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Project Summary

Resource and Environmental Impacts of Trends in U.S. Agriculture

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Trends in demand for agricultural production and agricultural technology in the United States suggest increasing pressure on the nation's land and water resources over the next several decades. The expected consequences would be rising economic costs of production and damages to the environment. This study analyzes these trends, assesses their economic and environmental impacts, and discusses policies for dealing with their impacts.

The quantities of land, water, and other resources farmers use to increase production depend basically on the kinds of technologies they employ. Two categories of technology are distinguished — land-using technologies and land-saving technologies. Farmers' choices from the spectrum of technologies are conditioned by the prices and productivities of the alternatives. The present trend to land-using technologies should continue if energy and fertilizer prices increase as expected.

Analysis of trends indicates that an additional 60 to 70 million acres will be brought into production by 2010 and that erosion will emerge as the most serious environmental problem of agriculture. Erosion on the projected scale would pose a significant threat to national water quality as well as to the productivity of the land. A slower rise in inputs of fertilizer per acre is expected and the total quantity of insecticide applied to crops should decline. Herbicide use is expected to decrease markedly.

More effective programs to gain farmer cooperation in controlling erosion may be required along with research to develop new technologies that serve both the farmers' economic interest and the social interest in reducing environmental damages. Development of improved land-saving technologies, such as a higher yielding variety of soybean, would reduce pressure on the land.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The future resource and environmental impacts of agricultural expansion in the United States depend fundamentally upon the growth of agricultural production, the kinds of technologies farmers employ, and the policies adopted in response to resulting resource and environmental problems. This study deals with these three key components of the emerging agricultural situation. The period covered extends to 2010.

Projections of Agricultural Production

The focus is on wheat, feedgrains, soybeans and cotton. These crops consistently account for 70 to 75 percent of the land harvested in the United States and for high percentages of the fertilizers and pesticides applied. Moreover, if the growth of agricultural production in the United States puts substantial pressure on the resource base and environment, it will be because of the growth of production of these crops, particularly in response to export demand. Production of all other commodities will grow primarily in response to United States population growth, expected to be less than 1 percent annually over the next several decades.

The projections are shown in Table 1. Those for 2010 for grains and soybeans were made in three steps: (1) project growth in world trade in each commodity; (2) project the United States percentage of trade; and (3) project domestic use. The projections for cotton were derived separately from a study by the U.S. Department of Agriculture (USDA).

The projections of domestic demand for feedgrains make no special allowance for use of corn to produce ethanol for combination with gasoline to make gasohol. Gasohol is presently competitive with gasoline only because it is heavily subsidized by exemption from federal and state gasoline taxes. The climate for federal and state fiscal policies suggests that these subsidies may be reduced, if not eliminated. More important over the long run, a number of studies indicate that by the end of the century, or even before, coal likely will be a more economical source of liquid fuel than ethanol from grain.

The projections to 2010 make no explicit allowance for changes in prices. However, the USDA projections to 1985 and 1990 incorporate increases in real prices from 1979 levels. The trajectory of these projections fits well with that of the projections to 2010. We assume, therefore, that the 2010 projections are consistent with some increase in real prices of commodities but we do not specify the amount of increase.

Farmers' Choices Among Technology

Two categories of technology are distinguished: (1) land-saving (low ratio of land to non-land inputs); and (2) land-using (high ratio of land to non-land inputs). We think of technologies as lying along a spectrum from land-saving at one end to land-using at the other.

Farmers' choices from the spectrum are determined fundamentally by the relative prices and productivities of the alternatives. From the end of World War II until the early 1970s, low prices of energy, fertilizer and irrigation water combined with high productivity of these inputs to favor land-saving technologies. The quantities of these inputs rose rapidly and the amount of

Table 1. *U.S. Production, Export, and Domestic Use of Wheat, Feedgrains and Cotton, 1978/80 and Projections to 1985, 1990 and 2010 (millions metric tons)*

							RFF: 2010			
							U.S. Share			
				Average	*USDA*		*Constant*		*Reduced*	
	1978	*1979*	*1980*	*1978/80*	*1985*	*1990*	*(1)*	*(2)*	*(1)*	*(2)*
Wheat										
Prod.	*48.3*	*58.1*	*64.5*	*57.0*	*67.6*	*77.1*	*98*	*100*	*84*	*85*
Export	*32.5*	*37.4*	*41.5*	*37.1*	*42.4*	*50.4*	*70*	*72*	*56*	*57*
Dom. Use	*22.8*	*21.3*	*22.9*	*22.3*	*25.2*	*26.7*	*28*	*28*	*28*	*28*
*Feedgrains**										
Prod.	*222.1*	*238.8*	*198.7*	*219.9*	*253.7*	*282.0*	*354*	*428*	*316*	*372*
Export	*60.2*	*71.4*	*74.3*	*68.6*	*81.0*	*97.1*	*167*	*241*	*129*	*185*
Dom. Use	*157.2*	*161.9*	*155.8*	*158.3*	*172.7*	*184.9*	*187*	*187*	*187*	*187*
Soybeans										
Prod.	*50.9*	*61.7*	*49.4*	*54.0*	*61.7*	*72.1*	*120*	*129*	*104*	*112*
Export†	*27.7*	*32.9*	*29.5*	*30.0*	*27.8*	*33.8*	*76*	*85*	*60*	*68*
Dom. Use	*23.5*	*23.7*	*24.0*	*23.7*	*33.9*	*38.3*	*44*	*44*	*44*	*44*
Cotton							*(share not calculated)*			
Prod.	*2.4*	*3.2*	*2.4*	*2.7*	*2.6*	*2.7*	*3.5-3.9*			
Export	*1.4*	*2.0*	*1.2*	*1.5*	*1.1*	*1.2*				
Dom. Use	*1.3*	*1.4*	*1.2*	*1.3*	*1.5*	*1.5*				

Sources: 1978-1980 from the U.S. Department of Agriculture (USDA). 1985 and 1990, USDA projections provided by Leroy Quance, done in the summer of 1980. The projections are preliminary and not official.

The RFF projections to 2010 are by Pierre Crosson. Constant U.S. shares means that the U.S. maintains the same percentage of world trade in the various commodities as in 1976/79; share reduced means a smaller percentage, as described in the text. The columns (1) assume that the Common Agricultural Policy of the European Community remains unchanged. The columns (2) assume that the policy is changed to permit more imports.

For 1978-80 the difference between production and the sum of exports and domestic use is the change in stocks. In the projections, stock changes are assumed to be zero.

**Corn and sorghum for grain, oats and barley.*

†The USDA projections are beans only. The 1978-80 figures are RFF projections to 2010 are beans plus soybean meal and oil exports converted to the bean equivalent.

cropland declined. Both crop yields and total productivity rose at unprecedented rates.

Since the early 1970s, real prices of energy and fertilizer have risen. The rise in energy prices increased the cost of pumping water for irrigation, and increasing competition for water for non-agricultural uses in the West increased the opportunity cost of the resource. Farmers shifted toward more land-using technologies. The amount of cropland increased over 50 million acres from 1972 to 1980 and the ratio of non-land inputs to land rose more slowly than in the two previous decades. The rate of increase of crop yields and total productivity slowed dramatically.

Between 1980 and 2010, real prices of energy and fertilizer are expected to rise and rising pumping costs and opportunity costs should make irrigation water in the West more expensive. There is considerable potential for expanded irrigation in the Mississippi Delta and, to a lesser extent in Georgia and Florida. Nonetheless, rising real costs of energy and fertilizer and of western irrigation would favor more land-using technologies in the future as they have in the 1970s, unless new land-saving technologies are developed and adopted by farmers.

Trends in Productivity and Crop Yields

The assertion that the trend of crop yields and total productivity slowed in the 1970s can be challenged. The evidence shown in Table 2 strongly supports the assertion. In every year from 1973 to 1980, except productivity in 1975, both yields and total productivity fell short of the trend values established in 1950 to 1972. In 1978 the weather was highly favorable in major crop producing regions, and in 1979 it was even better. Crop yields set successive records in those two years. Their failure to match trend values of yields, therefore, is especially strong evidence that the trend slowed after 1972.

Analysis of trends in yields of corn and soybeans in the Corn Belt and of wheat in the Plains States supports this conclusion for corn and wheat but not for soybeans. After adjustment for effects of weather, soybean yields in the Corn Belt continued to increase at the trend rate set in 1950 to 1972. Weather, however, does not explain slower growth in corn and wheat yields. Two other factors bearing on the trend of yields of these crops were examined: expansion of cropping to inferior land and improvements in technology.

It was concluded that expansion of the amount of land in wheat would have slowed the increase of wheat yields, but that this could not account for more than 10 percent of the difference between actual wheat yields and the trend values of yields. The two principal elements of technology examined were fertilizer use per acre and irrigation. Per acre application of fertilizer to wheat land increased more slowly after 1972 and this would have slowed the increase in yields. The percentage of wheat land fertilized before and after 1972, however, is not enough for this to have been very important. Precise data are lacking, but it is known that irrigation continued to expand in major wheat growing areas after 1972. So, irrigation does not explain the slower growth of wheat yields. No satisfactory explanation for this behavior is known.

The expansion of the amount of land in corn apparently explains a major part of the shortfall in corn yields. Slower growth in fertilizer application per acre also played a role, but irrigation evidently did not.

On balance, there is no conclusive evidence that slower growth of yields and total productivity after 1972 was owed to declining productivity potential of the technologies that farmers employed. There clearly is no evidence, however, that this potential was increasing. There is no reason, therefore, to expect the productivity of present technologies to rise fast enough to offset the prospective higher prices of energy, fertilizer and water. In this case, the trends of productivity and crop yields established in the 1970s are better guides to future trends than the trends established before the 1970s. The implication is that to meet the projected levels of crop production farmers will have to bring in much additional cropland.

The Demand for and Supply of Cropland

The demand for cropland in the ten USDA producing regions was projected in two steps. First, regional shares of production of wheat, feedgrains, soybeans and cotton were projected on the basis of historical shares, with a few exceptions. The share of Texas in cotton production has been increasing for some years at the expense of the Southeast and the Mississippi Delta. This reflects important economic advantages of Texas, particularly in pest management, and is expected to con-

Table 2. *Indexes of Crop Yields and Total Agricultural Productivity in the U.S.*

(1967=100)

	Yields			*Productivity*		
	Actual	*Trend**	*Actual Minus Trend*	*Actual*	*Trend**	*Actual Minus Trend*
1965	*102*	*99*	*3*	*100*	*97*	*3*
1966	*99*	*101*	*-3*	*97*	*99*	*-2*
1967	*100*	*103*	*-3*	*100*	*101*	*-1*
1968	*105*	*106*	*-1*	*102*	*103*	*-1*
1969	*110*	*108*	*2*	*103*	*104*	*-1*
1970	*104*	*110*	*-6*	*102*	*106*	*-4*
1971	*112*	*112*	*0*	*110*	*108*	*2*
1972	*118*	*114*	*4*	*110*	*110*	*0*
1973	*113*	*117*	*-4*	*111*	*112*	*-1*
1974	*103*	*119*	*-16*	*105*	*113*	*-8*
1975	*110*	*121*	*-11*	*115*	*115*	*0*
1976	*110*	*123*	*-13*	*115*	*117*	*-2*
1977	*115*	*126*	*-11*	*114*	*119*	*-5*
1978	*119*	*128*	*-9*	*116*	*121*	*-3*
1979	*126*	*130*	*-4*	*119*	*122*	*-3*
1980	*114*	*132*	*-18*	*115*	*124*	*-9*

Average deviation from Trend	*Average deviation from Trend*
1950-1972: 2.9	*1950-1972: 1.7*
1973-1980: 12.5	*1973-1980: 5.5*

**Trend of actual data in 1950-1972.*

tinue. The potential for irrigation in the Delta and Southeast is expected to increase those region's shares of soybean production at the expense of the Corn Belt. Double cropping of wheat with soybeans also will increase their shares of wheat land at the expense of the Northern Plains.

The second step was to project crop yields. This was done on the general assumption that yield trends in the 1970s provide the best guide to future yields, except for soybeans for which the trends established since 1950 were used.

Dividing the regional projections of production by regional projections of yields gave projections of the demand for cropland by region. For the nation as a whole, 477 million acres of cropland would be demanded by 2010. In 1977 there were 413 million acres, according to the National Resources Inventory (NRI) published by the Soil Conservation Service. The NRI showed that there were 125 million acres of land in pasture, forest and range with economic potential for conversion to crops, suggesting an ample supply to accommodate the projected increase in demand. However, urban and other non-agricultural uses will claim 25 to 30 million acres of cropland and potential cropland between 1977 and 2010. The land now in pasture, forest and range with potential for crops, therefore, would have to accommodate additional cropland and non-agricultural demands of 90 to 95 million acres. We expect this could not be done without a significant increase in the real economic cost of agricultural land.

The Demand for Fertilizer and Pesticides

The continuing adoption by farmers of land-using technologies implies that per acre applications of fertilizers will rise generally in the pattern established in the 1970s, which was much slower than in the 1950s and 1960s. By the end of the 1970s most farmers showed close to optimal per acre uses of fertilizers. If fertilizer prices rise as expected, farmers will have strong incentive to use fertilizer more sparingly. There are several ways to do this, e.g., improved knowledge of the amount of naturally occurring nitrogen made available by mineralization, split applications to time more closely the availability of nutrients to the plants' need for them, slow release fertilizer and nitrification inhibitors to reduce nitrogen losses to leaching and volatilization.

Since the late 1960s the amount of organochlorine insecticides used has declined sharply and the amount of organophosphorous and carbamate compounds increased. The organochlorines generally are not highly toxic to mammals but they persist for long periods. The organophosphorous and carbamate compounds generally are acutely toxic but relatively non-persistent. The switch from the organochlorine began because of increasing resistance of cotton insects to the materials and was hastened by EPA banning principal organochlorines, beginning with DDT in 1972.

The future amounts of insecticides used by farmers will depend heavily on trends in use on cotton and corn. In 1976, 40 percent of all insecticides used on crops were used on cotton and another 20 percent were used on corn.

Two trends suggest that the amount of insecticides used on cotton will decline over the next several decades. One is the continuing shift of cotton production from the Southeast and Mississippi Delta to Texas. In Texas, integrated pest management (IPM) based on a short season variety of cotton and complementary insect management practices makes it possible to achieve satisfactory insect control with a small per acre use of insecticides. By comparison, per acre use in the Southeast and Delta is several times higher. The continuing shift of cotton production to Texas will lower average use of insecticides even if per acre amounts used in all three regions remain the same.

But IPM is spreading also in the Delta and the Southeast, indicating that per acre use of insecticides on cotton will decline in those regions also. Growing conditions in those regions are more favorable to insects and yields are higher. Both conditions suggest that per acre use of insecticides will continue higher than in Texas. Some decline is likely, however.

IPM is less well developed to control insects of corn, and may have less potential. The principal insect pest of corn is the rootworm which, being a soil dwelling organism, is not so readily controlled by IPM, at least as currently practiced. Nonetheless, the use of "scouts" to provide better information about when and how much to spray to control corn insects is spreading and should lead to a decline in per acre amounts of insecticides.

The prospective decline in per acre amounts of insecticides applied to cotton and corn implies a decline in total amount of insecticides used on crops, unless amounts used on wheat and soybeans increase dramatically. Neither wheat nor soybeans presently are seriously threatened by insects and amounts of insecticides applied to these crops are low. The prospective relative shift of soybeans to the Mississippi Delta and Southeast may result in a doubling in the total amount of insecticides used on soybeans, but this would be far more than offset by the decreased use on cotton and corn. On balance, a significant decline is expected over the next several decades.

The use of herbicides, however, is expected to increase substantially, both because of the expansion of cropland and increasing per acre applications associated with the spread of conservation tillage. Conservation tillage means a variety of tillage technologies with three characteristics in common: (1) they use some implement other than the moldboard plow to prepare the seedbed, (2) they leave enough crop residue on the land to significantly reduce erosion, and (3) they rely more on herbicides and less on cultivation than conventional tillage to control weeds.

Conservation tillage expanded rapidly after the mid-1960s and in 1980 it was used on about one-quarter of the nation's cropland. With conservation tillage non-land costs per acre are roughly 5 to 10 percent less than with conventional tillage. Thus, where yields are comparable, conservation tillage has an economic advantage over conventional tillage. In general, yields are comparable on reasonably well drained soils where the growing season is not too short and where weeds can be adequately controlled with herbicides. These conditions are widely enough met that conservation tillage probably would be economical on 50 to 60 percent of cropland even if there are no technical breakthroughs, e.g., that would make yields comparable to those of conventional tillage on poorly drained soils.

Environmental Impacts

The prospective increases in resources used by farmers indicate that damages to the environment may rise. Four types of damage are considered: (1) effects of fertilizer on water quality, (2) effects of pesticides on unintended targets, (3) salinity resulting from irrigation, and (4) erosion.

Data are inadequate for warranted quantification of these damages. Instead, we make judgments of whether the damages are likely to increase from present levels and, if so, whether the increase likely would call for new policies.

Fertilizer

The principal environmental damages of fertilizers are to human and animal health from nitrate-N in ground and surface water and from nitrogen and phosphorus in accelerating eutrophication of lakes, reservoirs and other still bodies of water.

Except occasionally in some streams in the Midwest, nitrate-N concentrations in surface waters are less than the 10 ppm standard set by the U.S. Public Health Service. This is true also of groundwater except for some "hot spots" in California and Nebraska. The projections of nitrogen fertilizer use, taking account of improved practices and materials in reducing losses, suggest a nationwide increase of perhaps 30 percent in nitrate-N entering ground and surface waters. Given present nitrate-N concentrations in these waters, this is not a seriously threatening increase. In some regions, however, particularly where irrigated production on sandy soils is likely to increase (parts of the Southeast and Northern Plains), the projected increases in nitrogen applied and consequent losses may give cause for concern.

Phosphorus typically is the critical nutrient accelerating eutrophication. Municipal and industrial wastes provide more phosphorus to surface waters than agriculture. These wastes are expected to decline more than enough to offset any increase in agriculture's contribution of phosphorus.

Pesticides

The projected decline in the quantity of insecticides applied implies a lessening of the environmental damages from these materials. The substitution of synthetic pyrethroids for organophosphorous compounds also should ease the problem. The pyrethroids are not toxic to mammals. They may be highly toxic to fish, but they are used in such small quantity and are so quickly dissipated that the probability of their reaching water bodies in significant amount is low.

Although the organophosphorous and carbamate compounds are more toxic than the organochlorines they are replacing, the change may not imply increased environmental damage. The organophosphorous and carbamate materials are much less persistent than the organochlorines and do not accumulate in body tissue. These are strongly positive factors. And the acute toxicity of the organophosphates and carbamates may actually make it easier to control damages from these materials. Because the damages are immediate and obvious, design of practices to assure safe use and to fix responsibility for misuse is facilitated.

Present evidence does not suggest that the prospective large increase in use of herbicides is cause for major concern. Most herbicides are not toxic to animals and studies of their effects on soil microorganisms show no lasting damage. Not all pathways by which herbicides may impact on the environment have been investigated, but based on present knowledge the greater use of herbicides is not so threatening as to require measures to prevent it.

Salinity with Irrigation

The buildup of salt on irrigated land and in irrigation return flow already is a problem in parts of the arid West, particularly in the lower Colorado River basin and in California. The problem is endemic in arid areas where irrigation is used. It can be contained, however. One possibility is construction of evaporation ponds or drains to remove excessively salt-laden waters. There also are various management practices which reduce evaporation losses, thus permitting achievement of given yields with less water and less residual salt. Development of more salt resistant crop varieties also holds promise.

These various alternatives should hold the salinity problem within acceptable limits over the next several decades.

Erosion

Erosion impairs water quality, pollutes the air and damages the productivity of the land. In 1977, sheet and rill erosion (i.e. by water) from cropland was 1.9 million tons. Erosion by wind in the Plains States was 900 million tons. On a per acre basis, sheet and rill erosion of cropland was 4.7 tons and total erosion was 6.8 tons, 1.8 tons more than the maximum consistent with maintaining the productivity of the land, according to the SCS.

There are no good estimates of either the off-farm or on-farm (productivity) damages of erosion. Whatever the latter may have been, they were masked by the strong advance of technology in the 35 years following the end of World War II.

The projections of production and cropland indicate that sheet and rill erosion would increase from 1.9 billion tons in 1977 to 3.5 billion tons in 2010. No attempt was made to project wind erosion. Erosion per acre of cropland would rise from 4.7 tons to 7.4 tons. Sediment delivered from cropland to the nation's surface waters would about double.

It was believed that erosion on the projected scale would be viewed as significantly worse than at present and as a problem of major national concern. By comparison with it, the problems of fertilizer and pesticide pollution and of salinity would be judged of secondary importance.

Policy Issues

The Federal Government has taken three approaches to control environmental impacts of agriculture. One, the oldest, assigns responsibility to the Department of Agriculture for programs to control erosion. The prime objective has been soil conservation to protect the productivity of the land, so these programs have not been concerned with environmental quality, strictly defined. However, soil conservation often benefits water quality, and in any case, in this discussion, environmental quality incorporates the productivity dimension.

The second approach has been through Section 208 of the Federal Water Pollution Control Act. The purpose of Section 208 is to improve water quality by controlling non-point sources of pollution. The EPA has principal responsibility for programs under Section 208.

The third approach is for control of pesticides under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) as amended. This act gives the EPA authority to suspend or ban pesticides found to threaten environmental damages greater than the benefits of these materials. The EPA's actions can be challenged in the courts, but the record shows that its authority under FIFRA is substantial. It should be quite adequate to deal with future environmental threats of pesticides.

Under Section 208 each state has drawn up a plan (or plans) to deal with non-point pollution. The EPA Administrator must approve the plans. So far the plans have relied overwhelmingly upon voluntary measures of the sort long promoted by the USDA to secure farmer cooperation in measures to reduce erosion. Because the objective of these measures was to protect productivity, they are not always optimal for the water quality objective specified in Section 208.

To induce voluntary cooperation, the USDA programs share the cost of erosion control measures with the farmer. The past performance of the programs has been criticized for not being targeted on the farmers causing the most erosion and for funding productivity improvements rather than just protecting against erosion damage. Whatever the limitations of these programs in the past, they likely will be much more limited in dealing with future erosion if it emerges on the projected level. If properly targeted, the voluntary approach may give satisfactory results at reasonable cost when commodity prices are low and farmers' incentives for intensive use of the land correspondingly weak. In the projected scenario, however, commodity prices are relatively high, giving strong incentive to use the land intensively. In these circumstances, cost-sharing programs to induce farmers to adopt conservation programs on the necessary scale may be prohibitively expensive.

The voluntary approach likely will appear inadequate in these circumstances. Section 208 authorizes the EPA to take stronger measures to achieve water quality objectives. Where erosion is the main threat, regulations limiting the amount of soil loss or a soil loss tax are possibilities. Such measures could leave the design of control practices to the farmer, but they would hold him responsible for compliance under the threat of court action.

The EPA thus would apply the "polluter pays" principle to farmers just as it now does to industrial and municipal polluters. Application of the principle, however, would run against the long tradition of how the Federal Government deals with farmers to control erosion. Although the principle clearly applies to controlling off-farm effects, its departure from tradition likely would arouse strong opposition from farmers. Its political and administrative costs likely would be high.

Moreover, the principle is not appropriate for dealing with productivity effects of erosion. While control to protect water quality often will benefit productivity also, this is not necessarily the case. Where productivity is threatened and water quality is not, the legal basis for non-voluntary approaches is weak, if not non-existent.

It is likely that the voluntary and regulatory approaches, taken singly or in some combination, will prove inadequate to deal with both the water quality and productivity damages of erosion if these emerge on the projected scale. Alternative approaches should be considered. One is a research strategy to develop technologies which will simultaneously serve the farmers' economic interest in meeting rising demand and society's interest in limiting erosion damages. Two lines of technological development satisfy these conditions. One is to find inexpensive high yielding substitutes for fossil fuels, chemical fertilizers and irrigation water since it is the rising cost of these inputs which pushes farmers to adopt land-using technologies. And the spread of these technologies is the principal cause of the large projected increase in erosion. Research to improve photosynthetic efficiency in main crops and to build nitrogen fixing capacity in corn could eventually develop new, economically competitive land-saving technologies.

The other line of research would aim at extending the economic limits of conservation tillage, making it possible to contain the erosion costs of bringing more fragile lands under crops. Development of seed varieties that perform well in poorly drained soil would help to overcome present limits of conservation tillage, as would new herbicides or application techniques to deal with weeds now controlled only by deep plowing and cultivation. And a short season variety of corn would extend the northern limits of conservation tillage.

A research strategy to develop technologies of the sort described would not be a substitute for traditional voluntary programs to control erosion or for stringent regulatory approaches where these are appropriate and feasible. Over the long term, however — and the erosion problem is long term — a research strategy could be a valuable supplement to other programs. Its great strength is that it seeks to harmonize the farmer's interest and society's interest in the use of land, not by payment of expensive subsidies or the threat of legal sanctions, but through the economic forces of the market place. One need not have a philosophical preference for market solutions to recognize the market's advantages in flexibility and speed of response compared with management by government intervention. But the market solution will be acceptable only if it serves society's interest in erosion control as well as the farmer's interest in production. A carefully conceived and sustained research program to develop economically attractive technologies along the lines specified could be the socially most efficient way to achieve this coincidence of interest.

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The complete report, entitled "Resource and Environmental Impacts of Trends in U.S. Agriculture," (Order No. PB 83-200 634; Cost: $20.50, subject to change) will be available only from:

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