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Soil Deterioration and the Growing World Demand for Food

Soil losses by water erosion are estimated in five intensively farmed Wisconsin watersheds.

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Below that thin layer comprising the delicate organism known as the soil is a planet as lifeless as the moon.–G. Y. JACKS and R. O. WHYTE (*1*).

A major contemporary problem in agriculture is how the mounting world need for food and livestock feed can be met in the face of an enormous and continuing increase in population without irreparably damaging the soil base on which their production depends. Soil losses due to water or wind erosion are coextensive with crop production on tilled land. Throughout much of human history deprivation has been largely kept at bay by shifting to other territory as the soils of the old were exhausted. In our time this evasion no longer works; there are now few, if any, virgin, high-quality soils in the world to turn to. Much of the remaining new land is of marginal quality and will require expensive improvements to be made agriculturally productive, or it is subject to other limitations. Meanwhile, the demand for food soars as the world's population increases by about 80 million persons per year.

More than a generation ago Jacks and Whyte (*1*) called attention to soil erosion by wind and water as a problem of global extent. Ecklund (*2*) recently described the increasingly serious degradation that is occurring in heavily populated Third World countries. The issue is of immediate domestic concern also. According to an inventory of conservation needs prepared by the U.S. Department of Agriculture (USDA) in 1974, additional soil protective measures are needed to ensure permanent agriculture on about two-thirds of the cropland and pasture in the United States (*3*). Pimentel *et al.* (*4*) recently called attention to the large losses of U.S. farmland that have resulted from urban expansion and highway construction as well as from soil erosion.

Expanding market forces in industrialized countries have significantly increased the pressure on U.S. soils for food and livestock feed. Even more serious are the rapidly growing food requirements of Third World countries, many of which are now only marginally able to feed themselves. Simultaneous, widespread crop shortfalls in these countries could result in calls for relief of unprecedented magnitude.

We have fallen behind in recent years in accommodating ourselves to such rapidly changing conditions. A comprehensive program of soil erosion control was inaugurated in the United States in the 1930's; it was one of the most important conservation developments in this nation's history. There are now unmistakable signs, however, that the program is becoming inadequate to protect our soils from unacceptable losses. As a result of mounting pressures on the land, the need for soil saving measures is outrunning the capacity of conservation agencies, as now financed, to assist farmers in meeting it. The first step in securing remedial action is arousing public recognition of this fact. Circumstances have greatly changed since organized soil conservation under public auspices was begun about 40 years ago.

In this article we present estimates of the soil damage that is occurring in one productive farming area in the United States under the impact of modern agricultural technology and in response to the current upsurge of international market forces affecting food supplies; the results of this local study are meaningful for a wide area northward from the central corn belt and elsewhere in the United States where row cropping is prevalent on sloping land. We then consider the general outlook for demands on U.S. agricultural exports, with particular reference to the food needs of Third World countries. Finally, research areas and conservation measures that should be emphasized for soil erosion control in the United States are discussed.

Soil Erosion Survey of Five Wisconsin Watersheds

The 1975 survey of crop acreages and soil erosion in Dane County is part of an ongoing study by the Dane County Soil and Water Conservation District and the Regional Planning Commission in developing a county water quality plan. Four of the five watersheds are located in the glaciated eastern section of the county, and one is in the unglaciated or "Driftless" area.

These watersheds are representative of a broad area of the northern Corn Belt. The Driftless area, represented in the survey by the Mount Vernon Creek watershed, covers 4,780,000 hectares in southwestern Wisconsin, but includes small adjoining parts of northwestern Illinois, northeastern Iowa, and southeastern Minnesota. The USDA Soil Conservation Service (SCS) calls this region the Northern Mississippi Valley Loess

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Table 1. Distribution of cropland and estimated soil losses in five Dane County watersheds. The values in parentheses in columns 7 and 8 are metric tons per hectare per year.

Watershed	Cropland					Estimated soil losses (ton acre^{-1} year^{-1})	
	Percentage of total farmland	Corn (%)	Hay and rotation pasture (%)	Oats (%)	Other crops (%)	Average	Highest quarter-section
Maunesha River	80	76	12	8	1	5.9 (13.3)	13.7 (30.8)
Door Creek	66	70	12	4	4	8.6 (19.3)	24.8 (55.8)
Sixmile Creek	76	61	27	5	4	7.5 (16.9)	20.6 (46.3)
Pheasant Branch Creek	79	50	35	12	2	6.5 (14.6)	12.0 (27.0)
Mount Vernon Creek	57	34	57	7	0	5.2 (11.7)	16.0 (36.0)

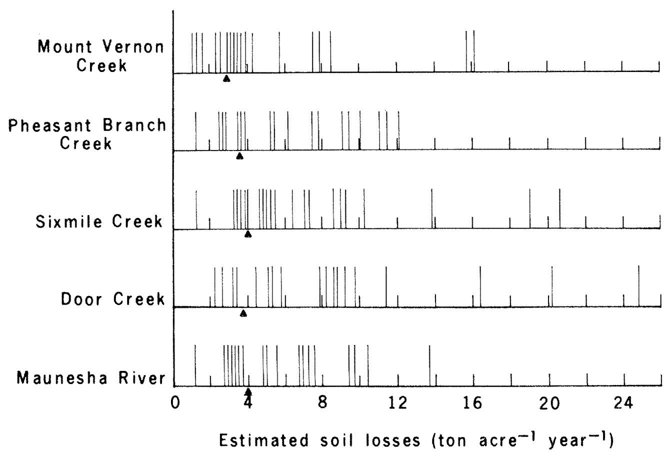

Fig. 1. Estimated annual soil losses from erosion on cropland in five intensively farmed watersheds in Dane County. Each vertical line represents one randomly chosen quarter-section (65 ha) sampled area. (▲) Respective estimated amounts of erosion that the soils can tolerate and still remain productive. (Multiply by 2.25 to convert the baseline scale to metric tons per hectare per year.)

Hills (5). The glaciated portion of Dane County is an area of deep or moderately deep silt loam soils and undulating to rolling topography. The major land resources area of which it is a part is designated by SCS as the Southeastern Wisconsin Drift Plain, which covers southeastern Wisconsin and extends well into northern Illinois (6).

The 4160-ha Mount Vernon Creek watershed has ridge and valley topography. It has the steepest slopes and shallowest soils of the five watersheds surveyed and therefore has the greatest erosion potential. It does not, however, have the highest soil loss, as will be discussed later.

Sixmile Creek watershed (15,860 ha) and Pheasant Branch Creek watershed (5200 ha) are located in areas of terminal and recessional moraines with gentle to steep slopes and commonly irregular topography. Both drain into 3645-ha Lake Mendota. Door Creek watershed (3640 ha) and Maunesha River watershed (9100 ha) are located in a drumlin-marsh area, characterized by gently rolling hills separated by wetlands, many of which are now tile-drained.

All the watersheds support a large number of dairy and beef cattle and swine. Corn, alfalfa, and oats are the leading field crops. Canning crops, particularly peas and sweet corn, are also important in all but the Mount Vernon Creek watershed.

Four especially noteworthy changes have occurred in the farming pattern in Dane County in the past decade. First, there has been a 57 percent increase in corn acreage. Most of the increase has been at the expense of oats acreage, which has decreased 46 percent, and includes land that has been in the federal soil bank and diverted acres programs. Second, the number of dairy herds has decreased by nearly 46 percent and the number of dairy cows by 26 percent (6). Third, there are fewer farms, and the farming is now being done by fewer people. Fourth, the amount and size of the power equipment used have increased greatly.

Survey technique. A standard SCS technique was used in the soil erosion survey. Eighteen or more quarter-sections (65 ha each) were randomly chosen for study within each watershed. Soil type, degree of slope, length of slope, and current crop were recorded. Farmers were interviewed to learn the crop rotations and tillage practices employed.

Soil losses resulting from water erosion were estimated for each sampled area within a watershed by using the universal soil loss equation (7) employed by the SCS for predicting soil erosion and planning conservation. This multiterm equation, developed by the USDA Agricultural Research Service, is based on the results of more than 30 years of research at 48 stations in 26 states on the environmental factors that affect soil erosion (8, 9).

The number of blocks and the percentage of each watershed sample varied according to the size of the watershed. The percentages of the total area sampled in the respective watersheds to give uniform statistical reliability to the derived values for soil loss were: Pheasant Branch Creek, 22.8; Sixmile Creek, 8.6; Door Creek, 14.5; Maunesha River, 13.2; and Mount Vernon Creek, 28.0.

Distribution of land between crops. The data on crop acreages collected for the five watersheds are summarized in Table 1. As shown in column 2 of Table 1, two-thirds or more of the farmland is used for crops in four of the five watersheds. The value is only 57 percent for Mount Vernon Creek watershed, which has 14 percent in woodland and 21 percent in permanent pastures. A striking feature of the crop distribution in the area, as shown in column 3, is that corn now occupies one-half to three-fourths of the cropland in four of the watersheds. Based on countywide data, this is an increase of about 33 percent in the last 6 years and 57 percent in the last 10 years. The highest value, that for Maunesha River, is 76 percent. The lowest value for corn land in the series is 34 percent for Mount Vernon Creek watershed.

The percentages of cropland used for hay and rotation pasture in the several watersheds are in reverse order to those for corn. Maunesha River and Door Creek devote only 12 percent to hay and rotation pasture. The proportion of cropland in hay and rotation pasture reaches its maximum in Mount Vernon Creek watershed, where the value is 57 percent. Countywide, oats acreage has decreased 46 percent in the last 10 years.

Estimated Soil Losses

Average soil losses from water erosion in the five watersheds, estimated from the universal soil loss equation, are shown in Table 1. The individual values vary widely from one sampled quarter-section to another in each watershed. Because of the high dispersion and the irregularity of the distributions, the soil loss value for each sampled area is entered separately in Fig. 1. The soil loss estimates for all the quarter-sections sampled ranged from 2.3 to 24.8 (short) tons per acre per year (5.2 to 55.8 metric tons per hectare per year).

The amount of soil lost by erosion that is considered tolerable varies with effective depth for each soil type, being higher for deep soils and lowest in the extreme case of a shallow soil over bedrock. Each soil in Dane County has been assigned a tolerated or allowable soil loss value by the SCS based on the amount of erosion it can tolerate and still remain productive. These so-called *T* factors ordinarily vary from 1 to 5 tons per acre per year (2.2 to 11.2 metric tons per hectare per year).

The five watersheds. Based on an analysis of the soil types on the cropland of the sample quarter-sections, an average *T* factor for the cropland in each of the five watersheds was determined. The average allowable soil loss for the Maunesha River and Sixmile Creek watersheds is 4 tons per acre per year. Mount Vernon Creek watershed, because of its somewhat more shallow soils, averages 2.8 tons per acre per year. The values for the Door Creek and Pheasant Branch Creek watersheds are 3.8 and 3.6 tons, respectively. The solid triangles on the soil loss scale in Fig. 1 mark the average *T* factors for the watersheds.

Of the 93 quarter-sections sampled in the five watersheds 65, or 70 percent, show estimated soil losses above the tolerated levels. Door Creek has the highest percentage of samples above the 4-ton level, namely 78 percent. The average *T* factor for the five watersheds is 3.6 tons per acre per year. Considering individual cases, the aggregate soil loss for the 65 individual entries in Fig. 1 that are above their respective allowable levels exceeds the value of 3.6 tons by 4.8 tons, on the average. That is, more than twice as much soil (3.6 + 4.8 tons) is being lost on 70 percent of the quarter-sections sampled than is consistent with proper land management.

In the four glaciated watersheds contour strip-cropping has been eliminated on nearly 2000 acres since 1967. This estimate is based on a comparison of 1967 aerial photographs of the quarter-section samples with present field patterns. Most of the fields in question are still contoured, but the alternate strips of hay and cultivated crops have disappeared because of the conversion to continuous corn growing. This change could more than double the soil loss.

Mount Vernon Creek watershed. This watershed is a special case because it lies within the Driftless area, where the soils tend to be shallow and the slopes, in general, are steep. Of the five watersheds surveyed, it has the lowest average predicted annual soil loss, 5.2 tons per acre of cropland. Note from Fig. 1 that the soil loss values for cropland of the 18 quarter-sections sampled in this watershed are clustered toward the lower end of the scale. In only two of these quarter-sections are the losses severe—15.7 and 16.0, respectively.

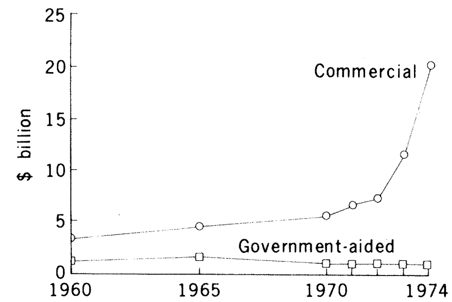

Fig. 2. U.S. agricultural exports from 1960 to 1974 (*24*).

Because of the steep topography of the area and the nearness of the bedrock to the surface, the soils in Mount Vernon Creek watershed are the ones most subject to destruction under row cropping. Why, then, does this watershed make the best showing among the five surveyed?

Since the establishment of the SCS, the Driftless area of southwestern Wisconsin has been the scene of a major research and educational effort in soil stabilization. This has transformed the region from one in which soil deterioration by sheet erosion and gully formation was widespread to one in which farming in accordance with sound conservation principles is now common.

The pressures to increase the acreage of row crops even in the Driftless area, however, must not be underestimated. A tabulation of data from the Wisconsin Department of Agriculture Statistical Reporting Service shows that the acreage of corn for grain and silage for the seven-county district in extreme southwestern Wisconsin, all in the Driftless area, rose from 420,000 to 520,000 in the period 1954 to 1974, a 24 percent increase.

Other areas. The estimated soil losses given above for five Dane County watersheds are probably indicative of what is happening over large areas of cropland in the United States. In a similar soil erosion study of the Obion–Forked Deer River Basin (1.2 million hectares) in northwest Tennessee, for example, the average erosion rate based on all cropland, bottomland as well as upland, was 9.1 tons per acre per year; for upland soils only it was 18.9 tons per acre per year (*10*). According to the study, erosion rates recently increased mainly because of a rise in soybean acreage.

Brune (*11*), the SCS state conservationist for Iowa, recently reported that the estimated average annual soil loss for unprotected sloping cropland in that state is 13 tons per acre. This is about two bushels of soil for each bushel of corn harvested on that land. Brune stated that in 1974, a disastrous erosion season in Iowa, soil losses of 40 to 50 tons per acre were not uncommon.

The severity and generality of the soil erosion problem on a national scale are further illustrated by the various additional instances cited by Pimentel *et al.* (*4*) of losses considerably exceeding the amounts consistent with the maintenance of agricultural productivity.

The Growing Demand for Food

Two factors are likely to keep the demand for cereals and soybeans grown in North America high in the years just ahead. They are (i) the large requirement at home and in other industrialized countries for food and especially for livestock feed, and (ii) the dependence of Third World countries mainly on the United States and Canada for relief in emergencies.

The average American uses about 1 ton of grain a year. Ninety-three percent of this is utilized indirectly as feed for cattle, hogs, and chickens, which supply our main protein sources, meat, milk, and eggs. Rising standards of living in other industrialized countries have led to increases in meat consumption. The amount of meat used in France, the United Kingdom, West Germany, Italy, and the Soviet Union, for example, increased 31 percent, on the average, between 1960 and 1970; in Japan the increase for the same period was 264 percent (*12*). Our much publicized grain sales to the Soviet Union in 1972 resulted from the Soviet government's decision to maintain the level of meat consumption in spite of a poor cereal crop at home. The United States and Canada are now the sources of about 80 percent of the food and feed grains imported by the industrialized nations.

The value of U.S. agricultural exports, as shown in Fig. 2, rose from about $5 billion in 1920 to $20 billion in 1974. Note that nearly all agricultural exports are now on a commercial rather than a government-aided basis under Public Law 480 (1954). In 1974 the United States supplied 85 percent of the soybeans, 60 percent of the feed grain (mostly corn and sorghum), 45 percent of the wheat, 30 percent of the cotton, and 24 percent of the rice moved in international trade (*13*).

With massive shipments abroad and rising consumption at home, the cumbersome agricultural surpluses that accumulated after World War II have disappeared. Brown (*14*) estimates that the world's reserve stock of grain in 1974 was a 33-day supply. We are essentially dependent, therefore, on current production.

Until 200 years ago world population was low and comparatively stable. High birth rates were balanced by high death rates. Then an abrupt demographic change began as a result of falling death rates. It took man from his emergence as a distinct species, perhaps 3 million years ago, until 1830 to assemble the first billion people. As has been frequently pointed out, it required only 100 years (from 1830 to 1930) to add the second billion. The third billion arrived in 30 years, and the fourth billion followed in only 15 years. About 10 years hence, barring a catastrophe, there will likely be 5 billion people on the earth (see Fig. 3).

This enormous population expansion is new to human experience. Its implications for human welfare are profound. Of special concern here is the danger that the increased pressure for food will undermine our soil resources.

Demographers estimate that of the billion people who will be added to the world's population in the next decade, 90 percent will be in the economically underdeveloped nations of Asia, Africa, and Latin America. How are these 900 million additional mouths to be fed?

A realist has remarked that some problems do not have solutions, only consequences. The world population-food problem is one of them, in the sense that poverty and distress have become important components of it, as Malthus (*15*) foresaw. The technological problems involved are varied and often complex and the strains on people resulting from overcrowding and a dearth of the necessities for life threaten the political fabric of nations. The surging world population is pushing man in many places to the limits of his adaptability.

A general solution is not in sight, but we can visualize certain consequences of rapid population growth. Some that are particularly relevant to the subject of this article are mentioned below.

1) The prospect of feeding the world adequately is hopeless if the present rate of population increase (about 2.2 percent per annum) continues. Exponential population growth cannot go on indefinitely. However, population control measures cannot solve the acute food problem that will develop in the decades just ahead. It would take about 75 years to obtain zero population growth even if a net reproduction rate of unity were achieved today. This is because of the age distribution in many underdeveloped countries. In Mexico, for example, not only is the growth rate very high, 2.4 percent, but 48 percent of the present population (60 million) is under 15 years of age. In Sweden, in contrast, where the growth rate is 0.2 percent, only 21 percent of the population (8.2 million) is under 15 years of age (*16*). Mexico's population would continue to surge even if the size of new families were reduced at once to 2.1, the replacement value. Sweden's would quickly decline under the same limitation.

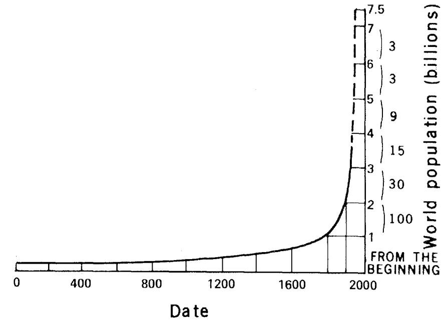

Fig. 3. World population growth, projected under the assumption of constant fertility levels and declining mortality (*25*).

2) The United States and Canada are the only remaining nations in the world with large surpluses of grain (*14*). Other nations that formerly either were self-sufficient or produced a surplus are now net importers. Rising prosperity and improved diets in the industrialized nations, especially Japan, European countries, and the Soviet Union, have used up the surplus stocks accumulated after World War II and have brought back into cultivation the idle cropland in the United States and Canada. The rising demand from the industrial nations means that there will be progressively less food available from the United States and Canada for poor countries. The inference is clear: the underdeveloped countries must look to themselves for the major portion of their additional food supply. Can they meet the demand, particularly in view of the fact that there will be about 900 million more people to feed within 10 years? Many with experience in the field are hopeful that food production can be greatly increased eventually in the underdeveloped countries, but this probably cannot take place rapidly enough to meet the shortages likely to develop in the decades just ahead. Apprehension arises from the fact that increasing agricultural production in much of the Third World involves not merely technical problems, but the political, social, and economic foundations of those nations.

3) Raising food production on a scale commensurate with population growth in the underdeveloped countries necessitates changing from subsistence farming to market agriculture. Growers need the purchasing power to obtain fuel, fertilizer, irrigation water, seed of improved varieties, pesticides, tools, machinery, storage facilities, and transportation and the management skills for a complex farming and marketing operation. This involves a reordering of the national economy in many instances and radical changes in patterns of living.

4) If large food shortages become widespread, they will affect not only the Third World countries but also the industrialized nations. Tensions between the rich and the poor countries will mount with respect to (i) the donation of food for the relief of starving people, (ii) the terms of international trade in various raw materials on which industry is dependent, and (iii) greatly increased monetary and technical assistance for Third World development.

Responses to the Crisis

Since no general international plan for coping with the population-food problem is now in sight, the several consequences of explosive population growth will have to be dealt with separately as they become evident. Crucial questions will arise, including how to contain inflation in the face of persisting food scarcities. Many specialists are already concerned with the agricultural research and development needed in a world swarming with people (*17, 18*). A much less conspicuous problem, but one that is also vital for the national welfare, is how to protect our soils from degradation as a result of the growing pressures on them. In our judgment, this is a domestic problem which should have the highest priority.

During the last 30 years important gains have been made in controlling erosion on the U.S. cropland most subject to soil losses. Millions of acres less prone to damage but vulnerable over time still await adequate protection. The acreage of the two leading row crops, corn and soybeans, which already extend onto much unprotected sloping land, may rise further; market forces favoring such a trend are strong. Furthermore, corn growing has gained extraordinary momentum as a result of the development by intensive breeding of inherently high-yielding, fertilizer-responsive, and widely adapted hybrid strains, effective pest control, and complete mechanization. The demand for soybeans as an economical source of both high-quality protein and edible oil may drive U.S. acreage in this crop upward. Provision must be made, therefore, in the development of conservation plans, for the protection of a large acreage of row crops from excessive soil losses.

The national goal for soil conservation should now be soil security for all sloping cropland. This calls for wider application of all the familiar devices and procedures working toward this end, including contour farming, strip-cropping, terraces, sod waterways, interplanting, and conservation tillage practices.

Research

Two research areas particularly merit increased attention in an expanded soil erosion control program. One of these is forage crop breeding and management and the other is conservation tillage of row crops.

Forage plants are highly important for livestock feed; they are also of prime significance in protecting the soil against erosion (*19*). Row crops, except for the canopy developed from about midseason to harvest, leave much of the surface bare and thus subject to abrasion and scouring by wind and water. Small grains offer some protection by their uniform, although somewhat sparse, coverage of the soil. Only grasses and close-growing perennial forage legumes can afford complete vegetative cover and ensure against excessive soil losses even on relatively steep slopes.

Row crops and meadow crops are frequently grown in rotation in livestock farming. In the Great Lakes states, for example, corn is often followed by several years of alfalfa. In regions where much of the land is steeply sloping, the balance between the acreage of corn, an annual row crop, and alfalfa, a perennial, close-growing, meadow crop, is particularly important in soil erosion control. In seven Wisconsin counties within the hilly Driftless area, the ratio of harvested acres of meadow crops (mostly alfalfa) to those of corn declined from about 1.3 to 1.1, or about 15 percent between 1965 and 1974. The acreage of both corn and alfalfa increased during the period, mostly at the expense of oats, but corn increased more than twice as much as alfalfa (*20*). The steady gains in productivity of corn and the relative efficiency and convenience with which this crop is now handled with machines are major reasons for the larger corn increase.

Research support for forage crops lags far behind that for corn. Hodgson (*21*) stated that grasses and legumes now receive only about 4 percent of the funds provided for U.S. agricultural research, even though these crops, grown for livestock feed, are the mainstay of U.S. agriculture. More forage research funds could be of inestimable value for regions where erosion control calls for a high ratio of meadow crops to row crops in rotation farming.

Conservation tillage is a relatively new factor in soil protection (*22*). Revolutionary developments in chemical weed control since 1945 have stimulated changes in cropping systems and tillage practices that are significant for soil conservation. Conservation tillage reduces soil erosion by leaving residues from the preceding crop on the surface. Moldboard plows, which tend to bury these residues, are being replaced by machines that diminish soil displacement during and after preparation for row planting and also leave most of the plant debris in manageable form on top of the soil. These residues, if sufficiently dense, break the fall of raindrops, reduce splash and the detachment of small particles from the aggregated soil mass, and slow down the water runoff. A marked reduction in erosion can result. The practice is also adapted to large-scale farming with modern, specialized power equipment.

Research is already attacking some problems encountered in adapting conservation tillage to the diversity of soil, topographic, and weather conditions. Weeds, soil insects that impair seedling establishment, and pathogenic fungi associated with crop residues are hazards in a system that leaves much plant debris on the surface to decay slowly. Thus a variety of pest control problems are brought into focus in a new framework. Other problems, such as soil compaction, also emerge. The wide adoption of conservation tillage awaits the resolution of these problems.

Other Measures

Cost sharing, using public funds, is already a well-established procedure for encouraging farmers to adopt soil conservation measures. This economic incentive is essential to the success of any voluntary soil conservation program involving outlays substantially beyond ordinary farm costs. Much land in need of soil-saving measures remains outside organized programs because the public funds available for cost sharing are inadequate to attract the owners.

In our predominantly urban society, it may be difficult to gain the public support needed for funding an adequate soil conservation program. Many Americans still think in terms of abundance and steadily rising expectations. But shortages of various kinds, including the energy shortage, are now raising prices and pushing inflation. Public opinion will shift with the worsening of the world food crisis, and as famine abroad becomes more commonplace. Recognition of the need for conservation in general will grow, and with it appreciation that we depend on the soil for food.

An immediate problem is to overcome the delay in large-scale application of available conservation methods. An underlying reason for the delay is that man, as a species, has yet to understand his true place in nature. If he did, he would have accepted what Leopold (*23*) has termed a "land ethic." Leopold stated, "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect. There is no other way for land to survive the impact of mechanized man. . . ." The land ethic demands a harmonious balance between nature and all the works of man. Systematic cultivation in the public mind, in this critical period, of an ethical sense of man's relationship to the soil would facilitate the conservation of cropland which has now become more vulnerable to destruction than ever before.

Summary

A recent survey of five watersheds in south-central Wisconsin, where corn is now the dominant annual crop, illustrates the soil erosion damage that is occurring on sloping land under modern agricultural technology and prevailing market forces. In 70 percent of the 93 quarter-sections sampled, estimated soil losses, on the average, were more than twice the amounts considered compatible with permanent agriculture. Scattered studies by others indicate that the findings are meaningful for a large area in the United States when row cropping is prevalent on sloping soils.

Pressures on cultivated land, in general, are mounting rapidly because of the rising demand for meat in industrialized nations and the soaring numbers of marginally fed people in Third World coun-

tries. The world population–food problem makes increasing stress on U.S. soils inevitable in the foreseeable future. Adequate protection against excessive loss of productive topsoil requires that the level of publicly supported soil conservation activities be promptly adjusted to this circumstance.

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Increasing Crop Production Through More Controlled Photosynthesis

Can photosynthetic and biosynthetic mechanisms be used to increase productivity in green plants?

James A. Bassham

Everyone is affected by the balance between world food supply and population. For people in more prosperous countries, insufficient or more costly food production results in higher food prices, diminished ability to buy other goods and services, and sometimes, for those lowest on the economic ladder, malnutrition. In less developed countries (LDC's) the people may have to depend on largess from wealthier nations when shortages occur in food production. Port facilities and internal distribution systems in such countries are often inadequate for the job of handling greatly increased imports, and relief sometimes comes too late. The plight of LDC's has been exacerbated by rapidly rising energy costs, which have led to a diminished capacity to use energy in agriculture—for example, in fertilizer production. There has been famine and starvation in some areas.

That many more such tragedies were averted was due to the green revolution, wherein food production was greatly increased in developing countries by the selection of improved plant varieties through breeding for desirable characteristics; by the application of fertilizers, pesticides, and herbicides; and by better methods of tilling, irrigation, and harvesting. Limitations are becoming apparent, however, particularly as the cost of fixed nitrogen fertilizers rises with the cost of gas and petroleum. Some high-yielding strains of cereals produced by extensive breeding programs may prove to be especially susceptible to diseases and pests. Plant breeding methods can be used to make resistant strains in time, but a large portion of one or more seasons' crops could be lost. Nearly complete establishment of high-yielding but vulnerable strains over large areas where the population is critically dependent on a single crop could lead to disaster. Other concerns include the possible adverse ecological effects of pesticides and herbicides, and even of excessive amounts of nitrogen fertilizers. New worries stem from predictions of a worsening weather pattern for agriculture on a global scale—predictions that seem more alarming in view of recent weather in the Northern Hemisphere.

Inextricably linked to the food problem is the energy problem: we need to find new supplies of energy and organic materials to replace the rapidly dwindling supply of the most useful fossil fuels, petroleum and natural gas. We will have to find ways to make more and better use of coal and oil shale, but the economic and environmental costs of developing and processing those stores are high. Alternative sources of organic compounds and even energy that were previously uneconomic are likely to become economic, particularly when environmental costs are considered.

An obvious source to turn to for these alternative supplies is green plants. In Brazil, ethyl alcohol from the fermentation of wastes in sugar processing is already being added to gasoline for auto-

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