI.

Table A4-5.--Average annual sheet and rill erosion on 1982 cropland

State	Capability class							
	I	II	III	IV	V	VI	VII	VIII
	(tons/acre)							
Alabama	4.3	6.3	8.3	7.7	2.6	12.7	19.7	-
Arizona	0.5	0.4	0.5	0.1	-	1.4	1.0	-
Arkansas	5.7	5.3	4.4	5.1	4.7	16.2	7.6	-
California	0.3	0.3	0.5	2.7	0.1	12.5	14.3	1.9
Caribbean	1.0	1.6	3.0	2.6	-	10.9	24.5	59.2
Colorado	1.2	1.8	1.6	2.4	0.0	3.9	4.2	-
Connecticut	2.1	3.5	3.0	1.8	-	1.9	1.0	-
Delaware	1.7	2.5	1.2	4.6	0.6	42.0	-	-
Florida	4.6	4.4	1.7	1.4	0.6	2.1	1.1	-
Georgia	3.4	5.4	8.9	11.5	2.3	17.2	12.3	-
Hawaii	1.0	2.3	4.0	8.8	-	14.9	25.4	-
Idaho	1.9	2.3	5.7	7.4	0.4	8.1	8.7	2.6
Illinois	3.8	5.2	9.6	18.9	3.3	32.0	34.3	-
Indiana	3.6	4.2	6.8	11.9	1.5	37.4	28.9	0.8
Iowa	3.4	5.0	15.0	24.2	2.5	27.2	29.8	-
Kansas	1.5	2.1	3.3	4.7	2.3	7.4	15.2	-
Kentucky	2.5	5.7	9.1	21.1	2.7	35.7	29.3	-
Louisiana	5.4	5.3	4.2	4.2	3.7	3.7	4.3	-
Maine	0.9	2.1	3.2	0.8	-	2.1	0.1	-
Maryland	2.1	3.5	4.8	9.7	1.4	19.0	13.8	-
Massachusetts	2.3	2.3	2.4	0.4	0.2	2.5	0.0	-
Michigan	1.5	2.0	2.4	3.4	0.1	4.0	2.9	-
Minnesota	2.0	2.1	3.5	3.0	0.7	6.5	16.5	-
Mississippi	4.8	5.5	6.6	9.2	3.6	32.6	38.9	-
Missouri	3.0	5.5	12.7	17.7	5.1	27.2	32.6	-
Montana	-	0.3	1.4	1.9	0.1	2.2	2.6	-
Nebraska	1.7	2.4	6.8	9.9	0.5	11.8	8.9	0.0
Nevada	0.0	0.1	0.0	0.1	0.0	0.1	0.1	-
New Hampshire	1.4	0.9	1.7	0.9	0.1	0.5	0.8	-
New Jersey	3.7	5.2	8.0	6.8	0.3	3.4	1.5	0.3
New Mexico	0.6	1.2	1.4	1.2	0.3	1.7	1.5	-
North Carolina	2.8	6.3	6.2	10.9	1.4	21.1	7.4	-
New York	2.5	2.4	3.1	4.7	0.9	4.6	0.8	-
North Dakota	-	1.5	2.2	2.6	0.6	4.9	3.6	8.3
Ohio	2.7	3.2	4.2	8.4	1.1	10.4	25.6	-
Oklahoma	1.4	1.9	2.1	3.0	1.1	4.6	3.5	-
Oregon	1.5	2.7	5.6	3.0	0.1	3.6	2.0	-
Pennsylvania	2.8	4.0	5.4	6.7	2.7	10.6	14.1	16.0
Rhode Island	3.2	2.5	1.1	2.9	0.2	0.0	-	-
South Carolina	2.3	3.6	3.7	5.2	0.6	8.7	5.7	-
South Dakota	2.0	2.1	2.7	4.2	0.8	5.5	4.5	-
Tennessee	3.0	6.8	10.2	15.4	3.7	27.4	33.9	-
Texas	1.8	2.5	2.7	3.2	2.1	3.8	2.1	-
Utah	0.5	0.4	0.7	1.1	0.1	1.5	0.9	0.1
Vermont	1.5	1.1	1.0	2.0	0.8	2.1	1.6	0
Virginia	2.1	4.6	7.1	12.0	1.8	13.0	12.6	-
Washington	0.7	2.1	4.3	6.6	0.0	9.5	4.8	0.4
West Virginia	0.7	1.1	1.9	4.4	1.0	5.1	6.5	2.4
Wisconsin	2.4	3.3	4.9	7.6	1.8	6.6	10.3	3.5
Wyoming	1.4	0.5	1.0	1.0	0.1	1.6	1.1	-

Source: 1982 NRI.

Table A4-6.--Estimated annual effects and cumulative net value of 100 years of erosion (under 1982 management conditions) on the nation's productive capacity, by farming region

Farming region	Cropland acres 1/ (1,000)	Annual loss: Productivity (percent)	Annual loss: "Equivalent acres" 2/ (1,000 acres)	Annual loss: Gross product ($1,000) 3/	Cumulative (100-year) net value ($1,000) 3/
		Sheet and rill erosion			
Northeast	17,260	0.000508	2.768	1,736.1	1,020,166.5
Lake States	43,924	0.000073	3.206	634.9	373.072.1
Corn Belt	92,395	0.000283	26.148	5,177.3	3,042,306.9
Northern Plains	93,381	0.000044	4.109	813.5	478,059.2
Appalachia	22,711	0.000370	8.403	1,663.8	977,703.2
Southeast	18,214	0.000103	1.879	372.0	218,603.6
Delta States	21,926	0.000139	3.048	603.4	354,597.2
Southern Plains	44,888	0.000015	0.673	133.3	78,340.6
Mountain	43,294	0.000023	0.996	197.2	115,858.7
Pacific	22,667	0.000193	4.375	866.2	509,012.1
United States (contiguous)	421,000	0.000146	61.604	12,197.7	7,167,720.0
		Wind erosion			
Northeast	17,260	0.000003	0.052	10.3	6,025.0
Lake States	43,924	0.000090	3.953	782.7	459,952.0
Corn Belt	92,395	0.000015	1.386	274.4	161,253.0
Northern Plains	93,381	0.000028	2.615	517.7	304,219.0
Appalachia	22,711	0.000000	0.000	0.0	0.0
Southeast	18,214	0.000000	0.000	0.0	0.0
Delta States	21,926	0.000000	0.000	0.0	0.0
Southern Plains	44,888	0.000109	4,893	968.8	569,275.0
Mountain	43,294	0.000088	3.810	754.4	443,285.0
Pacific	22,667	0.000044	0.997	197.5	116,044.0
United States	421,000	0.000042	17.706	3,505.7	2,060,053.0

1/ 1982 NRI total.
2/ "Equivalent acres" are the number of additional acres needed, after 100 years of erosion, to produce the amount of crops currently produced.
3/ Monetary loss estimates are in constant 1980 dollars. "Gross product loss" is calculated by multiplying the equivalent acres by the national average value of production of the major crops.

Source: EPIC/EPIS.

Table A4-7.--Acreage of cropland in each land capability class and subclass rated according to susceptibility to damage resulting from sheet and rill erosion and from wind erosion

Class and subclass	<2	2-5		5-10		10-15		>15		Total
		Water	Wind	Water	Wind	Water	Wind	Water	Wind	
	(1,000 acres)									
I	13,571.2	7,509.9	4,198.8	530.8	2,746.2	42.9	919.5	27.4	672.4	30,219.1
IIc	2,087.6	215.1	9,430.5	30.0	5,482.9	3.0	441.9	1.9	65.6	17,758.5
IIe	7,443.3	26,212.2	16,232.2	19,227.3	9,348.7	5,884.1	2,497.5	3,640.7	877.1	91,363.1
IIs	4,852.4	3,433.3	2,882.5	789.2	3,918.1	66.2	912.6	19.4	313.3	17,187.0
IIw	33,783.6	18,195.6	7,170.7	3,485.1	1,257.9	432.5	339.0	253.7	33.7	64,951.8
IIIc	403.0	174.6	480.8	58.5	2,482.9	10.6	1,488.9	0.9	64.4	5,164.6
IIIe	3,816.5	7,162.8	5,455.9	13,404.5	18,609.9	8,093.8	6,845.9	14,620.1	4,710.9	82,720.3
IIIs	4,473.6	1,512.8	2,982.8	520.1	1,893.1	168.3	389.5	91.5	466.4	12,498.1
IIIw	13,868.1	12,416.4	3,108.3	1,854.2	994.0	355.2	335.0	262.6	97.9	33,291.7
IVc	137.6	31.5	82.4	15.6	186.0	2.6	9.8	1.5	3.4	470.4
IVe	1,632.3	1,368.9	991.0	3,297.3	4,279.3	2,678.7	3,896.2	9,179.7	5,156.1	32,479.2
IVs	2,013.5	780.1	1,535.5	472.8	796.3	182.8	402.3	297.4	341.2	6,821.9
IVw	2,754.8	1,866.1	1,194.2	263.8	601.9	71.0	220.7	148.6	70.2	7,191.3
V	1,058.1	582.4	324.4	81.5	202.7	5.6	61.4	19.6	20.6	2,356.7
VIc	41.7	16.6	26.4	5.3	31.9	0.0	53.6	0.0	18.2	193.7
VIe	384.5	362.0	225.2	673.1	822.7	634.3	1,039.7	4,110.8	1,676.3	9,928.6
VIs	468.4	247.7	206.9	283.3	410.2	146.1	262.0	373.5.	403.2	2,801.3
VIw	630.0	115.8	132.3	16.1	88.4	1.9	124.5	1.5	70.5	1,181.0
VIIc	24.6	0.0	0.3	0.0	3.3	0.0	21.5	0.0	14.6	64.3
VIIe	54.8	32.0	3.1	50.5	17.2	58.3	40.7	919.6	127.4	1,303.6
VIIs	137.0	136.2	67.6	122.5	65.3	52.5	75.6	322.5	144.0	1,123.2
VIIw	178.7	14.9	56.8	1.3	18.3	0.3	12.6	0.0	15.7	298.6
VIII	8.9	1.3	4.3	1.1	3.6	2.6	0.1	8.5	4.1	34.5
TOTAL	93,824.2	82,388.2	56,793.3	45,183.6	54,260.8	18,893.3	20,390.5	34,301.4	15,367.2	421,402.5

Source: 1982 National Resources Inventory.

Rating of susceptibility to damage is based on the higher of the two ratings. For example, on the land assigned to the second group (index of 2 to 5), neither the index for sheet and rill erosion nor that for wind erosion is greater than 5. If the index for sheet and rill erosion (RKLS) is greater than the index for wind erosion (CI), the acreage is in the column headed water; if the CI index is greater, the acreage is included in the column headed wind.

Table A4-7a.--1982 cropland, by EI category and state

Region and state	EI <5	5-8	8-15	>15	Total
	(1,000 acres)				
NORTHEAST					
Connecticut	137.7	37.1	27.4	42.5	244.7
Delaware	419.1	77.4	12.3	10.3	519.1
Maine	520.2	184.4	160.1	88.7	953.4
Maryland	932.6	220.3	268.8	372.7	1,794.4
Massachusetts	167.7	28.3	36.4	64.8	297.2
New Hampshire	104.2	18.5	14.3	20.8	157.8
New Jersey	484.1	110.9	90.1	124.3	809.4
New York	3,082.5	835.3	898.6	1,095.7	5,912.1
Pennsylvania	1,234.4	881.1	1,338.2	2,442.6	5,896.3
Rhode Island	13.8	9.5	2.5	1.4	27.2
Vermont	358.3	94.0	102.3	93.8	648.4
Subtotal	7,454.6	2,496.8	2,951.0	4,357.6	17,251.0
LAKE STATES					
Michigan	8,238.9	586.4	424.5	193.3	9,443.1
Minnesota	19,360.1	2,027.9	1,113.1	523.0	23,024.1
Wisconsin	6,592.0	1,443.0	1,397.5	2,024.3	11,456.8
Subtotal	34,191.0	4,057.3	2,935.1	2,720.6	43,924.0
CORN BELT					
Illinois	18,154.9	2,463.7	2,175.7	1,933.1	24,727.4
Indiana	10,263.0	1,315.1	1,031.6	1,171.6	13,781.3
Iowa	15,666.0	2,559.9	3,221.3	4,993.5	26,440.7
Missouri	7,018.9	1,680.6	2,527.4	3,771.5	14,998.4
Ohio	8,668.5	1,430.9	1,037.8	1,309.9	12,447.1
Subtotal	59,791.3	9,450.2	9,993.8	13,179.6	92,394.9
NORTHERN PLAINS					
Kansas	6,101.6	12,422.1	7,789.7	2,804.9	29,118.3
Nebraska	10,051.0	3,593.5	4,167.0	2,465.2	20,276.7
North Dakota	20,481.4	4,286.3	1,958.0	313.5	27,039.2
South Dakota	12,387.5	2,856.3	1,359.7	343.7	16,947.2
Subtotal	49,021.5	23,158.2	15,274.4	5,927.3	93,381.4
APPALACHIA					
Kentucky	1,980.1	813.3	1,033.0	2,107.8	5,934.2
North Carolina	4,202.8	774.8	812.5	904.7	6,694.8
Tennessee	2,319.1	759.9	1,183.4	1,329.7	5,592.1
Virginia	1,248.0	536.0	581.7	1,031.2	3,396.9
West Virginia	413.3	73.9	134.3	471.6	1,093.1
Subtotal	10,163.3	2,957.9	3,744.9	5,845.0	22,711.1
SOUTHEAST					
Alabama	2,150.1	953.4	895.8	511.0	4,510.3
Florida	3,170.0	184.3	139.2	63.3	3,556.8
Georgia	4,710.3	775.0	610.4	472.7	6,568.4
South Carolina	2,860.6	248.4	298.0	171.7	3,578.7
Subtotal	12,891.0	1,961.1	1,943.4	1,218.7	18,214.2
DELTA STATES					
Arkansas	6,565.8	811.1	475.5	249.1	8,101.5
Louisiana	5,694.4	426.4	186.6	101.5	6,408.9
Mississippi	4,849.2	780.0	644.7	1,141.4	7,415.3
Subtotal	17,109.4	2,017.5	1,306.8	1,492.0	21,925.7
SOUTHERN PLAINS					
Oklahoma	4,501.0	2,367.9	3,120.2	1,579.0	11,568.1
Texas	9,939.3	9,477.3	8,941.7	4,961.3	33,319.6
Subtotal	14,440.3	11,845.2	12,061.9	6,540.3	44,887.7

Table A4-7a continued--1982 cropland, by EI category and state

Region and state	EI <5	5-8	8-15	>15	Total
	(1,000 acres)				
MOUNTAIN					
Arizona	46.0	56.8	354.4	749.1	1,206.3
Colorado	1,517.0	2,960.9	4,053.0	2,071.8	10,602.7
Idaho	2,514.1	1,226.5	1,843.5	806.0	6,390.1
Montana	3,139.3	4,499.5	7,367.6	2,190.5	17,196.9
Nevada	764.7	19.1	30.5	45.4	859.7
New Mexico	244.5	575.2	873.3	719.7	2,412.7
Utah	1,316.2	107.5	510.5	104.5	2,038.7
Wyoming	2,276.7	136.2	115.1	59.4	2,587.4
Subtotal	11,818.5	9,581.7	15,147.9	6,746.4	43,294.5
PACIFIC					
California	9,117.3	644.0	320.3	436.1	10,517.7
Oregon	2,856.4	531.0	759.3	209.7	4,356.4
Washington	3,906.2	1,491.1	1,720.2	675.9	7,793.4
Subtotal	15,879.9	2,666.1	2,799.8	1,321.7	22,667.5
OTHER					
Hawaii	143.3	59.3	71.8	58.8	333.2
Caribbean	121.6	29.9	16.2	240.6	408.3
Subtotal	264.9	89.2	88.0	299.4	741.5
TOTAL	233,005.7	70,481.2	68,247.0	49,668.6	421,402.5

Source: 1982 NRI.

Table A4-8.--Nonfederal cropland: susceptibility to damage resulting from sheet and rill erosion compared with susceptibility to damage resulting from wind erosion

	CI/T					
	<2	2-5	5-10	10-15	>15	Total
	(million acres)					
RKLS/T						
<2	93.9	47.0	41.0	15.3	10.3	207.5
2-5	77.2	14.9	11.7	3.6	3.0	110.4
5-10	39.4	4.6	2.8	1.3	1.2	49.3
10-15	17.0	1.0	0.7	0.3	0.4	19.4
>15	31.8	1.6	0.5	0.2	0.4	34.5
Total	259.3	69.1	56.7	20.7	15.3	421.1

Source: 1982 NRI.

Table A4-9.--Susceptibility to damage resulting from sheet and rill erosion on cropland, by state

State	RKLS/T <2	2-5	5-10	10-15	>15	Total
	(1,000 acres)					
Alabama	395	1,738	1,396	474	507	4,510
Arizona	1,203	4	0	0	0	1,206
Arkansas	1,580	4,959	1,083	233	247	8,102
California	9,554	382	184	83	314	10,518
Colorado	8,423	1,699	376	57	48	10,603
Connecticut	47	90	51	17	40	245
Delaware	340	127	35	7	10	519
Florida	2,446	733	244	73	62	3,557
Georgia	1,702	3,003	1,046	351	468	6,568
Hawaii	62	82	84	47	59	333
Idaho	2,640	1,626	1,418	375	331	6,390
Illinois	10,322	7,807	3,406	1,270	1,923	24,727
Indiana	6,164	4,073	1,790	594	1,160	13,781
Iowa	8,796	6,893	3,730	2,849	4,973	26,441
Kansas	12,590	9,761	4,638	1,182	947	29,118
Kentucky	734	1,235	1,213	648	2,105	5,934
Louisiana	1,440	4,243	519	103	99	6,409
Maine	221	299	255	90	88	953
Maryland	352	579	329	165	370	1,794
Massachusetts	76	91	46	20	64	297
Michigan	6,433	1,803	809	211	187	9,443
Minnesota	16,870	3,667	1,513	462	513	23,084
Mississippi	1,352	3,486	1,050	388	1,138	7,415
Missouri	4,274	2,722	2,649	1,610	3,744	14,998
Montana	13,156	2,809	906	191	135	17,197
Nebraska	10,645	4,339	2,104	1,219	1,971	20,277
Nevada	858	1	1	0	0	860
New Hampshire	58	46	23	10	21	158
New Jersey	182	304	150	51	123	809
New Mexico	1,194	152	56	9	3	2,413
New York	1,387	1,679	1,219	549	1,079	5,912
North Carolina	2,519	1,668	1,124	484	900	6,695
North Dakota	21,675	3,917	1,132	162	153	27,039
Ohio	5,245	3,401	1,909	583	1,309	12,447
Oklahoma	5,845	4,100	1,857	348	218	11,568
Oregon	2,125	1,095	645	311	181	4,356
Pennsylvania	283	928	1,413	853	2,420	5,896
Rhode Island	3	11	10	2	1	27
South Carolina	2,124	729	385	168	172	3,579
South Dakota	11,258	3,863	1,350	272	204	16,947
Tennessee	545	1,763	1,195	769	1,320	5,592
Texas	21,941	7,986	2,518	528	346	33,320
Utah	1,517	383	104	17	17	2,039
Vermont	166	191	149	50	92	648
Virginia	437	793	770	378	1,019	3,379
Washington	3,443	1,611	1,437	824	479	7,793
West Virginia	220	191	134	79	470	1,093
Wisconsin	3,492	3,209	1,875	868	2,013	11,457
Wyoming	2,148	300	108	14	18	2,587
Caribbean	48	73	37	9	241	408
TOTAL	210,530	106,644	50,475	20,057	34,302	421,441

Source: 1982 NRI.

Table A4-10.--Susceptibility to damage resulting from wind erosion on cropland, by state

State	CI/T <2	2-5	5-10	10-15	>15	Total
	(1,000 acres)					
Alabama	4,510.3	0.0	0.0	0.0	0.0	4,510.3
Arizona	9.3	36.7	251.1	160.1	749.1	1,206.3
Arkansas	8,101.5	0.0	0.0	0.0	0.0	8,101.5
California	9,184.5	511.4	671.5	28.5	121.8	10,517.7
Colorado	1,014.6	600.9	4,215.5	2,734.2	2,037.5	10,602.7
Connecticut	244.7	0.0	0.0	0.0	0.0	244.7
Delaware	257.3	212.8	47.8	1.2	0.0	519.1
Florida	2,727.0	814.2	14.3	0.0	1.3	3,556.8
Georgia	6,568.4	0.0	0.0	0.0	0.0	6,568.4
Hawaii	333.2	0.0	0.0	0.0	0.0	333.2
Idaho	3,799.9	237.3	1,513.1	353.1	486.6	6,390.1
Illinois	24,727.4	0.0	0.0	0.0	0.0	24,727.4
Indiana	13,447.9	328.1	5.3	0.0	0.0	13,781.3
Iowa	22,269.5	4,099.9	26.6	44.7	0.0	26,440.7
Kansas	7,534.2	3,869.8	12,612.3	3,217.9	1,884.1	29,118.3
Kentucky	5,934.2	0.0	0.0	0.0	0.0	5,934.2
Louisiana	6,408.9	0.0	0.0	0.0	0.0	6,408.9
Maine	9,53.4	0.0	0.0	0.0	0.0	9,53.4
Maryland	1,674.1	116.0	4.3	0.0	0.0	1,794.4
Massachusetts	297.2	0.0	0.0	0.0	0.0	297.2
Michigan	8,714.1	715.1	12.7	1.2	0.0	9,443.1
Minnesota	12,966.1	8,794.3	1,033.1	230.2	0.4	23,024.1
Mississippi	7,415.3	0.0	0.0	0.0	0.0	7,415.3
Missouri	14,998.4	0.0	0.0	0.0	0.0	14,998.4
Montana	3,076.3	323.9	7,979.2	3,682.2	2,134.8	17,196.9
Nebraska	6,817.0	7,908.2	4,143.5	923.7	484.3	20,276.7
Nevada	718.7	46.5	32.2	16.9	45.4	859.7
New Hampshire	157.8	0.0	0.0	0.0	0.0	157.8
New Jersey	738.6	66.5	4.3	0.0	0.0	809.4
New Mexico	33.4	214.4	886.9	558.8	719.2	2,412.7
New York	5,912.1	0.0	0.0	0.0	0.0	5,912.1
North Carolina	6,694.8	0.0	0.0	0.0	0.0	6,694.8
North Dakota	2,639.2	18,558.1	5,303.7	305.8	232.4	27,039.2
Ohio	12,215.3	230.8	1.0	0.0	0.0	12,447.1
Oklahoma	2,494.1	3,497.9	2,263.4	1,849.9	1,462.8	11,568.1
Oregon	2,493.2	1,008.1	711.4	114.5	29.2	4,356.4
Pennsylvania	5,896.3	0.0	0.0	0.0	0.0	5,896.3
Rhode Island	27.2	0.0	0.0	0.0	0.0	27.2
South Carolina	3,578.7	0.0	0.0	0.0	0.0	3,578.7
South Dakota	2,818.9	10,636.1	3,141.4	173.0	177.8	16,947.2
Tennessee	5,592.1	0.0	0.0	0.0	0.0	5,592.1
Texas	8,727.8	3,609.0	10,435.0	5,890.1	4,657.7	33,319.6
Utah	1,445.5	2.5	360.3	143.3	87.1	2,038.7
Vermont	648.4	0.0	0.0	0.0	0.0	648.4
Virginia	3,322.5	71.5	1.5	0.0	1.5	3,396.9
Washington	5,020.3	1,522.1	796.9	257.7	196.4	7,793.4
West Virginia	1,093.1	0.0	0.0	0.0	0.0	1,093.1
Wisconsin	10,278.4	1,037.2	133.8	0.0	7.4	11,456.8
Wyoming	2,319.8	70.9	110.2	44.1	42.4	2,587.4
Caribbean	408.3	0.0	0.0	0.0	0.0	408.3
TOTAL	259,259.2	69,140.2	56,712.2	20,731.7	15,559.2	421,402.5

Source: 1982 NRI.

Table A4-11.--Nonfederal pastureland eroding at rates greater than T

Farming region and state	Pastureland (1,000 acres)	Acres eroding in excess of T			
		Sheet & rill		Wind	
		(1,000 acres)	Percent	(1,000 acres)	Percent
NORTHEAST					
Connecticut	114.0	0.0	*	0.0	*
Delaware	35.2	1.3	4	0.0	*
Maine	569.0	8.5	2	0.0	*
Maryland	534.1	42.1	8	0.0	*
Massachusetts	201.6	1.2	*	0.0	*
New Hampshire	124.5	6.7	5	0.0	*
New Jersey	239.6	8.1	3	0.0	*
New York	3,871.8	96.4	3	0.0	*
Pennsylvania	2,592.6	224.1	9	0.0	*
Rhode Island	35.9	0.0	*	0.0	*
Vermont	500.7	9.7	2	0.0	*
Subtotal	8,818.9	398.1		0.0	
Regional average			5		*
LAKE STATES					
Michigan	2,911.0	33.2	1	8.8	*
Minnesota	3,589.8	65.0	2	0.0	*
Wisconsin	3,394.2	186.6	6	0.0	*
Subtotal	9,894.9	284.8		8.8	
Regional average			3		*
CORN BELT					
Illinois	3,157.3	469.0	15	0.0	*
Indiana	2,211.9	347.2	16	0.0	*
Iowa	4,536.1	394.2	9	1.5	*
Missouri	12,572.9	2,273.6	18	0.0	*
Ohio	2,713.9	556.3	21	0.0	*
Subtotal	25,192.1	4,040.3		1.5	
Regional average			16		*
NORTHERN PLAINS					
Kansas	2,240.9	202.5	9	0.0	*
Nebraska	2,125.3	199.0	9	5.0	*
North Dakota	1,271.9	21.9	2	1.3	*
South Dakota	2,703.0	18.1	*	0.0	*
Subtotal	8,341.1	441.5		6.3	
Regional average			5		*
APPALACHIA					
Kentucky	5,879.8	1,055.7	18	0.0	*
North Carolina	1,980.2	202.8	10	0.0	*
Tennessee	5,355.6	462.7	9	0.0	*
Virginia	3,392.0	724.9	21	0.0	*
West Virginia	1,869.1	569.9	31	0.0	*
Subtotal	18,476.6	3,016.0		0.0	
Regional average			16		*
SOUTHEAST					
Alabama	3,816.6	171.4	5	0.0	*
Florida	4,273.2	0.0	*	0.0	*
Georgia	2,976.6	95.1	3	0.0	*
South Carolina	1,208.0	10.8	*	0.0	*
Subtotal	12,274.3	277.3		0.0	
Regional average			2		*
DELTA STATES					
Arkansas	5,793.8	266.4	5	0.0	*
Louisiana	2,368.5	14.9	*	0.0	*
Mississippi	3,975.2	438.3	11	0.0	*
Subtotal	12,137.4	719.6		0.0	
Regional average			6		*
SOUTHERN PLAINS					
Oklahoma	7,137.9	493.9	7	0.0	*
Texas	17,042.7	633.3	4	33.0	*
Subtotal	24,180.6	1,127.2		33.0	
Regional average			5		*

Table A4-11.--Nonfederal pastureland eroding at rates greater than T--continued

Farming region and state	Pastureland (1,000 acres)	Acres eroding in excess of T			
		Sheet & rill		Wind	
		(1,000 acres)	Percent	(1,000 acres)	Percent
MOUNTAIN					
Arizona	79.3	0.0	*	0.4	*
Colorado	1,259.7	23.4	2	46.1	4
Idaho	1,274.2	40.1	3	2.5	*
Montana	3,036.0	36.3	1	5.5	*
Nevada	304.4	0.0	*	0.9	*
New Mexico	163.3	1.0	*	3.7	2
Utah	490.3	0.0	*	25.8	5
Wyoming	754.8	22.1	3	0.7	*
Subtotal	7,360.0	122.9		85.6	
Regional average			2		1
PACIFIC					
California	1,392.5	36.2	3	12.2	*
Oregon	1,965.9	147.4	8	18.6	*
Washington	1,344.6	20.7	2	3.2	*
Subtotal	4,703.0	204.3		34.0	
Regional average			4		*
OTHER					
Hawaii	974.0	255.0	26	0.0	*
Puerto Rico	955.0	466.4	49	0.0	*
Subtotal	1,929.0	721.4		0.0	
Average			38		*
TOTAL	133,310.5	11,353.3	9	169.2	*

* = less than 1 percent.

Source: 1982 NRI.

Table A4-12.--Nonfederal forest land eroding at rates greater than T

Farming region and state	Forest land (1,000 acres)	Acres eroding in excess of T			
		Sheet & rill		Wind	
		(1,000 acres)	Percent	(1,000 acres)	Percent
NORTHEAST					
Connecticut	1,828.3	4.6	*	0.0	*
Delaware	347.6	0.7	*	0.0	*
Maine	16,770.2	100.0	*	0.0	*
Maryland	2,425.3	17.6	*	0.0	*
Massachusetts	2,970.1	6.5	*	0.0	*
New Hampshire	4,085.1	18.2	*	0.0	*
New Jersey	1,848.4	60.6	3	0.0	*
New York	16,516.8	65.8	*	0.0	*
Pennsylvania	15,300.2	435.5	3	0.0	*
Rhode Island	405.5	0.4	*	0.0	*
Vermont	4,086.5	30.3	*	0.0	*
Subtotal	66,584.2	740.2		0.0	
Regional average			1		*
LAKE STATES					
Michigan	15,359.6	97.7	*	1.6	*
Minnesota	13,956.2	139.3	1	0.0	*
Wisconsin	13,392.7	243.5	2	0.0	*
Subtotal	42,708.7	480.5		1.6	
Regional average			1		*
CORN BELT					
Illinois	3,429.4	395.0	12	0.0	*
Indiana	3,639.9	130.1	4	0.0	*
Iowa	1,756.2	232.8	13	0.0	*
Missouri	10,985.5	1,511.5	14	0.0	*
Ohio	6,380.2	773.4	12	0.0	*
Subtotal	26,191.2	3,042.8		0.0	
Regional average			12		*
NORTHERN PLAINS					
Kansas	626.2	80.0	13	0.0	*
Nebraska	732.1	123.4	17	0.0	*
North Dakota	438.2	2.6	*	0.0	*
South Dakota	561.6	48.8	9	0.0	*
Subtotal	2,358.1	254.8		0.0	*
Regional average			11		*
APPALACHIA					
Kentucky	10,158.1	936.1	9	0.0	*
North Carolina	16,728.4	167.9	1	0.0	*
Tennessee	11,529.0	325.8	3	0.0	*
Virginia	13,625.2	784.1	6	0.0	*
West Virginia	10,422.4	1,080.3	10	0.0	*
Subtotal	62,463.5	3,294.2		0.0	
Regional average			5		*
SOUTHEAST					
Alabama	20,633.2	504.2	2	0.0	*
Florida	12,430.0	15.2	*	0.0	*
Georgia	21,883.5	232.3	1	0.0	*
South Carolina	11,025.4	98.1	*	0.0	*
Subtotal	65,972.4	849.8		0.0	
Regional average	131,944.5	1,699.6	1	0.0	*
DELTA STATES					
Arkansas	14,339.7	199.0	1	0.0	*
Louisiana	12,894.9	56.3	*	0.0	*
Mississippi	15,242.6	605.1	4	0.0	*
Subtotal	142,477.4	860.4		0.0	
Regional average			2		*
SOUTHERN PLAINS					
Oklahoma	6,538.7	708.1	11	0.0	*
Texas	9,323.6	416.0	5	0.0	*
Subtotal	15,862.2	1,124.1		0.0	
Regional average			7		*

Table A4-12.--Nonfederal forest land eroding at rates greater than T--continued

Farming region and state	Forest land (1,000 acres)	Acres eroding in excess of T			
		Sheet & rill		Wind	
		(1,000 acres)	Percent	(1,000 acres)	Percent
MOUNTAIN					
Arizona	4,760.2	250.7	5	54.4	1
Colorado	4,030.1	1,261.4	31	26.7	*
Idaho	3,977.1	24.7	*	0.0	*
Montana	5,228.0	495.4	10	0.0	*
Nevada	356.6	130.8	37	0.0	*
New Mexico	4,733.9	1,210.2	26	123.2	3
Utah	3,234.6	1,480.0	46	127.9	4
Wyoming	987.1	254.0	26	0.0	*
Subtotal	27,307.5	5,107.2		332.2	
Regional average			19		1
PACIFIC					
California	15,217.7	4,405.9	29	0.0	*
Oregon	11,889.2	2,003.5	17	0.0	*
Washington	12,690.2	216.0	2	0.0	*
Subtotal	39,797.2	6,625.4		0.0	
Regional average			17		*
OTHER					
Hawaii	1,473.5	333.7	23	0.0	*
Puerto Rico	516.6	413.8	80	0.0	*
Subtotal	1,990.1	747.5		0.0	
Average			38		*
TOTAL	393,713.3	23,126.8	6	333.8	1

* = less than 1 percent.

Source: 1982 NRI.

Table A4-13.--Annual sheet and rill erosion on pastureland, and the amount of erosion in excess of T, by erosion interval, 1982

Erosion interval (tons/acre)	Total acres (millions)	Cumulative percentage of acreage	Sheet & rill erosion (million tons)	Cumulative percentage of erosion	Erosion in excess of T (million tons)	Cumulative percentage of erosion in excess of T
>T+20	1.0	0.7	41.9	23.3	38.7	46.3
T+19 to T+20	0.1	0.8	1.7	24.2	1.4	48.0
T+18 to T+19	0.1	0.8	1.4	25.0	1.2	49.4
T+17 to T+18	0.1	0.9	2.1	26.2	1.8	51.5
T+16 to T+17	0.1	1.0	1.8	27.2	1.5	53.3
T+15 to T+16	0.1	1.0	1.9	28.2	1.5	55.2
T+14 to T+15	0.1	1.1	1.7	29.2	1.3	56.8
T+13 to T+14	0.2	1.2	2.6	30.6	2.0	59.2
T+12 to T+13	0.2	1.4	2.5	31.9	2.0	61.6
T+11 to T+12	0.2	1.5	2.4	33.3	1.8	63.8
T+10 to T+11	0.2	1.6	3.0	34.9	2.2	66.4
T+9 to T+10	0.3	1.9	4.4	37.4	3.2	70.[illegible]
T+8 to T+9	0.3	2.1	3.8	39.5	2.7	73.5
T+7 to T+8	0.4	2.4	4.5	42.0	3.1	77.2
T+6 to T+7	0.5	2.8	4.6	44.5	3.0	80.7
T+5 to T+6	0.6	3.2	5.0	47.3	3.2	84.5
T+4 to T+5	0.7	3.7	5.4	50.3	3.1	88.2
T+3 to T+4	0.9	4.4	6.2	53.7	3.2	92.1
T+2 to T+3	1.2	5.3	6.9	57.5	3.0	95.6
T+1 to T+2	1.7	6.6	7.6	61.8	2.4	98.5
T to T+1	2.7	8.6	9.1	66.9	1.2	100.0
<T	121.8	100.0	59.7	100.0	0.0	100.0
Total	133.3		180.1		83.7	

Source: 1982 NRI.

Table A4-14.--Annual sheet and rill erosion on forest land, and the amount of erosion in excess of T, by erosion interval, 1982

Erosion interval (tons/acre)	Total acres (millions)	Cumulative percentage of acreage	Sheet & rill erosion (million tons)	Cumulative percentage of erosion	Erosion in excess of T (million tons)	Cumulative percentage of erosion in excess of T
>T+20	2.8	0.7	139.0	37.6	131.8	61.0
T+19 to T+20	0.2	0.8	3.5	38.5	3.1	62.4
T+18 to T+19	0.2	0.8	3.2	39.4	2.8	63.7
T+17 to T+18	0.2	0.9	5.0	40.7	4.2	65.7
T+16 to T+17	0.2	0.9	4.1	41.8	3.5	67.3
T+15 to T+16	0.3	1.0	4.6	43.1	3.9	69.2
T+14 to T+15	0.3	1.1	5.4	44.5	4.6	71.3
T+13 to T+14	0.3	1.1	4.3	45.7	3.7	73.0
T+12 to T+13	0.3	1.2	4.4	46.9	3.7	74.7
T+11 to T+12	0.3	1.3	4.5	48.1	3.7	76.4
T+10 to T+11	0.4	1.4	5.2	49.5	4.2	78.3
T+9 to T+10	0.4	1.5	4.6	50.7	3.6	80.0
T+8 to T+9	0.7	1.7	7.4	52.7	5.7	82.6
T+7 to T+8	0.7	1.8	6.4	54.5	4.9	84.9
T+6 to T+7	0.7	2.0	6.4	56.2	4.6	87.0
T+5 to T+6	0.9	2.2	7.0	58.1	4.8	89.2
T+4 to T+5	1.1	2.5	7.8	60.2	5.0	91.5
T+3 to T+4	1.6	2.9	9.6	62.8	5.5	94.1
T+2 to T+3	2.2	3.5	10.5	65.6	5.4	96.6
T+1 to T+2	3.2	4.3	12.1	68.9	4.6	98.7
T to T+1	8.8	6.5	16.3	73.3	2.8	100.0
<T	368.1	100.0	98.8	100.0	0.0	100.0
Total	393.7		370.0		216.1	

Source: 1982 NRI.

Table A4-15.--Annual sheet and rill erosion on rangeland, and the amount of erosion in excess of T, by erosion interval, 1982

Erosion interval (tons/acre)	Total acres (millions)	Cumulative percentage of acreage	Sheet & rill erosion (million tons)	Cumulative percentage of erosion	Erosion in excess of T (million tons)	Cumulative percentage of erosion in excess of T
>T+20	3.0	0.7	122.8	21.9	117.4	41.0
T+19 to T+20	0.2	0.7	4.2	22.6	3.8	42.4
T+18 to T+19	0.2	0.8	4.8	23.5	4.4	43.9
T+17 to T+18	0.3	0.9	5.8	24.5	5.2	45.7
T+16 to T+17	0.4	1.0	7.4	25.8	6.5	48.0
T+15 to T+16	0.3	1.0	4.9	26.7	4.3	49.5
T+14 to T+15	0.5	1.2	8.7	28.2	7.7	52.2
T+13 to T+14	0.5	1.3	8.3	29.7	7.3	54.8
T+12 to T+13	0.6	1.4	9.1	31.3	8.0	57.6
T+11 to T+12	0.8	1.6	10.2	33.1	8.8	60.6
T+10 to T+11	0.7	1.8	9.0	34.8	7.5	63.3
T+9 to T+10	0.9	2.0	10.2	36.6	8.4	66.2
T+8 to T+9	1.1	2.3	11.8	38.7	9.4	69.5
T+7 to T+8	1.3	2.6	12.0	40.8	9.4	72.8
T+6 to T+7	1.6	2.9	13.4	43.2	10.3	76.4
T+5 to T+6	2.1	3.5	15.8	46.0	11.7	80.5
T+4 to T+5	2.5	4.0	16.0	48.8	11.0	84.3
T+3 to T+4	3.6	4.9	19.7	52.3	12.6	88.8
T+2 to T+3	5.4	6.2	23.5	56.5	13.2	93.4
T+1 to T+2	8.4	8.2	27.1	61.4	12.1	97.6
T to T+1	18.4	12.5	34.5	67.5	6.9	100.0
<T	353.1	100.0	182.5	100.0	0.0	100.0
Total	405.9		561.7		285.9	

Source: 1982 NRI.

Table A4-16.--Wind erosion on rangeland, and the amount of erosion in excess of T, by erosion interval, 1982

Erosion interval (tons/acre)	Total acres (millions)	Cumulative percentage of acreage	Wind erosion (million tons)	Cumulative percentage of erosion	Erosion in excess of T (million tons)	Cumulative percentage of erosion in excess of T
>T+20	6.3	1.5	453.8	74.5	427.4	83.1
T+19 to T+20	0.3	1.6	6.3	75.5	5.3	84.1
T+18 to T+19	0.3	1.6	7.5	76.7	6.3	85.3
T+17 to T+18	0.3	1.7	5.8	77.7	4.8	86.3
T+16 to T+17	0.5	1.8	10.7	79.4	8.6	87.9
T+15 to T+16	0.3	1.9	5.5	80.3	4.3	88.8
T+14 to T+15	0.4	2.0	7.7	81.6	6.0	90.0
T+13 to T+14	0.3	2.1	5.2	82.4	4.0	90.7
T+12 to T+13	0.3	2.1	5.2	83.3	4.2	91.5
T+11 to T+12	0.4	2.2	5.6	84.2	4.1	92.4
T+10 to T+11	0.3	2.3	4.4	84.9	3.2	93.0
T+9 to T+10	0.5	2.4	6.3	85.9	4.7	93.9
T+8 to T+9	0.7	2.6	8.3	87.3	6.2	95.1
T+7 to T+8	0.6	2.7	6.1	88.3	4.1	95.9
T+6 to T+7	0.8	2.9	7.7	89.6	4.9	96.8
T+5 to T+6	0.8	3.1	6.9	90.7	4.4	97.7
T+4 to T+5	0.6	3.2	5.1	91.5	2.9	98.2
T+3 to T+4	0.7	3.4	4.3	92.2	2.3	98.7
T+2 to T+3	1.4	3.7	7.3	93.4	3.4	99.4
T+1 to T+2	1.6	4.1	6.7	94.5	2.3	99.8
T to T+1	4.4	5.1	6.9	95.7	1.0	100.0
<T	384.2	100.0	26.3	100.0	0.0	100.0
Total	405.9		609.5		514.4	

Source: 1982 NRI.

Table A4-17.--Percentage of productivity lost due to sheet and rill erosion, under 1982 management, by state portion of land resource region (LRR): 100th-year estimate

State	LRR 1/	Loss (percent)	State	LRR 1/	Loss (percent)	State	LRR 1/	Loss (percent)
Alabama	N	6.8	Maryland	T	0.3	Oregon	A	6.1
Alabama	P	1.5	Maryland	T	0.3	Oregon	B	1.4
Alabama	T	1.1	Massachusetts	R	2.2	Oregon	D	0.3
Arkansas	N	5.6	Michigan	L	1.1	Pennsylvania	L	3.2
Arkansas	O	0.5	Michigan	M	4.1	Pennsylvania	N	4.7
Arkansas	P	5.5	Minnesota	K	1.1	Pennsylvania	R	9.9
California	A	57.7	Minnesota	M	1.4	Pennsylvania	S	5.5
California	C	17.7	Mississippi	O	0.6	Rhode Island	R	2.0
Colorado	D	0.2	Mississippi	P	6.5	South Carolina	N	4.5
Connecticut	R	2.9	Missouri	M	5.1	South Carolina	P	1.4
Delaware	S	1.0	Missouri	N	2.6	South Carolina	T	0.1
Delaware	T	0.4	Missouri	O	2.7	South Dakota	F	0.2
Florida	P	0.9	Missouri	P	10.5	South Dakota	G	4.9
Georgia	N	21.6	Montana	E	1.2	South Dakota	M	0.9
Georgia	P	1.1	Nebraska	H	1.0	Tennessee	N	7.1
Georgia	T	0.8	Nebraska	M	3.8	Tennessee	O	6.5
Idaho	B	2.1	New Hampshire	R	0.8	Tennessee	P	6.2
Idaho	E	5.2	New Jersey	L	11.1	Texas	J	1.5
Illinois	L	4.8	New Jersey	S	5.2	Texas	P	1.0
Illinois	M	5.1	New York	L	13.4	Utah	E	11.7
Indiana	L	1.9	New York	R	5.1	Vermont	R	1.3
Indiana	M	8.0	New York	S	11.1	Virginia	N	13.0
Indiana	N	14.9	North Carolina	N	10.9	Virginia	P	0.7
Iowa	M	3.8	North Carolina	P	3.2	Virginia	S	12.7
Kansas	H	0.2	North Carolina	T	0.3	Virginia	T	3.8
Kansas	M	1.4	North Dakota	F	0.1	Washington	A	5.5
Kentucky	N	10.9	North Dakota	G	1.0	Washington	B	2.8
Kentucky	O	4.9	Ohio	L	4.9	Washington	E	1.3
Kentucky	P	8.2	Ohio	M	5.4	West Virginia	N	5.2
Louisiana	O	1.9	Ohio	N	6.3	West Virginia	S	0.2
Louisiana	P	3.8	Ohio	R	6.0	Wisconsin	K	0.1
Louisiana	T	1.3	Oklahoma	J	0.9	Wisconsin	L	2.1
Maine	R	4.8	Oklahoma	M	0.6	Wisconsin	M	1.3
Maryland	N	6.7	Oklahoma	H	0.1			
Maryland	S	11.1	Oklahoma	N	0.4			

1/ Only those portions of land resource regions which experienced a loss in crop productivity are displayed.

Source: EPIC/EPIS estimates.

Table A4-18.--"Equivalent acres" required to compensate for productivity lost through sheet and rill erosion (1982 management), by state portion of land resource region (LRR): 100th-year estimate

State	LRR 1/	Loss 2/ (1,000 acres)	State	LRR 1/	Loss 2/ (1,000 acres)	State	LRR 1/	Loss 2/ (1,000 acres)
Alabama	N	62.9	Maryland	N	4.8	Oklahoma	N	0.3
Alabama	P	29.4	Maryland	S	76.2	Oregon	A	27.1
Alabama	T	0.1	Maryland	T	1.3	Oregon	B	21.9
Arkansas	N	13.1	Massachusetts	R	3.8	Oregon	D	0.3
Arkansas	O	1.5	Michigan	L	32.7	Pennsylvania	L	0.6
Arkansas	P	32.8	Michigan	M	14.6	Pennsylvania	N	47.3
California	A	12.7	Minnesota	K	21.2	Pennsylvania	R	251.3
California	C	222.5	Minnesota	M	81.8	Pennsylvania	S	33.5
Colorado	D	0.4	Mississippi	O	0.6	Rhode Island	R	0.2
Colorado	H	0.1	Mississippi	P	107.9	South Carolina	N	0.4
Connecticut	R	4.1	Missouri	M	380.3	South Carolina	P	11.7
Delaware	S	0.6	Missouri	N	25.6	South Carolina	T	0.1
Delaware	T	0.4	Missouri	O	1.4	South Dakota	F	3.4
Florida	P	2.8	Missouri	P	5.2	South Dakota	G	44.3
Florida	U	0.1	Montana	E	10.7	South Dakota	M	20.2
Georgia	N	17.5	Nebraska	H	50.3	Tennessee	N	105.8
Georgia	P	34.7	Nebraska	M	196.0	Tennessee	O	0.3
Georgia	T	0.5	New Hampshire	R	0.7	Tennessee	P	83.6
Idaho	B	63.4	New Jersey	L	37.9	Texas	J	44.1
Idaho	E	7.7	New Jersey	S	4.0	Texas	P.	2.1
Illinois	L	42.0	New York	L	181.7	Utah	E	6.1
Illinois	M	525.7	New York	R	78.1	Vermont	R	4.3
Indiana	L	2.3	New York	S	1.0	Virginia	N	43.4
Indiana	M	300.9	North Carolina	N	14.3	Virginia	P	8.9
Indiana	N	86.0	North Carolina	P	74.1	Virginia	S	59.7
Iowa	M	616.8	North Carolina	T	0.5	Virginia	T	2.9
Kansas	H	17.5	North Dakota	F	10.9	Washington	A	3.8
Kansas	M	42.0	North Dakota	G	2.3	Washington	B	133.9
Kentucky	N	329.9	Ohio	L	5.5	Washington	E	1.6
Kentucky	O	0.3	Ohio	M	182.9	West Virginia	N	24.2
Kentucky	P	27.4	Ohio	N	58.1	West Virginia	S	0.4
Louisiana	O	1.1	Ohio	R	63.1	Wisconsin	K	3.4
Louisiana	P	12.8	Oklahoma	H	1.4	Wisconsin	L	70.0
Louisiana	T	0.7	Oklahoma	J	2.3	Wisconsin	M	40.4
Maine	R	27.6	Oklahoma	M	1.1			

1/ Only those portions of land resource regions which experienced a loss in crop productivity are displayed.

2/ "Equivalent acres" are the number of additional acres that would be needed, after 100 years of erosion, to produce the amount of crops currently produced.

Source: EPIC/EPIS estimates.

Table A4-19.--Gross product loss resulting from sheet and rill erosion, 1982 management, by state portion of land resource region (LRR): 100th-year estimate

State	LRR 1/	Loss ($1,000)	State	LRR 1/	Loss ($1,000)	State	LRR 1/	Loss ($1,000)
Alabama	N	12,456	Maryland	N	952	Oklahoma	N	50
Alabama	P	5,811	Maryland	S	15,096	Oregon	A	5,364
Alabama	T	28	Maryland	T	257	Oregon	B	4,328
Arkansas	N	2,596	Massachusetts	R	752	Oregon	D	59
Arkansas	O	295	Michigan	L	6,481	Pennsylvania	L	117
Arkansas	P	6,488	Michigan	M	2,881	Pennsylvania	N	9,367
California	A	2,511	Minnesota	K	4,198	Pennsylvania	R	49,763
California	C	44,055	Minnesota	M	16,202	Pennsylvania	S	6,633
Colorado	D	71	Mississippi	O	127	Rhode Island	R	48
Colorado	H	10	Mississippi	P	21,362	South Carolina	N	69
Connecticut	R	804	Missouri	M	75,305	South Carolina	P	2,315
Delaware	S	121	Missouri	N	5,073	South Carolina	T	12
Delaware	T	73	Missouri	O	281	South Dakota	F	681
Florida	P	550	Missouri	P	1,022	South Dakota	G	8,779
Florida	U	12	Montana	E	2,113	South Dakota	M	4,008
Georgia	N	3,461	Nebraska	H	9,951	Tennessee	N	20,954
Georgia	P	6,869	Nebraska	M	38,798	Tennessee	O	65
Georgia	T	97	New Hampshire	R	129	Tennessee	P	16,547
Idaho	B	12,545	New Jersey	L	7,510	Texas	J	8,736
Idaho	E	1,517	New Jersey	S	786	Texas	P	416
Illinois	L	8,320	New York	L	35,979	Texas	T	8
Illinois	M	104,093	New York	R	15,466	Utah	E	1,200
Indiana	L	446	New York	S	194	Vermont	R	845
Indiana	M	59,570	North Carolina	N	2,825	Virginia	N	8,599
Indiana	N	17,024	North Carolina	P	14,676	Virginia	P	1,752
Iowa	M	122,124	North Carolina	T	97	Virginia	S	11,825
Kansas	H	3,459	North Dakota	F	2,156	Virginia	T	574
Kansas	M	8,314	North Dakota	G	453	Washington	A	760
Kentucky	N	65,312	Ohio	L	1,093	Washington	B	26,504
Kentucky	O	59	Ohio	M	36,220	Washington	E	311
Kentucky	P	5,415	Ohio	N	11,498	West Virginia	N	4,784
Louisiana	O	212	Ohio	R	12,484	West Virginia	S	87
Louisiana	P	2,526	Oklahoma	H	279	Wisconsin	K	677
Louisiana	T	147	Oklahoma	J	449	Wisconsin	L	13,862
Maine	R	5,459	Oklahoma	M	220	Wisconsin	M	8,007

1/ Only those portions of land resource regions which experienced a loss in gross product are displayed.

Source: EPIC/EPIS.

Table A4-20.--Percentage of productivity lost due to wind erosion, 1982 erosion rates, by state portion of land resource region (LRR)

State	LRR 1/	Loss (percent)	State	LRR 1/	Loss (percent)
California	D	0.7	North Dakota	G	0.6
Colorado	D	0.3	Oklahoma	H	0.2
Colorado	E	3.4	Oklahoma	J	1.3
Colorado	G	4.1	Oregon	B	0.5
Colorado	H	0.4	Oregon	D	0.4
Idaho	B	1.2	South Dakota	F	0.2
Kansas	H	0.4	South Dakota	G	5.0
Montana	D	0.7	Texas	D	2.9
Montana	E	2.6	Texas	H	4.3
Montana	G	1.1	Texas	I	1.7
Nebraska	G	0.7	Texas	T	0.5
Nevada	D	38.6	Utah	D	0.2
New Mexico	D	1.2	Washington	B	0.6
New Mexico	G	0.1	Wyoming	G	0.2
New Mexico	H	1.1			

1/ Only those state portions of land resource regions which experienced a loss in crop productivity are displayed.

Table A4-21.--Equivalent acres required to compensate for productivity lost through wind erosion, 1982 management, by state portion of land resource region (LRR): 100th-year estimate

State	LRR 1/	Loss (1,000 acres)	State	LRR 1/	Loss (1,000 acres)
California	D	2.7	North Dakota	G	1.5
Colorado	D	1.1	Oklahoma	H	15.5
Colorado	E	10.2	Oklahoma	J	3.6
Colorado	G	111.7	Oregon	B	9.1
Colorado	H	5.4	Oregon	D	0.3
Idaho	B	65.6	South Dakota	F	3.8
Kansas	H	43.1	South Dakota	G	46.2
Montana	E	26.5	Texas	D	2.8
Montana	G	51.8	Texas	H	342.5
Montana	F	30.0	Texas	I	18.0
Nebraska	G	19.0	Texas	J	16.4
Nevada	D	31.2	Texas	T	0.4
New Mexico	D	2.8	Utah	D	0.9
New Mexico	G	0.2	Washington	B	75.6
New Mexico	H	6.6	Wyoming	G	2.6
North Dakota	F	0.6			

1/ Only those state portions of land resource regions which experienced a loss in crop productivity are displayed.

Source: EPIC/EPIS estimates.

Table A4-22.--Gross product loss resulting from wind erosion on cropland classified e or VIs - VIIs - VIII, 1982 management, by state portion of land resource region (LRR): 100th-year estimate

State	LRR 1/	Gross product loss ($1,000)	State	LRR 1/	Gross product loss ($1,000)
California	D	544	North Dakota	G	299
Colorado	D	215	Oklahoma	H	3,074
Colorado	E	2,023	Oklahoma	J	713
Colorado	G	22,113	Oregon	B	1,806
Colorado	H	1,076	Oregon	D	63
Idaho	B	12,980	South Dakota	F	755
Kansas	H	8,533	South Dakota	G	755
Montana	D	5	South Dakota	M	4
Montana	E	5,251	Texas	D	547
Montana	G	10,248	Texas	H	67,806
Nebraska	G	3,769	Texas	I	3,569
Nevada	D	6,187	Texas	T	75
New Mexico	D	562	Utah	D	178
New Mexico	G	34	Washington	B	14,968
New Mexico	H	1,302	Wyoming	G	516
North Dakota	F	126			

1/ Only those state portions of land resource regions which experienced a loss in gross product are displayed.

Source: EPIC/EPIS estimates.

Table A5-1.--Cropland and pastureland soils affected by saline and/or sodic conditions, by aggregated subarea (ASA)

Water resources region	ASA	Sodic soils	Saline, not sodic (conductivity in mmhos/m^3) >8	4-8	2-4	Not affected	Total
		(1,000 acres)					
1	101	0.0	0.0	0.0	0.0	1375.3	1375.3
	102	0.0	0.0	0.0	0.0	299.5	299.5
	103	0.0	0.0	0.0	0.0	343.6	343.6
	104	0.0	0.0	0.0	0.0	304.1	304.1
	105	0.0	0.0	0.0	0.0	782.9	782.9
	106	0.0	0.0	0.0	0.0	1026.0	1026.0
	Total	0.0	0.0	0.0	0.0	4131.4	4131.4
2	201	0.0	0.0	0.0	0.0	2126.9	2126.9
	202	0.0	0.0	0.0	0.0	387.3	387.3
	203	0.0	0.0	0.0	0.0	2763.8	2763.8
	204	0.0	0.0	0.0	0.0	5533.3	5533.3
	205	0.0	0.0	0.0	0.0	4233.0	4234.0
	206	0.0	0.0	0.0	0.0	3166.8	3166.8
	Total	0.0	0.0	0.0	0.0	18212.1	18212.1
3	301	0.0	0.0	0.0	2.8	6579.8	6579.8
	302	0.0	0.0	0.0	0.0	7079.1	7079.1
	303	0.0	0.0	0.0	0.0	4977.4	4982.3
	304	0.0	16.4	0.0	0.0	4470.8	4487.2
	305	0.0	0.0	0.0	9.4	3188.6	3198.0
	306	0.0	0.0	0.0	0.0	4786.6	4786.6
	307	0.0	0.0	0.0	0.0	4613.0	4613.0
	308	0.0	0.0	0.0	0.0	3694.7	3694.7
	309	1.3	0.0	0.0	0.0	3191.4	3191.4
	Total	1.3	21.3	0.0	12.2	42581.4	42616.2
4	401	0.0	0.0	0.0	0.0	979.6	979.6
	402	0.0	0.0	0.0	0.0	3691.7	3691.7
	403	0.0	0.0	0.0	0.0	2813.2	2813.2
	404	0.0	0.0	0.0	0.0	7279.1	7279.1
	405	0.0	0.0	0.0	0.0	3340.1	3340.1
	406	0.0	0.0	0.0	0.0	7229.4	7229.4
	407	0.0	0.0	0.0	0.0	1947.0	1947.0
	408	0.0	0.0	0.0	0.0	4373.0	4373.0
	Total	0.0	0.0	0.0	0.0	31653.1	31653.1
5	501	0.0	0.0	0.0	0.0	2388.6	2388.6
	502	0.0	0.0	0.0	0.0	5179.8	5179.8
	503	0.0	0.0	0.0	0.0	8026.2	8026.2
	504	0.0	0.0	0.0	0.0	1660.8	1660.8
	505	0.0	0.0	0.0	0.0	10703.2	10703.2
	506	30.2	0.0	0.0	0.0	15978.0	16008.2
	Total	30.2	0.0	0.0	0.0	48265.1	48295.3
6	601	0.0	0.0	0.0	0.0	3893.8	3893.8
	602	0.0	0.0	0.0	0.0	4576.7	4576.7
	Total	0.0	0.0	0.0	0.0	8470.5	8460.5
7	701	1.3	9.3	273.2	1061.8	14525.7	15871.3
	702	0.0	0.0	0.0	0.0	8828.2	8828.2
	703	0.0	0.0	0.0	0.0	29606.9	29606.9
	704	10.0	0.0	0.0	0.0	15983.0	15983.0
	705	229.1	0.0	0.0	0.0	6740.9	6970.0
	Total	240.4	9.3	273.2	1061.8	75684.7	77269.4
8	801	556.2	0.0	0.0	0.0	11572.2	12128.4
	802	53.2	1.0	0.0	1.0	12067.3	12122.5
	803	36.1	39.8	0.0	51.9	4256.9	4384.7
	Total	645.5	40.8	0.0	52.9	27896.4	28635.6

Table A5-1.--Cropland and pastureland soils affected by saline and/or sodic conditions, by aggregated subarea (ASA)--continued

Water resources region	ASA	Sodic soils	Saline, not sodic (conductivity in mmhos/m^3) >8	4-8	2-4	Not affected	Total
		(1,000 acres)					
9	901	518.8	476.2	3830.6	2652.4	15262.9	22740.9
	Total	518.8	476.2	3830.6	2652.4	15262.9	22740.9
10	1001	95.0	166.9	1632.3	1302.3	3355.8	6552.3
	1002	64.9	93.5	802.9	1798.9	3208.3	5968.5
	1003	43.6	63.0	195.3	1212.8	553.2	2067.9
	1004	241.9	163.9	847.4	1788.0	2293.5	5334.7
	1005	1297.5	383.6	2119.1	2386.1	12156.3	18342.6
	1006	880.6	67.6	5769.2	2349.4	8062.6	17129.4
	1007	25.3	104.4	350.1	676.1	6876.0	8031.9
	1008	104.4	36.9	79.2	20.8	9916.4	10157.7
	1009	0.0	0.0	5.1	1.6	12406.8	12413.5
	1010	23.6	33.7	52.9	61.4	20232.2	20403.8
	1011	8.4	3.3	0.0	325.8	17735.9	18073.4
	Total	2785.2	1116.8	11853.5	11923.2	96797.0	124475.7
11	1101	64.0	0.0	0.0	0.0	4494.3	4558.3
	1102	39.9	18.1	96.4	175.3	1976.4	2306.1
	1103	95.6	26.0	83.1	431.7	17505.9	18142.3
	1104	43.2	201.6	1.3	384.0	9752.0	10382.1
	1105	44.7	25.8	28.5	66.4	7949.6	8115.0
	1106	253.7	9.9	0.0	684.2	9583.6	10531.4
	1107	13.1	6.8	0.0	0.0	6325.3	6345.2
	Total	554.2	288.2	209.3	1741.6	57587.1	60380.4
12	1201	23.3	0.0	2.6	0.0	3507.9	3533.8
	1202	72.2	3.2	27.8	0.0	7359.1	7462.3
	1203	0.0	0.0	0.0	206.6	13291.3	13497.9
	1204	3.5	10.5	107.7	195.2	7819.7	8136.6
	1205	41.6	808.2	274.2	868.8	3564.4	5557.2
	Total	140.6	821.9	412.3	1270.6	35542.4	38187.8
13	1301	90.7	119.4	126.5	102.6	218.8	658.0
	1302	6.7	37.6	111.9	379.2	212.6	748.0
	1303	0.0	76.1	75.0	326.0	23.6	500.7
	1304	0.0	26.4	12.6	133.0	138.7	310.7
	1305	21.1	213.6	92.7	1064.5	105.4	1497.3
	Total	118.5	473.1	418.7	2005.3	699.1	3714.7
14	1401	29.1	47.9	172.7	232.5	732.1	1214.3
	1402	2.6	51.7	162.8	92.5	442.4	752.0
	1403	0.0	3.9	18.6	99.3	394.5	516.3
	Total	31.7	103.5	354.1	424.3	1569.0	2482.6
15	1501	0.0	23.5	1.9	4.3	96.8	126.5
	1502	0.0	19.0	13.7	104.6	51.2	188.5
	1503	26.5	52.5	32.7	663.3	394.9	1169.9
	Total	26.5	95.0	48.3	772.2	542.9	1484.9
16	1601	116.2	78.5	121.8	377.6	1155.4	1849.5
	1602	17.3	93.9	58.5	123.1	268.8	561.6
	1603	7.5	367.9	144.5	163.0	190.2	873.1
	1604	8.2	81.0	36.3	36.9	104.7	267.1
	Total	149.2	621.3	361.1	700.6	1719.1	3551.3

Table A5-1.--Cropland and pastureland soils affected by saline and/or sodic conditions, by aggregated subarea (ASA)

Water resources region	ASA	Sodic soils	Saline, not sodic (Conductivity, in MMHOS/CM) 8	4-8	2-4	Not affected	Total
		(1,000 acres)					
17	1701	89.8	0.0	18.4	245.1	1829.2	2182.5
	1702	7.4	15.1	42.5	751.0	7856.9	8672.9
	1703	5.4	143.3	713.7	890.6	4064.0	5817.0
	1704	24.3	0.0	6.1	136.9	2779.8	2947.1
	1705	0.0	0.0	0.0	25.2	2596.3	2621.5
	1706	0.0	11.6	2.4	0.0	717.4	731.4
	1707	0.0	25.1	58.2	52.1	455.1	590.5
	Total	126.9	195.1	841.3	2100.9	20298.7	23562.9
18	1801	9.7	34.5	36.1	46.8	586.7	713.8
	1802	32.5	71.6	244.1	144.1	2411.1	2903.4
	1803	337.5	1209.6	611.3	784.3	3001.6	5944.3
	1804	3.3	41.1	70.2	24.8	441.5	580.9
	1805	35.6	3.1	78.0	10.8	795.8	923.3
	1806	8.2	77.3	275.4	144.6	541.4	1046.9
	1807	3.5	0.0	12.8	0.6	48.3	65.2
	Total	430.3	1437.2	1327.9	1156.0	7826.4	12177.8
20	2000	0.0	0.0	0.0	1.7	1305.5	1307.2
	Total	0.0	0.0	0.0	1.7	1305.5	1307.2
21	2100	0.0	15.8	0.0	4.2	1343.3	1363.3
	Total	0.0	15.8	0.0	4.2	1343.3	1363.3
National total		5799.3	5715.5	19930.3	25879.9	479388.1	554713.1

Source: 1982 NRI and National Cooperative Soil Survey.

Table A5-2.--Irrigated cropland and pastureland soils affected by saline and/or sodic conditions, by aggregated subarea (ASA)

WRA	ASA	SODIC SOILS	SALINE, NOT SODIC (CONDUCTIVITY, IN MMHOS/CM) >8	4-8	2-4	NOT AFFECTED	TOTAL
		(1,000 ACRES)					
1	101	0.0	0.0	0.0	0.0	3.0	3.0
	102	0.0	0.0	0.0	0.0	11.1	11.1
	103	0.0	0.0	0.0	0.0	21.9	21.9
	104	0.0	0.0	0.0	0.0	0.7	0.7
	105	0.0	0.0	0.0	0.0	9.1	9.1
	106	0.0	0.0	0.0	0.0	1.4	1.4
	TOTAL	0.0	0.0	0.0	0.0	47.2	47.2
2	201	0.0	0.0	0.0	0.0	4.1	4.1
	202	0.0	0.0	0.0	0.0	40.3	40.3
	203	0.0	0.0	0.0	0.0	127.4	127.4
	204	0.0	0.0	0.0	0.0	18.2	18.2
	205	0.0	0.0	0.0	0.0	100.3	100.3
	206	0.0	0.0	0.0	0.0	18.9	18.9
	TOTAL	0.0	0.0	0.0	0.0	309.2	309.2
3	301	0.0	0.0	0.0	0.0	306.2	306.2
	302	0.0	0.0	0.0	0.0	96.2	96.2
	303	0.0	2.4	0.0	0.0	301.5	303.9
	304	0.0	0.0	0.0	0.0	1060.7	1060.7
	305	0.0	0.0	0.0	6.3	1495.9	1502.2
	306	0.0	0.0	0.0	0.0	619.5	619.5
	307	0.0	0.0	0.0	0.0	75.9	75.9
	308	0.0	0.0	0.0	0.0	11.7	11.7
	309	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	0.0	2.4	0.0	6.3	3967.6	3976.3
4	401	0.0	0.0	0.0	0.0	5.0	5.0
	402	0.0	0.0	0.0	0.0	119.2	119.2
	403	0.0	0.0	0.0	0.0	59.1	59.1
	404	0.0	0.0	0.0	0.0	389.9	389.9
	405	0.0	0.0	0.0	0.0	36.2	36.2
	406	0.0	0.0	0.0	0.0	25.1	25.1
	407	0.0	0.0	0.0	0.0	5.7	5.7
	408	0.0	0.0	0.0	0.0	13.5	13.5
	TOTAL	0.0	0.0	0.0	0.0	653.7	653.7
5	501	0.0	0.0	0.0	0.0	0.0	0.0
	502	0.0	0.0	0.0	0.0	4.8	4.8
	503	0.0	0.0	0.0	0.0	18.4	18.4
	504	0.0	0.0	0.0	0.0	0.0	0.0
	505	0.0	0.0	0.0	0.0	19.8	19.8
	506	0.0	0.0	0.0	0.0	65.1	65.1
	507	0.0	0.0	0.0	0.0	5.0	5.0
	TOTAL	0.0	0.0	0.0	0.0	113.1	113.1

Table A5-2.--Irrigated cropland and pastureland soils affected by saline and/or Sodic conditions, by aggregated subarea(ASA)

WRA	ASA	SODIC SOILS	SALINE, NOT SODIC (CONDUCTIVITY, IN MMHOS/CM) >8	4-8	2-4	NOT AFFECTED	TOTAL
		(1,000 ACRES)					
6	601	0.0	0.0	0.0	0.0	10.8	10.8
	602	0.0	0.0	0.0	0.0	8.8	8.8
	TOTAL	0.0	0.0	0.0	0.0	19.6	19.6
7	701	0.0	0.0	1.7	1.9	350.6	354.2
	702	0.0	0.0	0.0	0.0	185.2	185.2
	703	0.0	0.0	0.0	0.0	111.1	111.1
	704	0.0	0.0	0.0	0.0	138.0	138.0
	705	0.0	0.0	0.0	0.0	15.5	15.5
	TOTAL	0.0	0.0	1.7	1.9	800.4	804.0
8	801	418.9	0.0	0.0	0.0	2436.7	2855.6
	802	5.1	0.0	0.0	0.0	1417.4	1422.5
	803	6.9	23.4	0.0	0.0	1022.4	1052.7
	TOTAL	430.9	23.4	0.0	0.0	4876.5	5330.8
9	901	0.0	0.0	12.0	4.9	77.8	94.7
	TOTAL	0.0	0.0	12.0	4.9	77.8	94.7
10	1001	0.0	65.1	64.4	27.7	48.6	205.8
	1002	0.7	18.0	35.0	274.7	669.9	998.3
	1003	4.6	9.2	33.8	57.2	88.5	193.3
	1004	19.1	83.0	222.3	523.1	439.3	1286.8
	1005	8.3	16.3	64.8	34.8	275.2	399.4
	1006	5.7	0.0	83.9	30.0	270.0	389.6
	1007	6.9	41.2	188.9	315.5	1526.7	2079.2
	1008	86.4	24.1	31.9	12.8	3737.0	3892.2
	1009	0.0	0.0	0.0	0.0	200.1	200.1
	1010	4.3	4.3	4.6	7.5	3982.7	4003.4
	1011	0.0	0.0	0.0	11.2	109.0	120.2
	TOTAL	136.0	261.2	729.6	1294.5	11347.0	13768.3
11	1101	28.1	0.0	0.0	0.0	253.5	281.6
	1102	3.3	11.7	77.8	65.1	361.3	519.2
	1103	9.0	5.6	2.0	133.7	2686.5	2836.8
	1104	0.0	0.0	0.0	0.0	138.6	138.6
	1105	0.0	5.4	5.8	8.2	2031.6	2051.0
	1106	0.0	0.0	0.0	25.5	1341.7	1367.2
	1107	0.0	0.0	0.0	0.0	80.6	80.6
	TOTAL	40.4	22.7	85.6	232.5	6893.8	7275.0

Table 5-2.--Irrigated cropland and pastureland soils affected by saline and/or sodic conditions, by aggregated subarea (ASA)

WRA	ASA	SODIC SOILS	SALINE, NOT SODIC (CONDUCTIVITY, IN MMHOS/CM) ≥ 8	4-8	2-4	NOT AFFECTED	TOTAL
		(1,000 ACRES)					
12	1201	0.0	0.0	0.0	0.0	155.4	155.4
	1202	0.0	0.0	7.2	0.0	622.0	629.2
	1203	0.0	0.0	0.0	3.6	3532.2	3535.8
	1204	0.0	0.0	34.6	134.5	1459.6	1628.7
	1205	3.8	50.9	77.9	110.0	411.8	654.4
	TOTAL	3.8	50.9	119.7	248.1	6181.0	6603.5
13	1301	86.9	116.7	118.7	96.0	200.4	618.7
	1302	6.7	34.4	107.2	362.8	158.1	669.2
	1303	0.0	72.2	28.6	158.0	21.7	280.5
	1304	0.0	17.7	12.1	132.2	91.1	253.1
	1305	4.1	150.4	44.9	529.8	25.8	755.0
	TOTAL	97.7	391.4	311.5	1278.8	497.1	2576.5
14	1401	24.7	37.0	118.5	158.4	518.1	856.7
	1402	0.9	50.3	141.2	86.6	223.6	502.6
	1403	0.0	1.0	11.6	92.5	208.1	313.2
	TOTAL	25.6	88.3	271.3	337.5	949.8	1672.5
15	1501	0.0	23.5	1.9	3.3	84.9	113.6
	1502	0.0	18.2	13.3	101.7	28.9	162.1
	1503	26.5	52.5	32.7	657.2	386.0	1154.9
	TOTAL	26.5	94.2	47.9	762.2	499.8	1430.6
16	1601	72.2	57.9	80.2	189.3	502.8	902.4
	1602	16.5	70.9	49.8	108.7	190.2	436.1
	1603	7.5	355.6	117.9	144.7	179.7	805.4
	1604	7.3	79.8	36.3	36.6	104.7	264.7
	TOTAL	103.5	564.2	284.2	479.3	977.4	2408.6
17	1701	66.8	0.0	11.2	125.1	505.0	708.1
	1702	0.0	5.0	24.6	155.6	2065.0	2250.2
	1703	3.1	114.5	649.8	761.4	2571.7	4100.5
	1704	0.0	0.0	3.4	55.5	248.7	307.6
	1705	0.0	0.0	0.0	3.8	520.8	524.6
	1706	0.0	4.3	0.0	0.0	70.1	74.4
	1707	0.0	25.1	51.9	49.0	366.1	492.1
	TOTAL	69.9	148.9	740.9	1150.4	6347.4	8457.5

Table A6-1.--Rangeland condition on nonfederal rangeland, by state

State	Excellent	Good	Fair	Poor	Other	Total
	acres					
Arizona	517.7	4,923.6	16,574.1	8,831.9	100.9	30,948.2
Arkansas	4.9	21.5	70.2	68.0	0.0	164.6
California	29.3	472.9	613.2	434.0	16,575.2	18,124.6
Colorado	333.2	5,802.6	14,012.2	4,033.2	41.3	24,222.5
Florida	24.5	272.5	1,831.4	1,640.1	35.4	3,803.9
Idaho	322.6	2,187.3	2,565.9	1,255.3	401.8	6,732.9
Kansas	965.5	8,091.9	6,121.9	1,666.2	63.4	16,908.9
Louisiana	12.5	148.5	54.0	26.3	0.0	241.3
Minnesota	20.4	47.8	100.3	27.6	2.4	198.5
Missouri	1.3	56.2	49.7	55.6	5.0	167.8
Montana	5,027.5	17,272.1	12,605.1	2,747.2	185.1	37,837.0
Nebraska	2,188.5	12,636.1	7,110.2	1,069.0	91.9	23,095.7
Nevada	239.2	2,674.4	4,027.0	658.8	308.4	7,907.8
New Mexico	658.7	12,262.5	22,617.4	5,421.5	21.8	40,981.9
North Dakota	1,524.2	6,295.3	2,760.7	368.2	0.0	10,948.4
Oklahoma	906.8	3,601.6	7,638.6	2,903.9	8.7	15,059.6
Oregon	226.4	1,813.2	3,485.5	3,731.1	135.8	9,392.0
South Dakota	1,876.7	13,715.9	6,486.0	704.0	1.0	22,783.6
Texas	479.9	13,546.3	53,542.8	25,680.6	2,103.5	95,353.1
Utah	154.9	1,724.5	4,027.0	2,451.3	131.6	8,489.3
Washington	629.0	1,168.5	1,816.1	1,933.0	90.4	5,637.0
Wyoming	331.0	11,609.6	13,988.1	976.4	10.0	26,915.1
Total	16,474.7	120,344.8	182,097.4	66,683.2	20,313.6	405,913.7

Source: 1982 NRI.

Table A6-2.--Conservation treatment needs on nonfederal rangeland, by state

State	Adequately protected	Treatment not feasible	Treatment needed	Rangeland Total
	1,000 acres			
Arizona	6,204.9	1,791.2	22,952.1	30,948.2
Arkansas	29.5	25.2	109.9	164.6
California	6,323.4	4,050.8	7,750.4	18,124.6
Colorado	6,366.6	1,253.5	16,602.4	24,222.5
Florida	658.7	163.1	2,982.1	3,803.9
Idaho	1,505.1	399.4	4,828.4	6,732.9
Kansas	7,948.4	82.2	8,878.3	16,908.9
Louisiana	33.3	15.2	192.8	241.3
Minnesota	115.7	8.4	74.4	198.5
Missouri	34.7	0.0	133.1	167.8
Montana	16,994.1	1,592.1	19,250.8	37,837.0
Nebraska	15,887.7	82.4	7,125.6	23,095.7
Nevada	2,311.5	1,359.3	4,237.0	7,907.8
New Mexico	11,360.4	1,192.0	28,429.5	40,981.9
North Dakota	7,585.9	207.6	3,154.9	10,948.4
Oklahoma	5,636.9	249.8	9,172.9	15,059.6
Oregon	1,145.9	692.7	7,553.4	9,392.0
South Dakota	13,460.6	256.3	9,066.7	22,783.6
Texas	21,778.2	2,599.0	70,975.9	95,353.1
Utah	1,141.5	276.6	7,071.2	8,489.3
Washington	1,538.7	314.8	3,783.5	5,637.0
Wyoming	8,222.7	2,296.7	16,395.7	26,915.1
TOTAL	136,284.4	18,908.3	250,721.0	405,913.7

Source: 1982 NRI.

Table A6-3.--Conservation treatment needs on nonfederal rangeland,by state

State	Erosion control	Protec-tion	Improve-ment	Improvement and brush management	Reestab-lishment	Brush mgmt. and rees-tablish-ment
	1,000 acres					
Arizona	1,369.9	8,234.7	8,420.0	1,980.4	1,355.0	1,592.1
Arkansas	6.6	6.6	5.2	17.1	0.0	74.4
California	2,248.4	3,257.5	916.3	756.6	404.8	166.8
Colorado	2,960.4	5,739.7	3,846.4	2,416.8	1,053.5	585.6
Florida	15.1	159.8	891.9	1,783.0	30.9	101.4
Idaho	227.6	1,169.5	715.5	1,951.0	359.4	405.4
Kansas	499.8	3,103.5	2,463.9	2,270.0	334.7	206.4
Louisiana	0.2	97.3	19.2	76.1	0.0	0.0
Minnesota	1.0	38.1	29.3	6.0	0.0	0.0
Missouri	9.8	19.6	11.4	64.4	3.1	24.8
Montana	555.3	11,353.9	4,988.9	1,753.8	503.4	95.5
Nebraska	351.2	3,241.1	2,473.0	581.8	455.3	23.2
Nevada	256.0	738.5	610.3	1,969.4	232.1	430.7
New Mexico	8,162.8	7,006.5	6,705.4	5,271.5	726.5	556.5
North Dakota	288.4	2,059.0	591.2	148.4	67.9	0.0
Oklahoma	731.8	1,834.5	2,634.7	2,984.5	650.8	336.6
Oregon	899.4	782.7	1,970.1	2,205.0	547.3	1,248.9
South Dakota	485.7	5,946.2	2,391.0	111.1	131.6	1.1
Texas	1,332.0	7,479.5	17,834.0	31,320.6	2,827.0	10,182.8
Utah	1,918.6	2,622.0	632.9	1,027.1	182.0	688.6
Washington	303.3	824.9	815.1	673.0	631.6	535.6
Wyoming	2,535.1	5,102.7	4,531.2	3,845.6	275.4	105.7
TOTAL	25,158.4	70,717.8	63,496.9	63,213.2	10,772.3	17,362.4

Source: 1982 NRI.

Table A6-4.--Range condition of state-owned rangeland, by land capability classification

	Excellent	Good	Fair	Poor	Not Aapplicable	Total
	(1,000 acres)					
I	2.5	0.6	0.0	0.0	0.0	3.1
IIe	14.4	84.3	53.8	7.8	0.0	160.3
IIw	6.8	4.1	1.6	9.8	1.8	24.1
IIs	0.0	0.5	0.0	0.0	0.0	0.5
IIc	9.3	37.0	81.7	2.5	0.0	130.5
All II	30.5	125.9	137.1	20.1	1.8	315.4
IIIe	99.4	691.5	541.7	87.7	0.7	1,421.0
IIIw	0.0	8.0	45.6	70.2	0.1	123.9
IIIs	4.1	22.9	40.7	23.1	0.0	90.8
IIIc	0.0	2.3	47.6	7.8	0.0	57.7
All III	103.5	724.7	675.6	188.8	0.8	1,693.4
IVe	159.4	972.6	1,150.1	156.6	13.0	2,451.7
IVw	7.1	93.2	127.8	35.4	4.2	267.7
IVs	12.7	147.2	52.8	9.2	0.0	221.9
IVc	2.8	10.8	166.2	40.9	0.0	220.7
All IV	182.0	1,223.8	1,496.9	242.1	17.2	3,162.0
V	16.3	66.4	62.0	19.5	0.0	164.2
VIe	261.4	2,588.9	4,263.0	684.0	52.6	7,849.9
VIw	11.1	50.7	181.0	40.6	40.6	323.9
VIs	59.4	1,230.6	2,968.2	548.9	12.6	4,819.7
VIc	0.0	31.6	324.4	114.6	13.7	484.3
All VI	331.9	3,901.8	7,736.6	1,388.1	119.4	13,477.8
VIIe	275.8	1,791.9	2,656.2	991.1	10.7	5,725.7
VIIw	1.5	38.5	50.6	25.7	0.2	116.5
VIIs	330.1	2,392.1	4,083.9	1,565.3	42.3	8,413.7
VIIc	11.8	99.9	338.1	251.5	2.6	703.9
All VII	619.2	4,322.4	7,128.8	2,833.6	55.8	14,959.8
VIII	3.5	59.8	133.4	42.9	11.1	250.7
TOTAL	1,289.4	10,425.4	17,370.4	4,735.1	206.1	34,026.4

Table A6-5.--Percentage distribution of rangeland in range condition classes, nonfederal and BLM -administered rangelands.

Year and Study	Condition Class 1/				
	Excellent	Good	Fair	Poor	Not Classified
1963 - Nonfederal	5	15	40	40	
1966 - BLM	2	7	52	40	
1977 - Nonfederal	12	28	42	18	
1975 - BLM	2	15	50	33	
1982 - Nonfederal	4	30	45	16	5
1984 - BLM	5	31	42	18	4

1/ Rounded to nearest whole percent.

Table A6-6.--Average number of animal units, by ranch size for each state, 1982

State	Small	Medium	Large
Arizona	68	292	1473
California	61	302	1259
Colorado	79	303	1803
Idaho	78	284	1136
Kansas	75	240	2688
Montana	68	275	1320
Nebraska	70	249	2013
Nevada	95	334	1184
New Mexico	94	228	660
North Dakota	65	266	1268
Oklahoma	59	283	1020
Oregon	73	301	1275
South Dakota	70	269	1364
Texas	61	270	1657
Utah	82	303	1046
Washington	66	256	1036
Wyoming	75	262	1309

Source: John Fowler, 1986.

Table 6-7.--Percentage of ranch operations in size classes in the 17 western states for 1982

State	Small (1-100 head)	Medium (200-499 head)	Large (500 + head)
Arizona[1]	70.7	18.1	11.2
California	82.9	11.4	5.6
Colorado	69.5	25.8	4.7
Idaho	76.8	20.0	3.2
Kansas	74.7	22.0	3.3
Montana	52.5	37.5	10.0
Nebraska	60.7	32.9	6.4
Nevada[1]	72.5	20.2	7.3
New Mexico	76.9	16.8	6.3
North Dakota	59.5	38.6	1.9
Oklahoma	80.3	17.9	1.8
Oregon[1]	79.1	18.3	2.6
South Dakota	52.0	43.2	4.8
Texas	86.0	11.6	2.4
Utah[1]	75.3	21.5	3.2
Washington[1]	85.7	12.8	1.5
Wyoming	49.1	36.4	14.5

[1] Individual state "Agricultural Statistics" were used when separate statistics were not available.

Source: Crop Reporting Board, Statistical Reporting Services, U.S. Department of Agriculture, 1982.

Table A7-1.--Cropland and pastureland needing drainage, by state (1,000 acres)

State	Cropland		Pastureland
	Nonirrigated	Irrigated	
Alabama	146.5	11.7	39.7
Arizona	0.0	0.0	0.0
Arkansas	988.9	604.8	48.9
California	72.0	481.4	25.7
Colorado	2.8	25.2	17.8
Connecticut	2.0	0.0	0.0
Delaware	22.7	0.0	3.0
Florida	42.5	201.8	54.9
Georgia	279.0	19.7	27.1
Hawaii	1.5	0.0	0.0
Idaho	24.5	28.0	23.8
Illinois	1,958.4	0.6	39.8
Indiana	3,430.9	3.7	68.0
Iowa	1,040.5	0.0	84.0
Kansas	173.3	4.1	11.8
Kentucky	364.3	0.0	44.6
Louisiana	1,099.7	319.1	69.3
Maine	53.3	0.0	34.0
Maryland	144.6	0.9	22.8
Massachusetts	15.3	0.0	6.0
Michigan	1,807.6	7.8	236.5
Minnesota	1,227.2	3.2	265.9
Mississippi	2,400.6	247.8	33.4
Missouri	1,585.3	166.7	34.4
Montana	19.0	4.9	25.7
Nebraska	114.1	28.4	11.0
Nevada	0.0	7.9	2.5
New Hampshire	8.4	0.0	3.1
New Jersey	22.3	0.0	3.5
New Mexico	0.0	3.9	0.2
New York	689.7	0.0	280.2
North Carolina	543.5	2.6	15.7
North Dakota	254.2	0.0	18.1
Ohio	3,874.0	2.8	85.2
Oklahoma	121.6	3.5	17.2
Oregon	182.6	87.7	102.6
Pennsylvania	273.8	1.0	140.8
Rhode Island	0.9	0.0	0.3
South Carolina	234.9	4.6	12.8
South Dakota	85.0	6.6	0.0
Tennessee	394.7	0.0	47.9
Texas	680.3	147.8	119.3
Utah	10.1	6.8	28.7
Vermont	48.6	0.0	23.7
Virginia	122.4	0.0	26.2
Washington	52.8	12.2	55.3
West Virginia	26.2	0.0	26.9
Wisconsin	579.7	4.5	93.7
Wyoming	0.0	22.9	27.6
Caribbean	18.3	8.9	10.3
Total	25,240.5	2,483.5	2,369.9

Source: 1982 NRI
Includes only cropland and pastureland where drainage is the primary need. Land needing both erosion control and drainage is not included.

Table A8-1.--Flood-prone areas, by state and farming region

Farming region and state	Million acres
Northeast	6.8
Connecticut	0.1
Delaware	0.1
Maine	1.2
Maryland	0.6
Massachusetts	0.3
New Hampshire	0.2
New Jersey	0.7
New York	2.0
Pennsylvania	1.4
Rhode Island	0.05
Vermont	0.2
Lake States	10.5
Michigan	1.4
Minnesota	3.2
Wisconsin	5.9
Corn Belt	21.9
Illinois	4.6
Indiana	2.5
Iowa	4.9
Missouri	8.1
Ohio	1.8
Appalachian	15.8
Kentucky	3.0
North Carolina	5.8
Tennessee	4.0
Virginia	2.3
West Virginia	0.7
Southeast	30.4
Alabama	5.7
Florida	14.7
Georgia	7.7
South Carolina	2.9
Delta States	27.9
Arkansas	6.9
Louisiana	11.5
Mississippi	9.6
Northern Plains	20.4
Kansas	6.2
Nebraska	6.4
North Dakota	2.5
South Dakota	5.2
Southern Plains	26.0
Oklahoma	6.0
Texas	20.0
Mountain	23.2
Arizona	2.8
Colorado	3.7
Idaho	1.7
Montana	3.9
Nevada	1.9
New Mexico	4.0
Utah	2.4
Wyoming	2.8
Pacific	11.3
California	7.1
Oregon	2.6
Washington	1.6
Alaska	0.0
Hawaii	0.2
Caribbean	2.9
TOTAL	197.3

Table A11-1.--Quality factors affecting habitat value

Land use/cover type	Habitat layer	Quality factor
Fruit, nuts, and other horticulture	Water surface	1.00 if wetland
		0.00 if non-wetland
	Subsurface	1.00
	Terrestrial surface	1.00
	Midstory	0.00
	Tree canopy	1.00
Row crops, small grains, and vegetables	Water surface	1.00 if wetland
		0.00 if non-wetland
	Terrestrial subsurface	1.00 if cons. tillage
		0.00 if not
	Terrestrial surface	0.33 if winter cover height is 6" or less
		0.66 if winter cover is 7" to 12"
		1.00 if winter cover is more than 12"
Grass/hay	Water surface	1.00 if wetland
		0.00 if non-wetland
	Subsurface	1.00
	Surface	0.75 because cut for hay
Grass/pasture	Water surface	1.00 if wetland
		0.00 if non-wetland
	Subsurface	1.00
	Surface	1.00 if good condition
		0.90 if fair condition
		0.80 if poor condition
	Midstory	1.00 if woody canopy is 10-55%
		0.33 if woody canopy is more than 55%
		0.00 if woody canopy is less than 10%
Rangeland	Water surface	1.00 if wetland
		0.00 if non-wetland
	Subsurface	1.00
	Surface	1.00 if good to excellent condition
		0.90 if fair condition
		0.80 if poor condition
	Midstory	1.00 if woody canopy is 10-55%
		0.33 if woody canopy is more than 55%
		0.00 if woody canopy is less than 10%
Forest	Water surface	1.00 if wetland
		0.00 if not wetland
	Subsurface	1.00 if not wetland
		0.00 if other
	Surface	1.00 if understory is grass-forbs and is not grazed
		0.66 if understory is grass-forbs and is grazed
	Midstory	1.00 if understory is woody vegetation
		0.66 if understory is woody and is grazed
	Tree bole	1.00 if diameter at breast height is 12" or more
		0.80 if diameter at breast height is between 8"-12"
		0.00 if diameter at breast height is less than 8"
	Tree canopy	1.00
		.45 if forest is low productivity type

Table A11-2.--Wet soils needing drainage, by vegetative cover type, in each farming region (1982 NRI)
E

Drainage 1/ Needs	Vegetative Cover: Cropland	Pasture	Range	Forest	Other	Total Wet Soils
	(million acres)					
Northeast						
Adequate or not feasible to drain	4.13	1.07	-	7.47	.69	13.35
Needs drainage to enhance prod.	1.00	.38	-	-	.05	1.43
Needs drainage for conversion to crop	-	1.38	-	1.20	.11	2.69
Lake States						
Adequate or not feasible to drain	13.52	1.29	.09	11.50	4.93	31.33
Needs drainage to enhance prod.	3.16	.48	-	-	.17	3.81
Needs drainage for conversion to crop	-	1.56	.03	1.42	.29	3.30
Corn Belt						
Adequate or not feasible to drain	27.84	1.05	.01	2.05	.67	31.62
Needs drainage to enhance prod.	10.82	.26	-	-	.08	11.16
Needs drainage for conversion to crop	-	2.31	.01	1.59	.23	4.14
Northern Plains						
Adequate or not feasible to drain	6.72	.43	2.86	.40	.29	10.69
Needs drainage to enhance prod.	.44	.02	-	-	.01	.47
Needs drainage for conversion to crop	-	.46	.91	.08	.05	1.50
Applachian						
Adequate or not feasible to drain	4.69	.46	-	5.69	.36	11.20
Needs drainage to enhance prod.	1.33	.14	-	-	.05	1.52
Needs drainage for conversion to crop	-	1.06	-	3.17	.10	4.33
Southeast						
Adequate or not feasible to drain	3.74	2.11	2.36	17.78	2.38	28.37
Needs drainage to enhance prod.	.85	.10	-	-	.05	1.00
Needs drainage for conversion to crop	-	2.12	.99	2.50	.12	5.73
Delta States						
Adequate or not feasible to drain	11.02	.93	.19	8.33	1.09	21.55
Needs drainage to enhance prod.	5.33	.13	-	-	.01	5.47
Needs drainage for conversion to crop	-	1.78	.01	2.58	.07	4.44
Southern Plains						
Adequate or not feasible to drain	5.47	1.77	3.42	2.62	.15	13.43
Needs drainage to enhance prod.	.58	.07	-	-	-	.65
Needs drainage for conversion to crop	-	1.81	1.49	.26	.02	3.58
Mountain						
Adequate or not feasible to drain	2.40	.89	4.04	.29	.30	7.92
Needs drainage to enhance prod.	.07	.04	-	-	.03	.14
Needs drainage for conversion to crop	-	.41	.26	.04	.01	.72
Pacific						
Adequate or not feasible to drain	3.19	.76	.84	.71	.40	5.90
Needs drainage to enhance prod.	.58	.11	-	-	.02	.71
Needs drainage for conversion to crop	-	.78	.25	.31	.02	1.36
Contiguous U.S.						
Adequate or not feasible to drain	82.72	10.76	13.81	56.84	11.26	175.36
Needs drainage to enhance prod.	24.16	1.73	0.00	0.00	0.47	26.36
Needs drainage for conversion to crop	0.00	13.67	3.95	13.15	1.02	31.79

Source: 1982 Natural Resource Inventory

Table A12-1.--Population, gross national product, and disposable personal income in the United States, projections to 2030

Year	Population		Gross national product		Per capita gross national product		Disposable personal income		Per capita disposable personal income	
	Million	Annual rate of Change	Billion 1972 dollars	Annual rate of change	1972 dollars	Annual rate of change	Billion 1972 dollars	Annual rate of change	1972 dollars	Annual rate of change
1990	249.7	.9	1,970	3.4	7,890	2.4	1,380	3.4	5,530	2.4
2000	268.0	.7	2,580	2.7	9,630	2.0	1,800	2.7	6,720	2.0
2010	283.1	.5	3,310	2.5	11,690	2.0	2,310	2.5	8,160	2.0
2020	296.3	.5	4,070	2.1	13,740	1.6	2,840	2.1	9,580	1.6
2030	304.3	.3	5,050	2.2	16,600	1.9	3,520	2.2	11,570	1.9

Sources: Population: U.S. Department of Commerce, Bureau of the Census. Population estimates and projections--Curr. Pop. Reps. Ser. P-25.
Gross national product: Council of Economic Advisers. Projections--U.S. Department of Commerce, Bureau of Economic Analysis. 1980 OBERS BEA regional projections, vol. 1: methodology, concepts, and state data. July 1981.
Disposable personal income: Council of Economic Advisers.
Projections--U.S. Department of Agriculture, Forest Service and Soil Conservation Service.

Table A12-2.--Regional projections of population

Farming region	Projected population 1990	2000	2030
	----------thousands----------		
New England	55,144	53,584	41,761
Lake States	18,563	18,652	16,847
Corn Belt	35,818	34,949	27,783
Northern Plains	5,420	5,450	4,936
Appalachia	23,493	25,071	27,975
Southeast	27,435	32,489	47,258
Delta States	10,089	10,943	12,817
Southern Plains	21,027	24,651	35,085
Mountain States	15,748	20,226	34,289
Pacific States	35,328	40,088	52,911
United States (contiguous)	248,065	266,102	301,660
Alaska & Hawaii	1,635	1,898	2,640
United States, total	249,700	268,000	304,300

Source: U.S. Bureau of the Census.

Table A12-3.--Export demand

Commodity	Unit	1980 1/	1990 2/	2000 2/	2030 2/
			(millions)		
Intermediate level					
Wheat	bu	1,509.0	1,798.0	2,316.4	4,275.4
Soybeans	bu	929.1	1,057.7	1,642.5	3,720.3
Corn	bu	1,870.0	2,876.0	4,203.9	8,190.0
Grain Sorghum	bu	214.0	268.0	296.3	718.0
Oats	bu	3.0	10.1	12.5	18.2
Barley	bu	47.0	60.1	78.6	111.6
Low level					
Wheat	bu	1,510.0	1,474.1	1,779.4	2,809.6
Soybeans	bu	724.3	930.0	1,285.0	2,355.0
Corn	bu	2,355.0	2,450.0	3,245.0	5,333.0
Grain sorghum	bu	299.0	221.9	281.4	461.5
Oats	bu	13.0	4.6	5.4	7.1
Barley	bu	77.0	40.0	49.0	65.0

1/ Source: Agricultural Statistics.
2/ Source: Miranowski.

Table A12-4.--Projected acreage in nonagricultural uses, 1982-2030

State and region	1982	Projected 1990	Projected 2000	Projected 2030	Change from 1982 projected 1990	Change from 1982 projected 2000	Change from 1982 projected 2030
	1,000 acres						
Maine	857	976	1111	1450	119	254	593
New Hampshire	425	561	741	1324	136	316	899
Vermont	375	392	413	467	17	38	.92
Massachusetts	1619	1715	1782	1727	96	163	108
Rhode Island	231	246	259	263	15	28	32
Connecticut	1046	1110	1160	1168	64	114	122
New York	3404	3585	3699	3514	181	295	110
New Jersey	1794	1921	2030	2132	127	236	338
Pennsylvania	5564	5718	5814	5639	154	250	75
Delaware	294	311	329	365	17	35	71
Maryland	1485	1609	1735	1976	124	250	491
District of Columbia	39	39	39	39	0	0	0
Northeast	17133	18183	19110	20065	1050	1977	2932
Michigan	6411	6528	6592	6423	117	181	12
Wisconsin	5260	5400	5541	5789	140	281	529
Minnesota	7426	7620	7813	8138	194	387	712
Lake States	19097	19548	19946	20350	451	849	1252
Ohio	5417	5634	5805	5813	217	388	396
Indiana	3469	3614	3754	3971	145	285	502
Illinois	4333	4536	4708	4816	203	375	483
Iowa	3141	3235	3322	3435	94	181	294
Missouri	4047	4198	4343	4571	151	296	524
Corn Belt	20407	21217	21933	22606	810	1526	2199
North Dakota	2863	2880	2898	2933	17	35	69
South Dakota	2571	2590	2610	2652	19	39	81
Nebraska	2396	2442	2492	2606	46	96	210
Kansas	3140	3238	3342	3580	97	202	440
Northern Plains	10970	11150	11342	11770	180	372	800
Virginia	2847	3206	3636	4921	359	789	2074
West Virginia	1595	1647	1706	1853	52	111	258
North Carolina	3485	3832	4245	5462	347	760	1977
Kentucky	2819	2999	3217	3890	180	398	1071
Tennessee	3202	3581	4031	5357	379	829	2155
Appalachia	13948	15264	16835	21482	1316	2887	7534
South Carolina	2355	2584	2864	3724	229	509	1369
Georgia	3096	3526	4046	5625	430	950	2529
Florida	5705	6963	8604	13745	1258	2899	8040
Alabama	3121	3503	3944	5153	382	823	2032
Southeast	14277	16576	19458	28247	2299	5181	13970
Mississippi	2107	2260	2441	2958	153	334	851
Arkansas	2550	2730	2950	3628	180	400	1078
Louisiana	4953	5180	5456	6288	227	503	1335
Delta States	9610	10170	10846	12874	560	1236	3264
Oklahoma	3474	3861	4346	5918	387	872	2444
Texas	12828	14448	16575	23914	1620	3747	11086
Southern Plains	16302	18309	20922	29832	2007	4620	13530

Table A12-4.--Projected acreage in nonagricultural uses, 1982-2030

State and region	Projected acreage 1982	1990	2000	2030	Change From 1982 projected 1990	2000	2030
	1,000 acres						
Montana	3035	3058	3058	3154	23	50	119
Idaho	1637	1723	1855	2411	86	218	774
Wyoming	2194	2298	2485	3431	104	291	1237
Colorado	3791	4113	4607	6631	322	816	2840
New Mexico	5901	6011	6160	6657	110	259	756
Arizona	5115	6034	7599	14559	919	2484	9444
Utah	2115	2477	3082	5817	362	967	3702
Nevada	1260	1609	2260	5633	349	1000	4373
Mountain	25048	27324	31133	48293	2276	6085	23245
Washington	4308	4480	4693	5327	172	385	1019
Oregon	1782	1895	2040	2490	113	258	708
California	9136	9767	10511	12537	631	1375	3401
Pacific	15226	16142	17244	20353	916	2018	5127
48 States	162018	173882	188769	235872	11864	26751	73854
Alaska	70008	70082	70177	70480	74	169	472
Hawaii	1358	1386	1420	1514	28	62	156
United States	233384	245350	260367	307865	11966	26983	74481

Source: National Interregional Agricultural Production system.

Table A12-5.--Projected annual rates of increase in yield for 11 major crops

	Crop					
	Feedgrains*	Alfalfa	Wheat	Cotton	Rice	Soybean
Most probable:						
1982-2000	1.887	1.018	2.278	1.013	3.926	2.646
2001-2030	1.196	0.746	0.964	0.964	0.746	1.067
High:						
1982-2000	2.646	2.086	3.158	1.887	5.222	4.478
2001-2030	1.499	1.242	1.196	0.649	0.610	0.807
Optimistic:						
1982-2000	3.926	2.646	3.926	3.926	6.294	5.222
2001-2030	1.361	1.499	1.361	1.361	0.515	1.579
Low:						
1982-2000	1.018	0.531	1.247	0.0	2.278	1.468
2001-2030	0.746	0.427	0.610	0.606	0.964	0.695

*Feedgrains consist of barley, corn, corn silage, oats, sorghum and sorghum silage.
Source: Future Agricultural Technology and Resource Conservation, Iowa State University Press, 1984.

Table A13-6.--Potential for increased efficiency of producing foods of animal origin in 2000 and 2030

Animal/product	Unit	2000	2030
		Percent improvement [1]	
Beef	Liveweight marketed per breeding female	25	60
Pork	Liveweight marketed per breeding female	35	60
Dairy	Milk marketed per breeding female	30	65
Sheep	Liveweight marketed per breeding female	35	70
Broiler chickens	Liveweight marketed per breeding female	30	35
Turkeys	Liveweight marketed per breeding female	40	40
Laying hens	Number of eggs	20	25
Fish (Catfish)	Age to market weight (one pound)	50	200

1 Best estimate of work group.
Source: Future Agricultural Technology and Resource Conservation, Iowa State University Press, 1984.

Table 12-7.--Alternative futures, intermediate and high and low stress

		Intermediate future			High stress	Low stress
		1990	2000	2030	2030	2030
Cropland available	mil ac	370.4	364.0	346.9	347.3	354.8
Cropland used						
Total	mil ac	289.9	218.3	218.4	345.8	160.6
Water use (net dpl)						
Surface	mil acft	19.0	15.5	7.0	14.1	3.9
Ground	mil acft	35.5	11.9	10.7	58.0	4.5
Total	mil acft	54.5	27.4	17.7	72.1	8.4
Crop yields						
Corn	bu/ac	122.8	158.3	197.7	184.0	266.1
Soybeans	bu/ac	44.1	56.9	68.7	69.8	103.4
Wheat	bu/ac	45.0	60.9	69.8	65.8	101.2
Crop production						
Corn	mil bu	7232.6	7755.8	9917.0	16984.1	9274.7
Soybeans	mil bu	2240.0	2744.3	4150.0	6552.9	3974.3
Wheat	mil bu	2528.0	2562.7	3674.7	6374.7	3386.8
Tillage						
Conventional	mil ac	127.0	45.0	16.8	74.7	11.6
w/o wntr covr		33.3	11.5	1.8	23.6	2.3
w/ wntr cover		93.7	33.5	15.0	51.1	9.3
Conservation	mil ac	118.9	123.1	143.9	217.9	95.9
No-till	mil ac	15.9	23.1	33.5	29.0	29.0
Erosion rates (USLE)						
Sheet & rill	ton/ac	3.1	2.7	2.3	4.2	2.1
Wind	ton/ac	3.8	1.9	1.4	3.4	2.1
Total erosion						
Sheet & Rill	mil ton	807.0	512.2	480.0	1439.2	254.3
Wind	mil ton	1002.9	356.4	296.4	1159.2	286.4
Distribution of cropland by erosion interval:						
≤ 2.49	percent	26.7%	36.5%	42.1%	24.2%	41.9%
2.5-4.99	percent	36.4%	44.6%	46.4%	22.7%	45.3%
5.0-9.99	percent	17.2%	9.7%	6.2%	28.5%	7.1%
10.0-24.99	percent	17.3%	8.1%	4.6%	20.8%	4.1%
≥ 25.0	percent	2.4%	1.1%	0.7%	3.8%	1.6%
Livestock production:						
Beef	mil cwt	413.6	443.5	533.3	540.1	533.3
Pork	mil cwt	228.4	233.5	263.8	265.4	263.8
Dairy	mil cwt	1344.6	1328.3	1553.7	1559.9	1553.7
Cost of production						
Crops						
Fertilizer	mil $	5633.0	5856.9	7745.0	12805.8	6388.5
Pesticides	mil $	3513.2	2957.2	3489.8	5700.3	2271.0
Machinery	mil $	5076.2	3679.2	3677.2	6699.9	2452.1
Labor	mil $	2206.9	1589.0	1595.7	2837.0	1061.5
Water	mil $	1358.0	760.8	893.4	2631.2	296.1
Other	mil $	12670.5	9832.8	10343.8	17909.0	6852.8
Total crops	mil $	30457.8	24675.9	27744.9	48583.2	19422.0
Livestock						
Mach & Equip	mil $	6492.0	6321.8	6595.9	6788.4	6500.2
Labor	mil $	3866.5	3548.7	3567.9	3844.0	3510.5
Other	mil $	8641.8	8351.5	8471.1	8663.3	8453.9
Total lvstk	mil $	19000.3	18222.0	18634.9	19295.7	18464.6
Transportation	mil $	3561.5	4276.7	5645.1	10165.6	4980.3
Total cost	mil $	53109.6	47174.6	52024.9	78044.5	42866.9
Fertilizer use						
Per acre:						
N	lb/ac	55	74	88	94	107
P	lb/ac	29	40	52	51	58
K	lb/ac	20	27	33	33	40
Total:						
N	mil ton	8.0	8.1	10.0	17.1	8.7
P(205)	mil ton	4.1	4.3	5.9	9.3	4.7
K(20)	mil ton	2.9	3.0	3.8	6.1	3.2
Energy use						
Crop	trl btu	832.2	694.2	812.6	1573.9	638.0
Livestock	trl btu	169.2	169.5	183.0	194.4	180.9
Total	trl btu	1001.4	863.7	995.6	1768.3	818.9

Source: CARD/RCA linear programming model.

Table A12-8.--Projected use of agricultural products, First and Second RCA Appraisals

Projection year		2000		2030	
Appraisal		RCA1	RCA2	RCA1	RCA2
POPULATION (millions)		260.4	268.0	300.3	304.3
CONSUMPTION (pounds per capita)					
Beef and Veal		140.0	110.4	152.0	110.9
Pork		70.0	64.0	74.0	62.8
Lamb		1.4	1.9	1.2	2.0
Chicken		65.0	59.6	58.0	60.1
Turkey		11.7	11.5	13.9	12.7
Milk		529.0	511.2	549.3	516.1
Eggs		33.0	29.8	30.0	31.0
Wheat		158.0	156.5	173.0	146.6
Rice		14.2	26.8	15.3	30.6
Corn		126.0	67.5	140.0	61.0
Peanuts		11.0	10.3	11.4	10.4
Irish potatoes		134.0	131.3	140.0	145.9
Dry beans and peas		5.3	5.9	4.3	5.7
Noncitrus fruit		109.0	121.1	115.0	133.8
Citrus fruit		139.0	140.1	145.0	150.2
Sugar		95.0	63.2	94.0	63.6
Vegetables and melons		273.0	275.4	290.0	298.3
Cotton		14.0	8.5	13.4	5.0
FEED USE (millions)					
Barley	bu	310.0	241.8	357.2	215.7
Corn	bu	4,766.0	2,495.0	5,413.0	2,458.0
Legume hay	ton	90.8	48.6	103.8	18.2
Nonlegume hay	ton	63.4	11.6	73.6	8.6
Oats	bu	688.2	11.1	762.5	0.0
Silage	ton	123.7	41.6	133.6	40.5
Sorghum	bu	974.6	1,372.9	1,130.8	1,554.3
Soybeans	bu	831.3	1,198.6	927.7	1,391.5
Wheat	bu	226.8	0.0	259.1	0.0
EXPORTS (millions)					
Wheat	bu	1,999	1,779	2,411	2,810
Rice	cwt	188	35	208	50
Soybeans	bu	1,436	1,285	1,866	2,355
Corn	bu	2,520	3,245	3,229	5,333
Sorghum	bu	322	281	413	462
Oats	bu	21	5	26	7
Barley	bu	79	49	101	65
AVERAGE YIELDS (units per acre)					
Corn	bu	107.0	158.3	144.0	197.7
Wheat	bu	35.0	60.9	42.0	69.8
Soybeans	bu	36.0	56.9	44.0	68.7
Cotton	bale	1.1	1.9	1.4	1.9
Sorghum	bu	57.0	97.9	67.0	126.8
Legume hay	tons	3.2	4.4	3.8	4.2
CROPLAND NEEDS (million acres)		385.9	218.3	388.8	218.5

Table 15-1.--Nonfederal land, by subclass and classes I, V & VIII

Farming region and state	Land capability subclass					Land Capability Class		Other 2/ land	Grand total
	e	w	s	c	Total	I	V & VIII 1/		
NORTHEAST:									
Connecticut	225.2	225.2	1676.8	0.0	2127.5	52.4	148.8	779.8	3108.5
Delaware	185.3	424.3	231.1	0.0	840.7	89	94.1	179.7	1203.5
Maine	2689.8	2668.1	12297.3	0.0	17655.2	76.4	1212.7	757.4	19701.7
Maryland	2430.3	1317.8	776.7	0.0	4524.8	184.2	396.3	1008.6	6113.9
Massachusetts	259.7	381	2719.9	0.0	3360.6	39.9	373	1149.6	4923.1
New Hampshire	736.4	314.4	3251.4	77.1	4379.3	26	156.9	471	5033.2
New Jersey	723.5	1002.5	976.6	1.5	2704.1	105.5	474.2	1351.1	4634.9
New York	11096.2	7147.3	7303	0.0	25546.5	389.6	1089	3058.6	30083.7
Pennsylvania	12549.8	3386.3	8333.8	0.0	24269.9	314.7	257.3	3217.8	28059.7
Rhode Island	31.5	64.9	338.9	0.0	435.3	18.3	43.8	174.1	671.5
Vermont	1793.6	518.1	2827.4	3.1	5142.2	29.2	143.5	304.3	5619.2
Subtotal	32721.3	17450.2	40732.9	81.7	90986.1	1325.2	4389.6	12452	109152.9
APPALACHIA:									
Kentucky	17027	1862.2	2730.7	0.0	21619.9	1105.2	31.9	1521	24278
North Carolina	12869.6	8954.3	2859.1	0.6	24683.6	618.2	912.6	2896.2	29110.6
Tennessee	13861.1	3029.1	5208.3	0.0	22098.5	710.3	248.6	1922.5	24979.9
Virginia	14078	2685.1	3277.7	0.0	20040.8	472.4	586.8	1962.6	23062.6
West Virginia	7738.7	516.8	5158.9	0.0	13409.4	64.2	194	662.3	14329.9
Subtotal	65574.4	17047.5	19229.7	0.6	101852.2	2970.3	1973.9	8964.6	115761
SOUTHEAST:									
Alabama	17929.3	4242.6	4807.6	0.0	26979.4	550.4	1986.9	2036.7	31553.4
Florida	1226.7	17773.7	6233.9	0.0	2523.3	97.3	2286	3910.6	31528.2
Georgia	15880.9	6697.6	4884.2	0.0	27462.7	935.5	3986.4	2693.5	35078.1
South Carolina	6233.4	6393.8	2783.7	0.0	15410.9	624.7	502.4	1635.2	18173.2
Subtotal	41270.3	35107.7	18709.3	0.0	95087.3	2207.9	8761.7	10276	116332.9
DELTA STATES:									
Arkansas	12205.7	10136.2	4157.9	0.0	26499.8	756.3	1468.8	1495.6	30220.5
Louisiana	7279.6	12367	354.8	0.0	20001.4	520.2	4626.3	1954.6	27102.5
Mississippi	15006.	8964.5	544.1	0.0	24514.6	514.1	1958.4	1570.4	28557.5
Subtotal	34491.3	31467.7	5056.8	0.0	71015.8	1790.6	8053.5	5020.6	85880.5
CORN BELT:									
Illinois	14351.	11927.1	1146.2	0.0	27424.3	4261.1	251.5	3200.3	35137.2
Indiana	8539.4	9582.4	1345.3	0.0	19467.1	806.3	172.4	2067.7	22513.5
Iowa	19008.4	9417.6	1519.4	0.0	29945.4	3328.1	382.1	1988	35643.6
Missouri	18956.	6819.	12423.5	0.0	38228.5	1070.1	133	2551.7	41983.3
Ohio	12308.1	9118.9	748.8	0.0	22175.8	340.2	80.3	3295.7	25892
Subtotal	73162.9	46895	17183.2	0.0	137241.1	9805.8	1019.3	13103.4	161169.6
LAKE STATES:									
Michigan	8951.2	9968.4	8223.8	0.0	27143.4	38.7	2699.2	3486.9	33368.2
Minnesota	13742.3	20174.8	6267.1	968	41152.2	2238.9	1542.8	2523.4	47457.3
Wisconsin	15110.9	8291.7	5908	0.0	29310.6	458.2	913.3	2381.9	33064
Subtotal	37804.4	38434.9	20398.9	968	97606.2	2735.8	5155.3	8392.2	113889.5

Table 15-1.--Nonfederal land, by subclass and classes I, V & VIII

Farming region and state	Land capability subclass					Land Capability Class		Other 2/ land	Grand total
	e	w	s	c	Total	I	V & VIII 1/		
NORTHERN PLAINS:									
Kansas	32935.	3182.2	3480.3	5826.5	45424.	3459.8	721.	2179.9	51784.7
Nebraska	34871.3	3826.3	3025.2	1781.	43503.8	2666.8	795.7	1483.1	48449.4
North Dakota	26305.5	2896.1	4667.5	5901.3	39770.4	0.0	1228.7	1434.6	42433.7
South Dakota	26562.2	2749.5	7363.2	4606.6	41281.5	1954.1	1258.1	1268.1	45761.8
Subtotal	169979.7	219285.4	18536.2	18115.4	425916.7	8080.7	4003.5	6365.7	188429.4
SOUTHERN PLAINS:									
Oklahoma	24512.4	2918.	8908.5	1357.7	3769.6	1601.	1427.8	2057.3	42782.7
Texas	74726.3	14729.5	49524.9	9525.6	148506.3	1502.7	7193.9	7562.4	164765.3
Subtotal	99238.7	17647.5	58433.4	10883.3	186202.9	3103.7	8621.7	9619.7	20754_
MOUNTAIN:									
Arizona	8489.2	447.8	22346.2	4871.6	36154.8	789.5	2623.3	1035.8	40603.4
Colorado	29538.2	1401.8	5532.	2952.2	39424.2	208.5	1537.8	1525.8	42696.3
Idaho	12171.7	995.1	3315.9	1686.2	18168.9	120.1	617.9	542.5	19449.4
Montana	52540.3	2127.2	8381.7	129.9	63179.1	0.0	1465.	1303.	65947.1
Nevada	932.1	1364.6	5837.9	1302.5	9437.1	1.1	343.2	377.1	10158.5
New Mexico	32730.2	456.1	14360.8	926.7	48473.8	222.2	1795.	756.	51247.
Utah	7249.2	925.2	5245.7	698.8	14116.9	45.8	2061.1	479.3	16703.1
Wyoming	25040.3	1044.5	4100.	496.4	30681.2	0.9	1542.7	577.7	32602.5
Subtotal	168691.2	8762.3	69120.2	13062.3	259636.	1388.1	11986.	6597.2	27960.7
PACIFIC:									
California	28744.3	3687.1	9894.6	702.9	43028.9	2188.4	4407.7	4845.5	54470.5
Oregon	15336.9	2299.7	9229.4	476.8	27342.8	203.7	684.7	1100.9	29332.1
Washington	20529.1	2003.8	4622.1	392.1	27547.1	160.3	671.7	1712.6	30091.7
Subtotal	64610.3	7990.6	23746.1	1571.8	97918.8	2552.4	5764.1	7659.	113894.3
TOTAL	787544.5	440088.8	291146.7	44683.1	1563463.1	35960.5	59728.6	88450.4	1491665.6

1/ Data on subclasses of land in classes V and VIII were not collected for the 1982 NRI.
2/ Data on capability classification were collected only for rural agricultural land.
Source: 1982 NRI.

Table A16-1.--Groundwater resources

Water resources regions	Underground storage: Estimated total (a) volume	Underground storage: Available (b)1/	Underground storage: Recoverable volume of water (b)2/	Surface area overlying recoverable groundwater (b)	Minimum recharge rate (a) 3/	Groundwater withdrawals: Offstream uses (d): Nonag. (c)	Groundwater withdrawals: Offstream uses (d): Irrigation & livestock(c,d)	Groundwater withdrawals: Overdraft in excess of recharge(a,d)
	(million acre-feet)			(million acres)		(million acre-feet per year)		
1. New England	N	N				0.72	0.01	
2. Mid-Atlantic	3,564	1,271				2.49	.22	0.1
3. So. Atlantic	N	13,692				4.95	1.71	.4
4. Great Lakes	N	801				1.53	.36	.1
5. Ohio	4,295	1,176				2.60	.13	
6. Tennessee	N	1,627				.28	.02	
7. Upper Miss.	14,239	6,886				2.30	.75	
8. Lower Miss.	7,970	3,905			5.00	2.02	5.37	.5 - 2.4
9. S-R-R	2,158	528			.10	.06	.12	.1
10. Missouri	3,432	1,366	2,650	62.00	8.80	1.31	15.89	2.9 - 8.4
11. A-W-R	2,039	1,532	525	32.00	3.80	.94	8.28	5.4 - 6.1
12. Texas-Gulf	8,605	4,402	727	74.00	1.90	1.33	8.31	6.2 - 7.7
13. Rio Grande	49,221	5,753	4,151	6.10	1.90	.34	1.76	.2 - .7
14. Up. Colorado	3,236	240	-	.03	.14	.07	.25	.1 - .2
15. Lo. Colorado	1,753	N	1,028	8.70	2.90	.68	3.62	1.4 - 2.7
16. Great Basin	2,898	525	323	19.00	.94	.63	2.17	.7 - 1.9
17. C-N-P	4,227	553	264	25.00	7.50	3.42	8.67	.7 - 4.6
18. California	1,004	252	192	16.00	19.00	3.73	15.73	1.5 - 2.4
Contiguous U.S.						29.40	73.37	20.0 -37.8
19. Alaska	N	3,443				.05	.01	
20. Hawaii	N	N				.36	.45	
21. U.S. Caribbean	N	49				.19	.20	
National total						30.00	74.03	18.0 -37.8

Sources: (a) Second National Water Assessment, Vol 3, Appendix II, Table II-1.
(b) Compiled by CARD from USGS Papers 813 and HA-648, Texas Department of Water Resources report 238, DOC 1978 Farm and Ranch Irrigation Census, Columbia-North Pacific Technical Staff paper - Appendix V, and DOC Six-State High Plains Ogallala Aquifer Regional Resources Study.
(c) USGS Circular 1001.
(d) 1985 RCA Analysts.

1/ Amount of the total that can be tapped with conventional wells and methods.
2/ Available water that is suitable for irrigation and practical for withdrawal.
3/ Overdrafts are withdrawal rates that exceed groundwater recharge rates. The recharge rate in subregions where there are no overdrafts is not known.

Table 16-2.--Summary of freshwater supply and use and additional water available for agriculture

Water resources region	Condition	Stream inflow	Supply: Natural outflow	Supply: Net import	Supply: Groundwater overdraft 1/	Use: Consumption: Non-ag.	Use: Consumption: Ag.	Use: Net evapo.	Use: Net export	Remaining stream outflow	Instream flow req. 3/	Remaining additional water for ag.
		- million gallons per day -										
1. New England	1985 Ave	0	78,661	0	0	597	35	0	0	78,028	69,001	9,027
	2030 Ave	0	78,661	0	0	1,558	35	0	0	77,067	69,001	8,066
	Dry 5/	0	63,211	0	0	1,558	46	0	0	61,606	47,197	14,409
2. Mid-Atlantic	1985 Ave	0	80,522	479	32	2,134	226	0	0	78,672	68,840	9,832
	2030 Ave	0	80,522	479	32	4,610	226	0	0	76,196	68,840	7,356
	Dry	0	62,563	479	32	4,610	279	0	0	58,184	48,313	9,871
3. S.Atlantic-Gulf	1985 Ave	0	232,544	0	339	3,422	2,589	0	0	226,871	188,655	38,216
	2030 Ave	0	232,544	0	339	13,012	2,589	0	0	217,281	188,655	28,626
	Dry	0	168,668	0	339	13,012	3,866	0	0	152,128	139,526	12,602
4. Great Lakes	1985 Ave	0	75,262	19	27	3,046	401	0	0	71,860	63,951	7,909
	2030 Ave	0	75,262	19	27	7,218	401	0	0	67,688	63,951	3,737
	Dry	0	59,832	19	27	7,218	483	0	0	52,176	45,157	7,019
5. Ohio	1985 Ave	40,800	138,998	0	0	2,347	180	0	0	176,941	160,520	16,421*
	2030 Ave	39,027	138,998	0	0	7,257	180	0	0	170,567	160,520	10,047*
	Dry	34,126	106,898	0	0	7,257	224	0	0	133,520	107,681	25,838*
6. Tennessee	1985 Ave	0	41,113	0	0	601	40	0	0	40,471	38,480	1,991
	2030 Ave	0	41,113	0	0	2,065	40	0	0	39,007	38,480	527
	Dry	0	36,213	0	0	2,065	43	0	0	34,104	24,667	9,436
7. Upper Mississippi	1985 Ave	44,100	76,024	2,064	0	1,091	647	43	0	119,457	110,750	8,707*
	2030 Ave	41,231	76,024	2,064	0	3,422	647	46	0	114,193	110,750	3,443*
	Dry	24,447	61,664	2,064	0	3,422	817	46	0	82,726	71,505	11,220*
8. Lower Mississippi	1985 Ave	361,600	75,015	0	412	1,297	3,965	0	0	430,059	359,033	71,026*
	2030 Ave	343,663	75,015	0	412	4,380	3,965	0	0	410,141	359,033	51,108*
	Dry	249,101	15,405	0	412	4,380	4,433	0	0	255,336	241,897	13,438*
9. Souris- Red-Rainy	1985 Ave	0	6,138	0	0	55	129	16	0	5,937	3,673	2,264
	2030 Ave	0	6,138	641	0	89	129	19	0	6,541	3,673	2,868
	Dry	0	3,488	641	0	89	165	19	0	3,855	1,841	2,014
10. Missouri	1985 Ave	0	61,525	411	2,557	1,081	15,336	4,924	0	43,151	33,958	9,193
	2030 Ave	0	61,525	0	2,557	2,792	15,336	5,595	137	40,221	33,958	6,263
	Dry	0	46,695	0	2,557	2,792	17,444	5,595	137	23,283	18,457	4,825
11. Ark.-White-Red	1985 Ave	0	67,694	128	5,457	1,063	6,106	2,615	0	63,494	46,169	17,325
	2030 Ave	0	67,694	200	2,343	2,722	6,106	3,111	0	58,297	46,169	12,128
	Dry	0	42,494	200	2,343	2,722	7,118	3,111	0	32,085	20,308	11,777

Table 16-2.--Summary of freshwater supply and use and additional water available for agriculture

Water resources region	Condition	Stream inflow	Supply: Natural outflow	Supply: Net import	Supply: Groundwater overdraft 1/	Use: Consumption: Non-ag.	Use: Consumption: Ag.	Use: Net evapo.	Use: Net export	Remaining stream outflow	Instream flow req. 3/	Remaining additional water for ag.
		- million gallons per day -										
12. Texas-Gulf	1985 Ave	0	35,626	30	5,578	2,433	6,282	1,705	0	30,813	22,917	7,896
	2030 Ave	0	35,626	30	3,245	8,585	6,282	1,992	0	22,041	22,917	-875
	Dry	0	19,622	30	3,245	8,585	7,090	1,992	0	5,229	10,687	-5,458
13. Rio Grande	1985 Ave	0	5,309	234	657	361	2,660	730	0	2,448	2,287	161
	2030 Ave	0	5,309	199	657	701	2,660	785	0	2,018	2,287	-268
	Dry	0	4,349	199	657	701	2,954	785	0	764	1,592	-828
14. Upper Colorado	1985 Ave	0	13,956	0	0	330	2,429	711	805	9,680	7,947	1,733
	2030 Ave	0	13,956	0	0	823	2,429	728	1,095	8,880	7,974	933
	Dry	0	10,976	0	0	823	2,687	728	1,095	5,642	4,186	1,455
15. Lower Colorado	1985 Ave	10,000	-605	0	2,415	739	3,044	1,202	4,463	2,041	6,864	-4,822*
	2030 Ave	8,921	-605	0	2,415	1,769	3,044	1,236	3,896	744	6,864	-6,119*
	Dry	5,708	2,185	0	2,415	1,769	3,133	1,236	3,896	208	2,904	-2,695*
16. Great Basin	1985 Ave	0	5,976	101	591	649	3,096	327	0	2,595	3,389	-793
	2030 Ave	0	5,976	251	591	1,205	3,096	333	0	2,183	3,389	-1,205
	Dry	0	5,060	251	591	1,205	3,493	333	0	870	1,792	-922
17. Pacific N.W.	1985 Ave	0	268,523	47	627	1,162	12,402	2,014	0	253,618	214,004	39,614
	2030 Ave	0	268,523	47	627	3,094	12,402	2,083	0	251,617	214,004	37,613
	Dry	0	226,586	47	627	3,094	15,655	2,083	0	206,427	80,556	125,871
18. California	1985 Ave	0	68,050	4,438	2,197	2,680	19,689	669	0	51,646	32,607	19,039
	2030 Ave	0	68,050	3,881	857	4,927	19,689	686	0	47,485	32,607	14,878
	Dry	0	50,442	3,881	857	4,927	21,180	686	0	28,386	20,415	7,971
Contiguous U.S. Regions 1-18	1985 Ave	0	1,330,331	2,677	20,889	25,088	79,263	14,956	0	1,234,589	1,035,221	199,936
	2030 Ave	0	1,330,331	2,677	14,102	70,229	79,263	16,614	0	1,181,003	1,035,221	145,782
	Dry	0	986,351	2,677	14,102	70,229	91,117	16,614	0	825,169	645,192	179,978

*Volumes of water remaining for additional agriculture include surplus water from upstream regions.

1/ Future (2030) overdrafts are limited to current (1975) or "allowable" overdrafts, whichever is the lesser. Allowable overdrafts are determined by dividing the stock resource (recoverable ground water) by 200 (to last 200 years).

2/ Irrigation water requirements for the dry year fully satisfy the crop requirement 8 of 10 years.

3/ Instream-flow approximations (IFA) for fish and wildlife provide optimum habitatin average years. Instream-flow requirements for good survival habitat in dry years are assumed to be 60 percent of mean natural flow in the humid area (regions 1 through 8) and 30 percent of mean natural flow in the subhumid, semi-arid, and arid areas (regions 9 through 18) in dry years.

4/ Natural annual streamflows are exceeded 80 percent of the time.

Sources:

1975 Average Condition from "The Nation's Water Resources 1975-2000 (NWA) inflow and natural outflow - NWA, Vol. 3, Table II-5 for annual average; and
Appendix N, Table N-2 for annual dry condition. To column 17 (assessed total streamflow), add column 10 (net evaporation) and column 6 (net exports).

Future (2030) net imports exports, and evaporation are NWA 2000 projections from Vol. 1, table on pages 54 and 55.

Recoverable water estimates from CARD memo dated 1/11/85.

Table A16-3.--Irrigated area, irrigation water use efficiencies and volumes, by water resources region, 1982

Water Resource Region	Irrigated Area: Cropland by Source and System, and Pasture: Groundwater: Pressure	Groundwater: Gravity	Surface: Pressure	Surface: Gravity	Pasture	Total	Irrigated during 1982	Irrigation Water Efficiencies: Off-farms Conveyance Efficiencies	Net Depletions: Crop & Pasture	Incidential Loss	Return Flows	Water Use: Withdrawals: Gross Diversions	Consumption: Net Depletions
	- - - - - - - - - - thousand acres - - - - - - - - - -							- - Percent of gross diversions - -				1,000 acre-feet per year	
1. New England	3	<1	39	4	1	47	34	96	65	5	30	31	21
2. Mid-Atlantic	145	2	140	13	7	309	242	96	65	5	30	266	184
3. So. Atlantic	1,199	204	1,511	523	539	3,976	2,378	96	64	5	30	3,969	2,732
4. Great Lakes	366	3	257	24	4	654	462	96	65	5	30	527	365
5. Ohio	63	2	41	3	4	113	86	96	65	5	30	108	75
6. Tennessee	2	3	9	3	3	20	12	96	64	5	30	20	14
7. Upper Miss.	684	14	93	13	<1	804	646	96	68	7	25	601	441
8. Lower Miss.	577	3,982	113	655	5	5,331	3,235	96	64	6	30	6,376	4,386
9. S-R-R	63	<1	31	1	<1	95	115	82	51	14	35	178	113
10. Missouri	5,155	3,511	823	3,450	828	13,768	11,575	82	49	14	37	27,359	16,673
11. A-W-R	2,830	3,592	176	524	153	7,275	4,843	94	60	11	29	9,492	6,600
12. Texas-Gulf	2,320	3,303	99	782	99	6,604	3,583	93	60	11	29	9,885	6,844
13. Rio Grande	400	469	122	1,207	379	2,577	1,591	86	55	13	32	4,403	2,942
14. Up. Colorado	7	53	123	1,059	429	1,673	1,380	75	38	15	47	5,154	2,693
15. Lo. Colorado	82	984	6	284	75	1,431	1,158	86	55	10	35	5,356	3,358
16. Great Basin	439	179	241	1,056	494	2,409	1,756	79	40	15	45	6,409	3,434
17. C-N-P	2,140	353	2,218	2,320	1,426	8,458	6,995	73	36	14	50	28,800	13,804
18. California	2,413	1,983	1,371	3,330	933	10,029	8,631	76	53	13	35	34,625	21,938
Contiguous	18,877	18,637	7,413	15,250	5,380	65,570	48,719		49	13	38	143,561	86,617
19. Alaska					<1	<1	<1						
20. Hawaii	65	46	63	44	3	220	146	75	50	8	42	938	538
21. U.S. Caribbean	4	33	5	44	7	92	75	74	48	12	40	467	261
Nation	18,946	18,716	7,481	15,338	5,390	65,882	48,940		48	13	39	144,966	87,416

Table A16-4.--Surface water resources

Water Resource Regions	Surface area of inland water: Large water bodies(a)1/	Streams <1/8 mile wide(b)	Ponds(b) 2-40 acres	Ponds(b) < 2 acres	Total water surface	Reservoir area storage, and evaporation(c): Pool surface area	Storage maximum 3/	Storage normal 4/	Net Evaporation 5/ estimated volume	Net Evaporation 5/ percent of mean flow	Natural outflow(c)6/ (replenishable supply): average year	dry year
	(1,000 acres)					(million acre-feet)			(million ac ft/yr)	(percent)	(billion gallons per day)	
1. New England	2,450					412	19.4	14.5	0	—	78.66	63.21
2. Mid-Atlantic	2,044					142	24.1	19.2	0	—	80.52	62.56
3. S. Atlantic-Gulf	7,068					1,766	60.7	41.1	0	—	232.54	168.67
4. Great Lakes	2,711					182	12.9	10.1	0	—	75.26	59.83
5. Ohio	994					681	43.3	15.8	0	—	139.00	106.90
6. Tennessee	721					466	23.7	11.0	0	—	41.11	36.21
7. Upper Mississippi	2,710					469	23.2	13.0	0.04	0.03	76.02	61.66
8. Lower Mississippi	2,923					542	19.6	6.2	0	—	75.02	15.41
9. Souris-Red-Rainy	1,316					18	7.5	4.4	0.01	0.18	6.14	3.49
10. Missouri	3,428					2,087	118.1	83.4	4.43	6.94	61.53	46.70
11. Ark.-White-Red	1,864					1,515	69.9	30.2	2.13	2.91	67.69	42.49
12. Texas-Gulf	2,490					930	55.0	25.5	1.44	3.79	35.63	19.62
13. Rio Grande	418					173	13.5	7.8	0.73	13.60	5.31	4.35
14. Upper Colorado	608					318	11.3	10.2	0.77	5.55	13.96	10.98
15. Lower Colorado	443					251	72.1	61.3	1.29	18.59	2.19	2.19
16. Great Basin	1,770					130	4.2	3.8	0.36	2.31	5.98	5.06
17. Pacific NW	2,575					1,280	65.2	54.7	2.14	0.72	268.52	226.59
18. California	1,665					413	44.2	39.0	0.72	0.89	68.05	50.44
Regions 1-18	38,198				48,271	11,775	688.0	449.3	14.07	1.11	1,330.33	986.35
19. Alaska						12	0.9	0.8	0	—		
20. Hawaii	29				52	7	0.1	>0.1	>0.01	0.01		
21. U.S. Caribbean	10				32	1	0.4	0.3	0	—		
Total 2/	38,237	5,451	3,265	1,402	48,355	11,795	689.2	450.3	14.07	0.61		

Sources: (a) Compiled from Statistical Abstract of the United States (18)
(b) 1982 National Resources Inventory (14a)
(c) Second National Water Assessment (29)

1/ Large water bodies include streams one-eighth mile wide or wider and lakes of 40 acres or more. The Great Lakes, coastal waters, bays, and estuaries are not included.
2/ Exclusive of Alaska.
3/ Maximum storage is flood capacity and normal storage.
4/ Normal storage is that capacity designated for purposes other than flood control.
5/ Zero values indicate that evaporation losses are offset by precipitation.
6/ Natural outflow is the long-range streamflow that would be available at the outflow point of a region if consumption were eliminated, groundwater overdrafting were discontinued, water transfers would cease, and there were no net evaporative losses from reservoirs. The natural flow is a measure of replenishable supplies.

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