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Abstract

This report examines evidence on the relationship between agricultural land-use changes, soil productivity, and indicators of environmental sensitivity. If cropland that shifts in and out of production is less productive and more environmentally sensitive than other cropland, policy-induced changes in land use could have production effects that are smaller—and environmental impacts that are greater—than anticipated. To illustrate this possibility, this report examines environmental outcomes stemming from land-use conversion caused by two agricultural programs that others have identified as potentially having important influences on land use and environmental quality: Federal crop insurance subsidies and the Conservation Reserve Program (CRP), the Nation's largest cropland retirement program. The report finds that lands moving between cultivated cropland and less intensive agricultural uses are, on average, less productive and more vulnerable to erosion than other cultivated lands, both nationally and locally. These lands are also associated with greater potential nutrient runoff and leaching compared with cultivated cropland nationally. Crop insurance subsidies and CRP have estimated effects on erosion and other environmental factors that are disproportionate to the acreage and production effects, but specific environmental impacts vary with the features of each program.

Keywords: Conservation Reserve Program (CRP), crop insurance, erosion, extensive margin, farm policy, imperiled species, land use, land-use change, land quality, nutrient loss, soil productivity.

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Summary

While total U.S. cropland has remained roughly constant for 100 years, this stability belies larger underlying movements of land into and out of crop production. Almost three-quarters of the cropland that shifted into or out of cultivation between 1982 and 1997 had soil productivity ratings below the average acre of cropland. Farmers tend to keep highly productive cropland in cultivation regardless of changing economic conditions. But economic conditions, such as changing commodity prices or production costs, encourage farmers to expand production to less productive land or to shift less productive croplands to other uses. Agricultural and conservation policies also affect land use. These land-use changes affect environmental quality, particularly when affected lower-quality lands are environmentally sensitive.

What Is the Issue?

Although many have speculated that less productive croplands are more environmentally sensitive, little empirical evidence is available to substantiate this idea. If cropland that shifts in and out of production is less productive and more environmentally sensitive than other cropland, policy-induced changes in land use could have production economic effects that are smaller—and environmental impacts that are greater—than anticipated.

This report examines how the attributes of lands shifting into and out of crop production differ from those of continuously cultivated cropland. We focus particularly on cropland change affected by the Conservation Reserve Program (CRP) and Federal crop insurance, government programs that others have identified as potentially having important influences on land use and environmental quality. Since 1985, CRP has been the largest driver of cropland changes. This land retirement program pays farmers to retire cropland acreage to achieve environmental goals. In 2005, the CRP paid farmers $1.7 billion to retire a land area almost the size of Iowa. Due to its competitive bidding process and selection criteria, CRP enrolls land that is less productive and more environmentally sensitive than average cropland. The Federal crop insurance program, on the other hand, raises incentives to expand crops to less productive land. Environmental groups, economists, and others have expressed concern that this may induce cultivation in frequently flooded and other risky areas containing wetlands or other environmentally sensitive lands.

What Did the Study Find?

Between 1982 and 1997, there was a net decline in cultivated cropland of 43 million acres (11 percent). Over the same time, more than 127 million acres or 32 percent of cultivated cropland shifted between cultivated cropland and less intensive uses. These shifting lands are generally less productive than continuously cultivated croplands.

On average, land shifting in and out of cultivation is more vulnerable to erosion (from rainfall and often wind) and—except for CRP acreage—has greater nutrient runoff and leaching potential than more productive cropland. While these nutrient loss estimates take into account land erodibility, they may not accurately reflect differences in fertilizer applications on lower productivity lands.

Lands enrolling in CRP are generally less productive than other lands shifting into and out of crop production. On average, CRP acres (if returned to cultivation) would be more vulnerable to erosion, but do not have higher potential nutrient runoff and leaching to water, than other cropland areas. The 8-percent reduction in cultivated cropland area attributed to CRP reduced aggregate wind and water erosion by an estimated 16 and 7 percent annually, as of 1997.

Increased crop insurance subsidies in the mid-1990s motivated farmers to expand cultivated cropland area in the contiguous 48 States by an estimated 2.5 million acres (0.8 percent) in 1997, with the bulk of this land coming from hay and pasture. This land-use change increased annual wind and water erosion by an estimated 1.4 and 0.9 percent, as of 1997.

Lands brought into or retained in cultivation due to these crop insurance subsidy increases are, on average, less productive, more vulnerable to erosion, and more likely to include wetlands and imperiled species habitats than cultivated cropland overall. Based on nutrient application data, these lands are also associated with higher levels of potential nutrient losses per acre.

Lands shifting in and out of cultivation are generally located in areas with more imperiled plant and vertebrate species than cropland persisting in cultivation. Lands in cultivation due to increased insurance subsidies tend to lie in watersheds with higher average counts of imperiled vertebrate, plant, and fish/mollusk species, relative to cultivated cropland overall. CRP lands are in areas with greater average counts of imperiled birds but not of other imperiled species examined. (Our species indicator is the number of species considered imperiled throughout their range from NatureServe's Natural Heritage data. Although these data are the most comprehensive measure of U.S. biodiversity conservation status, the available data are insufficient to determine whether the associated changes in land use have an impact—either positive or negative—on imperiled species.)

These results suggest that policies that increase incentives for crop cultivation and stimulate production on economically marginal land may have disproportionately large unintended environmental consequences. Conversely, large environmental benefits could be achieved at lower cost using targeted conservation programs because owners of low-quality and environmentally sensitive land require less payment to remove land from production than owners of higher quality land.

How Was the Study Conducted?

Historical patterns of land-use change are examined to establish relationships between land quality and land use. This report also estimates land-use and environmental impacts stemming from two government programs that may affect less productive and environmentally sensitive croplands: federally subsidized crop insurance and the CRP.

The report compares the economic and environmental characteristics of lands that persist in cultivation and those that have recently shifted between cultivated cropland and other, less intensive, uses such as hay, forest, pasture, range, and CRP. These are lands on which uses actually have been affected by recent economic changes or other factors. Using parcel-level data on land use and land characteristics from USDA's National Resources Inventory (NRI), the report examines associations between measures of agricultural productivity, enrollment in CRP and other land-use changes, and environmental factors including rainfall and wind erosion; potential nutrient losses reaching groundwater, surface water, and estuaries; and location relative to imperiled species habitat.

While lands in CRP are analyzed directly, we estimate the extent, location, and characteristics of lands cropped due to insurance subsidies through a statistical analysis of land-use changes surrounding the large increase in crop insurance subsidies after the 1994 Crop Insurance Reform Act. The report compares land-use changes between 1992 and 1997 given different increases in the expected gains from the newly increased subsidies.

Chapter 1

Agricultural Policy and Environmental Effects of Marginal Cropland Changes

Environmental groups, ecologists, economists, and others have expressed concern that agricultural programs that stimulate production can have unintended and undesired environmental consequences. This view is based on two ideas: first, that as more land is used in agricultural production, less land remains for wildlife or other environmental purposes; and second, that less productive agricultural lands are particularly susceptible to environmental damages. This report examines both ideas, but focuses mainly on the second one, in the context of agricultural production in the United States.

While the loss of forests and other areas to crop production may be critical in developing countries with expanding cropland areas, the amount of land used for U.S. crop production has remained relatively stable for the last 100 years. The use of particular lands in the United States has changed over time, however, with some cropland converted to urban, forest, and other uses, and some forests, pasture, and range switching to cropland. Little information exists on the environmental implications of these land-use transitions and the degree to which policies may be affecting them. If cropland that shifts in and out of production is less productive and more environmentally sensitive than other cropland, policy-induced changes in land use could have production effects that are smaller—and environmental impacts that are greater—than anticipated.

The view that economically marginal lands are environmentally fragile draws on basic economic and agronomic principles. For example, all else being the same, highly sloped lands are more erodible and may be more difficult to cultivate. Some also argue that poorer soils require greater nutrient applications if engaged in intensive agricultural uses, which may cause greater nutrient runoff depending on application methods and levels, rainfall runoff, soil erosion, and other factors. Thus, it makes sense that some environmentally fragile lands would be near the economic margin between cropland and less intensive agricultural uses, such as pasture. These marginal lands could be more likely to shift uses due to changes in governmental policies, commodity prices, or production costs. Thus, crop insurance subsidies, income support programs, and other government programs that may stimulate agricultural production could harm the environment more than the change in cropland acres would suggest. Conversely, large environmental benefits could be achieved at lower cost using targeted conservation programs because owners of low-quality and environmentally sensitive land might require less payment to remove land from production than would owners of higher quality land.

Although there is some logic to this view, little empirical evidence exists on the relationships between soil productivity and environmental sensitivity.

Moreover, there are surely exceptions. In southeast Washington, for example, deep fertile soil in the rolling (erodible) hills of the Palouse Country supports much of the State's wheat farming (Pimentel and Kounang, 1998). Even the broader environmental implications of erodibility are unclear. For example, if highly erodible lands lie farther from waterways, sediment and nutrient runoff from agricultural activities on these lands may cause less offsite damage.

Whether or not the link between land quality and environmental sensitivity is valid, it emphasizes the importance of examining economic and environmental factors jointly. The view that government farm policies that stimulate production are particularly damaging to the environment hinges on the following three logical premises:

(1) Economic forces are likely to cause lower quality land to transition into and out of crop production.

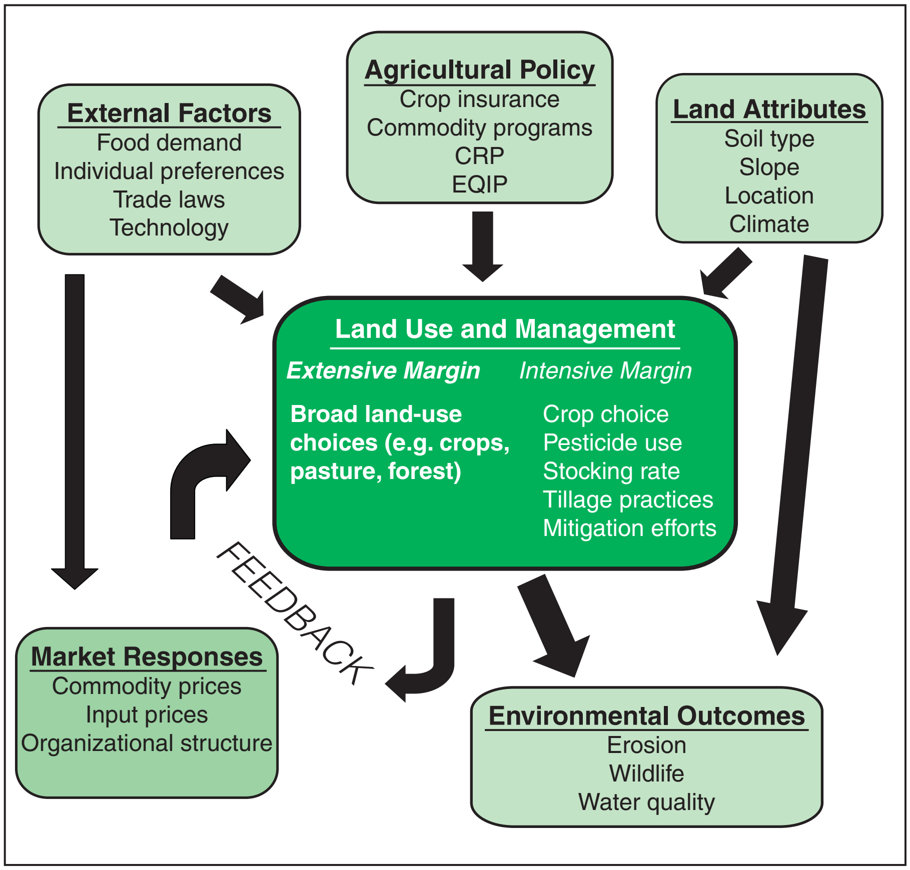
(2) Lower quality croplands are more environmentally sensitive.

(3) Agricultural policies affect land use on these low-quality and environmentally sensitive lands at the economic margin of crop production.

By exploring each of these assumptions, we begin to trace out the links between agricultural policy, land use, and its environmental consequences (fig. 1.1). External forces—such as food and fiber demand, technology, and indi-

Figure 1.1

Tracing the links between policy, land use, and the environment



vidual producer preferences—together with agricultural policy and land attributes directly affect incentives pertaining to land use and land management.

Land use and management influence the supply of agricultural commodities, and thus their prices and the organizational structure of U.S. agriculture. These market outcomes, in turn, influence land use. The land uses that culminate from these forces interact with land attributes to determine environmental outcomes. Our objective is to trace out some of these links.

Economics of Land-Use Change

Historical patterns of land-use change can be used to more firmly establish relationships between land quality and land use. Lands that have recently shifted into or out of cultivated cropland from other, less intensive uses are at the *extensive margin* of cultivated land, with land use evidently susceptible to economic or other forces (see box, "The Extensive and Intensive Margins of Cropland Use"). One may compare land attributes (such as yield potential, slope, and location) of transitioning lands and lands that have not shifted to a different land use to infer economic forces driving land-use change and whether transitioning lands are of lower quality.

There can be many extensive margins, including land straddling crop and pasture uses and land straddling crop and forest uses.[1] Although land moving from agricultural to urban uses is a prominent issue near some metropolitan areas, this is a small area nationally because urban areas comprise such a small share of total land use in the United States. Between 1982 and 1997, transitions from cultivated cropland to urban land occurred on just 1.5 percent of cultivated cropland.[2] By comparison, transitions to hay, Conservation Reserve Program (CRP), and "other" uses (pasture, range, and forest) occurred on over 24 percent of cultivated cropland. Lands that shifted into crop cultivation from these less intensive uses during 1982-97 constituted 9 percent of cultivated cropland in 1997 (USDA/NRCS, 2000). Because urban land uses are so valuable relative to agricultural uses on some lands, these transitions are driven by factors considerably different from those that drive transitions between intensive and less intensive agricultural uses. Agricultural-to-urban transitions are also less likely to be influenced by Federal agricultural policies.[3]

Environmental Characteristics of Transitioning Lands

Are lands of low agricultural value also more likely to move into and out of intensive agricultural uses, and are they more susceptible to environmental damages? Comparing various measures of environmental sensitivity (erosion, nutrient leaching/runoff, and encroachment on species habitat) on low-quality or recently transitioning lands versus higher quality or nontransitioning lands indicates whether the former are more prone to certain environmental damages. Quantifying these differences suggests the environmental consequences of the various economic forces that drive land-use change.

This report seeks to illustrate the environmental outcomes stemming from extensive margin choices. Intensive margin choices, however, are made

[1] In keeping with common usage in economics, we use the term "extensive margin" to refer generically to the economic margin between any two land-use alternatives. With respect to cropland uses, changes at the extensive margin can be defined in terms of broad land-use categories, as in this report, or more specifically in terms of specific crops (e.g., Wu, 1999). Other authors (Barlowe, 1958) use the term "extensive margin" to refer only to the economic margin beyond which all land uses cease to provide economic rents and land is left abandoned or unused.

[2] Urban land use is defined in accordance with the definition given by USDA's National Resources Inventory (NRI) as: "A land cover/use category consisting of residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; other land used for such purposes; small parks (less than 10 acres) within urban and built-up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas. Also included are tracts of less than 10 acres that do not meet the above definition but are completely surrounded by urban and built-up land."

[3] With the exception of the USDA Farm and Ranch Lands Protection Program, which funds purchases of development rights on agricultural lands, Federal agricultural policies are unlikely to influence land-use change at the agricultural-urban fringe. Other researchers have examined local zoning laws and other factors affecting urbanization of agricultural land (Carrion-Flores and Irwin, 2004; Irwin et al., 2003; Heimlich and Anderson, 2001; Bockstael, 1996).

The Extensive and Intensive Margins of Cropland Use

Lands near the economic margin of two or more competing uses lie on the *extensive margin* of the higher value use. Changes in broad categories of land use, including movements of land into and out of crop production, are termed extensive margin choices. *Intensive margin* choices refer to the particular crop choices (e.g., corn versus soybeans) and crop-specific application rates of inputs such as pesticides, water, and fertilizer. In other words, the difference between extensive and intensive choices refers to the difference between how the land is used in a general sense and how it is managed more specifically. This report focuses on the economics and environmental implications of changes in the use of land for crop cultivation versus other less intensive uses and on the role of agricultural policies in influencing these extensive margin choices. Other research has examined policy impacts on crop choices and input use and the associated environmental consequences (Babcock and Hennessy, 1996; Smith and Goodwin, 1996; Wu and Brorsen, 1995; Wu and Segerson, 1995; Horowitz and Lichtenberg, 1993; Quiggin et al., 1993).

simultaneously with extensive margin choices (see box, "The Extensive and Intensive Margins of Cropland Use"). Ideally, we would consider both sets of choices simultaneously, but the complexity of the modeling and data requirements make such an analysis infeasible. Because the environmental effects of broad land-use changes induced by policy have received little empirical attention, we focus on extensive margin changes, while drawing on assumptions about intensive margin choices that are based on more aggregated data and pre-existing models.[4]

Impacts of Federal Agricultural Policies: Crop Insurance and the Conservation Reserve Program

In addition to broadly examining relationships between soil productivity, environmental sensitivity, and land-use change, this report examines environmental outcomes stemming from land-use conversion caused by specific agricultural programs that may have particular relevance for lower quality land. Researchers have noted the potential for farm programs to generate unintended negative environmental consequences by increasing the amount of cultivated cropland (e.g., Goodwin and Smith, 2003; Wu, 1999; Plantinga, 1996). Many agricultural policies have been cited as encouraging producers to cultivate additional land or retain land in cultivation when it would not otherwise be profitable to do so. These studies include land-use effects of commodity programs (e.g., Plantinga, 1996; Wu and Segerson, 1995; Wu and Brorsen, 1995), acreage effects of crop insurance subsidies (Goodwin et al., 2004; Deal, 2004; Goodwin et al., 1999; Griffin, 1996; Keeton et al., 1999; Wu, 1999; Young et al., 1999), and disaster payments (Gardner and Kramer, 1986). A few studies have also analyzed the environmental effects of these changes (Deal, 2004; Goodwin and Smith, 2003; Wu, 1999; Plantinga, 1996). These studies, however, have mainly examined environmental outcomes for particular regions, not for the Nation as a whole.

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[4] We generate environmental indicators for nutrient runoff and leaching using the Environmental Policy Integrated Climate Model (EPIC), a crop biophysical simulation model that estimates the impact of management practices on crop yields, soil quality, and various environmental emissions at the field level (Mitchell et al., 1998).

Environmental outcomes depend on the magnitude of land-use changes induced by policies and on land attributes of affected versus nonaffected parcels. We focus on two major Federal farm programs: crop insurance subsidies and the CRP.[5] Crop insurance subsidies may lead to unintended environmental damages by inducing the conversion of land from pasture, range, and other uses into crops. The CRP, established by the Food Security Act of 1985, is a major Federal program that does just the opposite—it offers incentives to convert cultivated cropland to grasslands or tree cover for environmental gains.

Crop insurance subsidies, which have grown markedly since the Crop Insurance and Reform Act of 1994, may encourage farmers to plant crops on land that would not be economically viable without subsidized insurance. There has been particular concern over the environmental characteristics of those lands that could be brought into production due to risk-reducing farm programs such as crop insurance subsidies (e.g., Goodwin and Smith, 2003; Wu, 1999; Environmental Defense, 1999). The concern is that cultivation induced in areas where farming is economically risky may coincide with areas where cropping is particularly harmful to the environment.

The CRP has been estimated to be the most important driver of cropland change from 1982 to 1997, and may have offset the increase in agricultural output associated with other direct Federal farm payments (Lubowski et al., 2003).[6] It provides annual rental payments to farmers who voluntarily remove environmentally sensitive cropland from production under 10- to 15-year contracts. The contracts are allocated through a competitive bidding process based on an index that includes several environmental indicators, plus a cost component. Land enrolled in CRP is generally lower quality than other cropland (Sullivan et al., 2004). This is a natural consequence of the competitive bidding process because farmers wish to retain their higher quality lands for crop production. But CRP lands differ from extensive margin lands as a whole, as well as from land that has remained in cultivated crops. This is the first study to examine, on a national scale, the economic characteristics and environmental impacts of lands affected by crop insurance and the CRP.

[5] The Federal crop insurance program cost over $15 billion from 1981 to 1999, and roughly $3 billion per year since 2001 (Glauber and Collins, 2002). The CRP currently pays about $1.8 billion per year and has disbursed over $27 billion since its start in 1985 (USDA/FSA, 2004a and 2004b).

[6] Land-use definitions in this report are based on the National Resources Inventory (NRI). In the NRI, cropland includes cultivated plus uncultivated cropland while CRP is a distinct land-use category. In contrast, in the ERS Major Land Uses data series, cropland idled under government programs, such as CRP, is considered part of "total cropland" (see appendix A for more details).

Chapter 2

The Extensive Margin of Cultivated Cropland

Lands at the extensive margin of cultivated crop production tend to move between annually cultivated crops, such as wheat or corn, and less intensively managed land uses such as for hay, grazing, or timber. In general, less intensive land management involves the use of fewer inputs, such as fertilizers or pesticides, less mechanical or manual cultivation, and less use of specialized machines per acre (Barlowe, 1958).

The amount of U.S. land in crop production has remained relatively constant over the past century, but its distribution and composition have varied. A great deal of land moves in and out of cultivation each year even as the *net* changes in cropland area are relatively small. Some cropland has moved into pasture/range, forest, recreational uses, and urban/suburban uses. Other land has moved into crop production, maintaining the constant level of cropland.

This chapter describes land-use changes over recent decades. We focus here on the movement of non-Federal land between cultivated crops and three other broad land-use categories: uncultivated crops (mainly hay); land enrolled in the Conservation Reserve Program (CRP); and grazing, forest, and other rural land. Cultivated crops and these other uses account for over 90 percent of the non-Federal land in the contiguous 48 States, and reallocations of land among them are relatively common. A shift from cultivated cropland to one of these other land uses generally represents a decrease in the intensity of land use.[1]

Historical Changes in Total Cropland Used for Crops

Almost 100 years of data are available for U.S. area used for all crops (including cropland harvested, cropland failed, and cultivated summer fallow) from the USDA/ERS Major Land Uses data series.[2] U.S. cropland used for crops was 330 million acres in 1910 and 340 million acres in 2004, a difference of 3 percent. Of course, this masks land-use changes within regions and from year to year. For example, cropland used for crops peaked in 1982 at 383 million acres, falling to 331 million acres only 5 years later—a decline of roughly 13 percent.[3]

From 1945 to 2002, U.S. cropland used for crops declined by 23 million acres, or 6 percent. Over this period, cropland used for crops in the Corn Belt, Northern Plains, Pacific Northwest, and Mountain and Pacific regions increased by about 18 million acres (9 percent) while decreasing by 41 million acres (25 percent) in all other regions.[4] Thus, even as aggregate land-use patterns remained relatively stable, a large land area shifted in and out of crop production, changing the particular lands cultivated across the country.

[1] Of course, there are exceptions. For example, some grazing is intensively managed through rotational grazing or other systems to increase forage output. Also, uncultivated cropland includes land devoted to horticultural crops, which are often managed very intensively.

[2] The USDA/ERS Major Land Uses data are available at: www.ers.usda.gov/data/majorlanduses/. State-level data on total cropland (defined as the sum of cropland used for crops, cropland used for pasture, and cropland idled) are available at roughly 5-year intervals from 1945 to 2002.

[3] This rapid decline in cropland for crops coincided with an equally dramatic upswing in cropland acreage idled, most likely resulting from large annual acreage set-asides and the CRP, both initiated in the 1985 Food Security Act (the Omnibus Farm Bill) (Lubowski et al., 2006).

[4] Major Land Uses data are aggregated to the USDA Farm Production Regions (see fig. B-1 in Appendix B). ERS constructed a set of Farm Resource Regions (USDA/ERS, 2000) to be used, when possible, in place of the Farm Production Regions. Farm Resource Regions (used in the remainder of this report) require county-level data, which are not available for most land classes in the State-based Major Land Uses series.

Land-Use Changes at the Extensive Margin of Cropland, 1982-97

Land-use dynamics can be more fully characterized using a land-use change matrix (table 2.1). The matrix is based on data and definitions from USDA's National Resources Inventory (NRI), which provides data on land use and land conditions at about 900,000 "points" of non-Federal land in the contiguous 48 States surveyed at 5-year intervals between 1982 and 1997 (see appendix A). Because this survey includes the same points of land over time, it can provide estimates of **gross** land-use change, as well as **net** changes. Because the land-use definitions in NRI do not match those used in the USDA/ERS Major Land Uses data series and because the NRI excludes Federal lands, results derived from the two data sources are not directly comparable, although they are complementary and lead to similar conclusions about net land-use trends (Lubowski et al., 2006).

Because the great majority of land tends to remain in the same use over any 5-year period, we examine changes over 15 years, the longest period for which the NRI data are available, so as to observe the largest possible amount of cropland transitions. The land-use change matrix in table 2.1 provides an estimate of every possible land-use change, given the land-use categories defined in the table. For example, the cell in the upper left corner represents land that was cultivated cropland in both 1982 and 1997. The next cell to the right represents land that was cultivated cropland in 1982 but was uncultivated cropland in 1997. These land-use changes do not account for changes that may have taken place during the years between 1982 and 1997. For example, some land may have moved from cropland to pasture and back to cropland again.

Table 2.1

Changes in land use between 1982 and 1997 (1,000 acres)

1982 land use	1997 land use					1982 Total
	Cultivated cropland	Uncultivated cropland	CRP	Grazing, forest, and other rural land	Developed land, Federal land, and water	
Cultivated cropland	297,124 78.9%	18,352 4.9%	29,366 7.8%	24,741 6.6%	6,867 1.8%	376,450 100%
Uncultivated cropland	**11,685** **26.3%**	23,104 51.9%	1,046 2.4%	6,955 15.6%	1,715 3.9%	44,505 100%
Grazing, forest, and other rural land	**17,278** **1.7%**	8,462 0.80%	2,280 0.20%	948,322 94.7%	25,389 2.5%	1,001,731 100%
Developed, Federal, and water	697 0.1%	296 0%	4 0%	4,048 0.8%	516,399 99%	521,444 100%
1997 Total	326,784 16.8%	50,214 2.6%	32,696 1.7%	984,066 50.6%	550,370 28.3%	1,944,130 100%

Note: Rows represent 1982 land uses while columns represent 1997 land uses. The sum of an entire row is total land in a particular land use in 1982. Likewise, the sum of each column is total land in a particular land use in 1997. Percentages are of 1982 totals. Read right or left across a row to see how land in a particular land use in 1982 was later used in 1997. Read the table up and down a column to see how land in a particular land use in 1997 was previously used in 1982. The cells shaded in green and grey constitute the changes in extensive margin of both cultivated and uncultivated cropland as defined in this report. The numbers in bold are changes at the extensive margin of just cultivated cropland. The grey colored cells indicate land-use changes generally representing increases in land-use intensity, while green cells show changes that generally decrease land-use intensity (see fig. 2.1 for a schematic representation of these relationships).

Source: 1997 National Resources Inventory.

Changes at the extensive margin of cultivated and uncultivated cropland (the shaded cells in table 2.1) are much larger than would be suggested by net changes in cropland area. The amount of land-use change at the extensive margin of cultivated crop production is the total land area moving between cultivated cropland and less intensive land uses (uncultivated cropland, CRP, and grazing, forest, and other rural uses).[5] Changes at the extensive margin of cultivated cropland involved over 100 million acres between 1982 and 1997—or more than one-fourth of cultivated cropland area (376 million acres) in 1982.[6] This gross change in cultivated cropland compares with a net decline in cultivated cropland of less than 50 million acres (13 percent). Given that CRP has gradually enrolled lands since 1985 and requires land retirement under 10- to 15-year contracts, a small proportion of the land enrolled in the program shifted out of CRP as of 1997.[7] Shifts of cultivated cropland into and out of land uses other than CRP involved more than 72 million acres, or 3.6 times the **net** shift of 20 million acres from cultivated cropland to these non-CRP uses.

The difference between gross land-use flows and net changes in land area is greater with respect to changes in uncultivated cropland. While uncultivated cropland increased on net by 6 million acres (13 percent) between 1982 and 1997, more than 46 million acres shifted to and from uncultivated cropland and another agricultural or forest use—an area larger than the entire 44.5 million acres of uncultivated cropland in 1982 (table 2.1).

The net movement of land among agricultural and forest uses from 1982 to 1997 decreased the intensity of land use

From 1982 to 1997, there was a net change of 60 million acres from either cultivated or uncultivated cropland to our less intensive land-use categories (CRP and grazing, forest, and other rural uses). While 26 million acres shifted to cultivated or uncultivated cropland from a less intensive use between 1982 and 1997, and another 12 million shifted from uncultivated to cultivated cropland, shifts toward the less intensive land uses accounted for about 80 million acres (fig. 2.1).[8] About 90 percent of this total is movements of cultivated cropland into uncultivated cropland, CRP, and grazing, forest, and other rural uses.

Reductions in the intensity of land use included net shifts from cultivated crops to uncultivated crops, CRP, pasture, and forest land uses

CRP enrollment of roughly 30 million acres accounted for most of the 8-percent decline in cultivated cropland from 1982 to 1997. A net of 6.7 million acres (1.8 percent) shifted from cultivated to uncultivated cropland: 18.4 million acres were shifted from uncultivated to cultivated cropland while 11.7 million acres went the other way (fig. 2.1). There was also a large shift of pasture to cultivated cropland (9.4 million acres), with 14.7 million acres shifting the other way. More than 5.4 million acres (1.4 percent) of cultivated cropland in 1982 were converted to urban use by 1997. Changes to urban development are essentially one-way, with a negligible amount of land converting from urban use back to other land uses, including cultivated cropland.[9]

[5] Cultivated cropland includes land identified as being in row or close crops, summer fallow, aquaculture, in crop rotation, or other cropland not planted. Cultivated cropland includes cropland in short-term set-aside programs; double-cropped horticulture; and land in either hay or pasture which had at least one of the three previous years in row or close-grown crops. The NRI definition of uncultivated crops includes land in hay with no rotation and single-cropped horticulture. While lands used for single-cropped horticultural uses are often intensively managed, NRI definitions are used in this report as the land area in these uses is relatively minor, accounting for 15 percent (13 percent) of uncultivated cropland and 1.6 percent (1.7 percent) of total cropland in 1982 (1997).

[6] Specifically, from 1982 to 1997, the amounts of cultivated cropland converting to (from) uncultivated crops, CRP, and grazing, forest, and other rural uses were 18.3 (11.7), 29.4 (0), and 24.7 (17.3) million acres, respectively. These land areas total 101.4 million acres, about 27 percent of the 376.4 million acres of cultivated cropland in 1982.

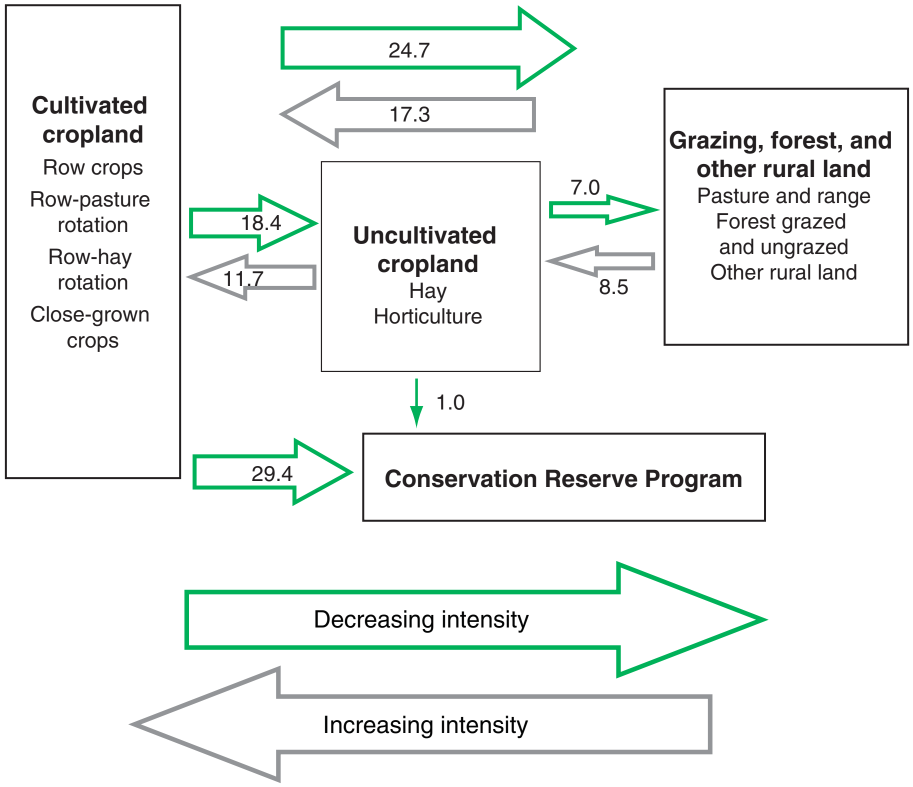
[7] Approximately 11 percent of the 34 million acres enrolled in CRP as of 1992 dropped out of the program in 1997, the year the first contracts began to expire. Approximately, 63 percent of the acres that dropped out returned to cultivated or uncultivated crop production in 1997 (Sullivan et al., 2004).

[8] While ground cover in CRP and uncultivated cropland may often be similar, we consider CRP as a less intensive use than uncultivated cropland given contractual restrictions on grazing and haying on CRP lands. Shifts from uncultivated cropland to CRP were only 1 percent of changes between cultivated or uncultivated cropland and the "less intensive" land-use categories.

[9] Changes to CRP are also one-way from 1982 to 1997 since the program was established in 1985 and requires land owners (or operators) to retire land from crop production under 10- to 15-year contracts. Data from the 1992 and 1997 NRI surveys, when the first CRP contracts began to expire, show land shifting out of CRP and into other land uses (Sullivan et al., 2004).

Figure 2.1

The extensive margin of cropland with respect to other agricultural and forest uses, 1982-97 (million acres)



Note: The green (gray) colored arrows indicate land-use changes constituting a decrease (increase) in the relative intensity of use. The width of the arrows is roughly proportional to the size of land-use movements.

Source: 1997 National Resources Inventory.

Most of the change in uncultivated cropland was movement of land between cultivated and uncultivated cropland (fig. 2.2). Movement between uncultivated cropland and grazing, forest, or other rural uses was also significant, with over 16 million acres shifting one way or the other. Total land movement into and out of uncultivated cropland (16.5 million acres) by 1997 was about 37 percent of all uncultivated cropland in 1982 (44.5 million acres).

While cultivated crop area declined by 50 million acres from 1982 to 1997, uncultivated cropland increased by 5.7 million acres (12.8 percent), chiefly due to the net shifts of 6.7 million acres from cultivated crops (fig. 2.3). Pasture and range also contributed acreage. On the other hand, uncultivated cropland lost almost 1.5 million acres (3.3 percent) to urban development, 1 million acres to CRP, and about 450,000 acres to forest uses.

Land-use changes between 1982 and 1997 mask some changes occurring within that time period

Because our data discussed to now are based on a snapshot at two points in time, they do not reveal shifts in land-use intensity during an interim period between 1982 and 1997. While we lack information on all land-use changes

Figure 2.2

Shifts to and from cultivated cropland, 1982–97

Source: 1997 National Resources Inventory.

Figure 2.3

Shifts to and from uncultivated cropland, 1982–97

Source: 1997 National Resources Inventory.

that occurred between 1982 and 1997, we can identify some additional changes that took place based on data from the 1987 and 1992 NRI surveys. For example, a land parcel may have been cultivated in both 1982 and 1997, but used for pasture in 1987 and/or 1992.

Of the 297 million acres that were in cultivated cropland in both 1982 and 1997, 13.9 million acres (4.6 percent) were in a less intensive use in either 1987, 1992, or both years. Of this total, about 10 million acres (72 percent) shifted to uncultivated crops, 2.2 million acres (16 percent) to pasture or range, and 1.6 million acres (12 percent) to CRP. Another 12.1 million acres shifted into cultivated crops from a less intensive land use and then shifted back out of cultivation over 1982-97. In total, 26 million acres shifted between cultivated cropland and a less intensive use between 1982 and 1987 and/or 1992 (though not between 1982 and 1997). This is in addition to the 100 million acres of land at the extensive margin of cultivated cropland captured by the 1982-97 span. Taken all together, this area (127 million acres) is equal to a third of U.S. cultivated cropland in 1982 and about three times the net shift in cultivated cropland to less intensive agricultural and forest uses during 1982-97.[10]

The Extensive Margin of Cultivated Cropland Is Not Equally Active in All Regions

The location of land-use change depends on the land use involved. Figure 2.4 shows land entering and exiting cultivated crop production from 1982 to 1997. Figure 2.5 shows land shifting from cultivated crops to another use, by land use, while figure 2.6 shows land shifting into cultivated crops. Transitions to and from uncultivated cropland were more common in the North, while transitions between cultivated crops and grazing are more evenly distributed. The margin between cultivated cropland and forest was active only in the Southeast. CRP enrollments were concentrated in the Plains States.

Regions that have more acreage of cultivated cropland also tend to have relatively large movement of land both into and out of cultivated crop production. The Heartland, Northern Great Plains, and Prairie Gateway account for about 70 percent of U.S. cultivated cropland, and have the most land transitioning into and out of cultivated crop production (fig. 2.7). In all three regions, CRP was a major factor in land transitions out of cultivated cropland (fig. 2.8).

Regions that started with a lot of cultivated cropland in 1982 also tended to have large net reductions in cultivated cropland (fig. 2.7). The reduction in cultivated cropland was particularly large in the Prairie Gateway (10.9 million acres), where CRP enrollment was also high (9.6 million acres). Although the Southern Seaboard started with less cultivated cropland acreage, the net reduction from 1982 to 1997 was large, especially shifts to grazing and forests; 1.4 million acres, or 8 percent, of the cultivated cropland in 1982 shifted to pasture and a similar amount shifted to forests by 1997. In the Northern Crescent, the extensive margin of crop production was active in both directions, despite a relatively small base of cultivated cropland and relatively little CRP enrollment.

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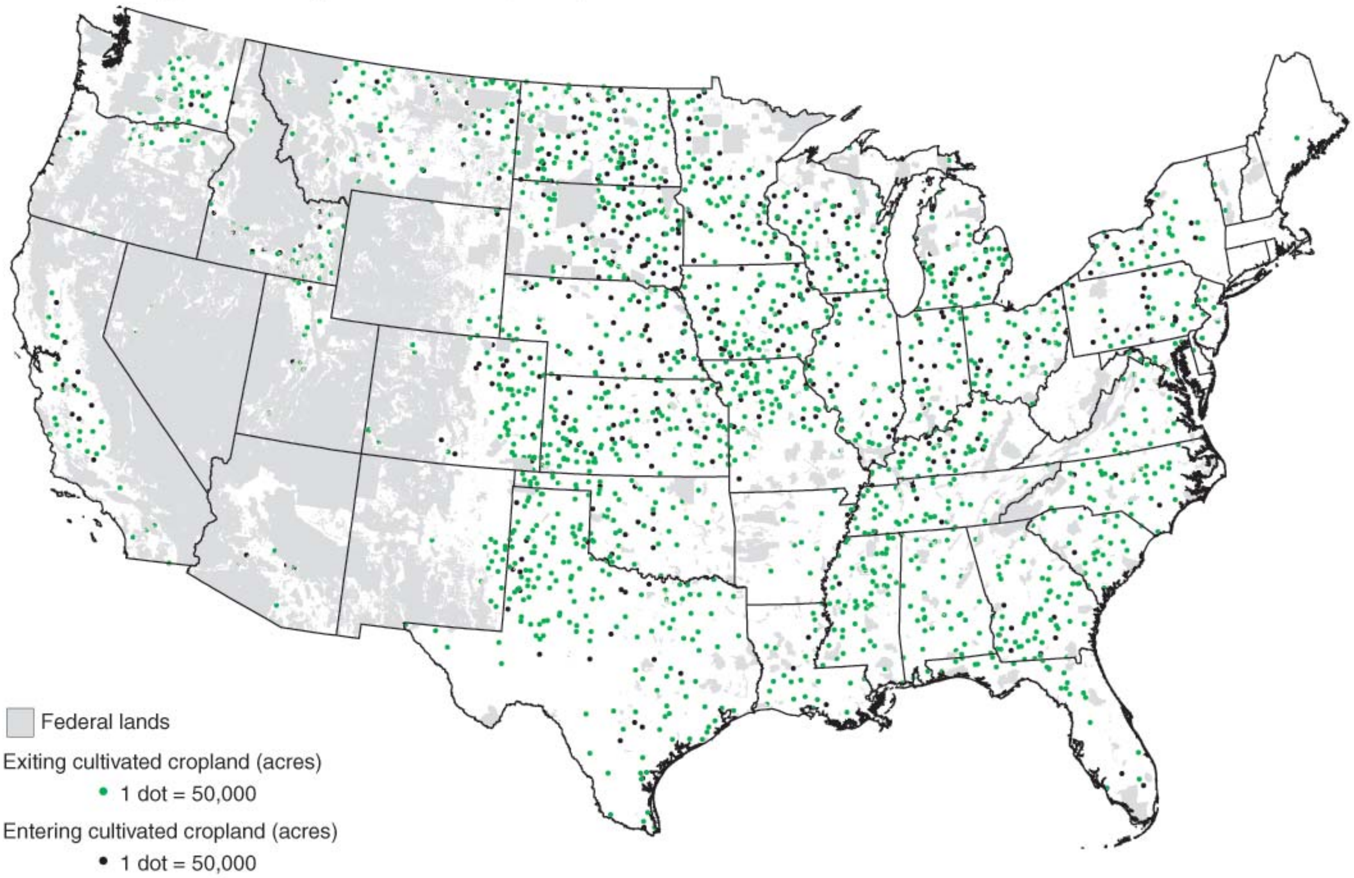
[10] There were 5.3 million acres in uncultivated crops in both 1982 and 1997 that moved to a less intensive use in 1987 or 1992 (with 4.6 million and 0.5 million shifting to grazing and CRP). Some 1.8 million acres of land not in uncultivated crops in either 1982 or 1997 shifted to uncultivated cropland from a less intensive use in 1987 or 1992. In total, at least 7.1 million acres changed use at the extensive margin of uncultivated cropland, in addition to the 16.5 million acres described earlier. The total movement of land at the extensive margin of uncultivated crops thus exceeds 23.6 million acres, more than half of the 44.5 million acres of uncultivated crops in 1982.

Figure 2.4

Land entering and exiting cultivated cropland, 1982-97



Note: Size of dots is not proportional to actual land area.

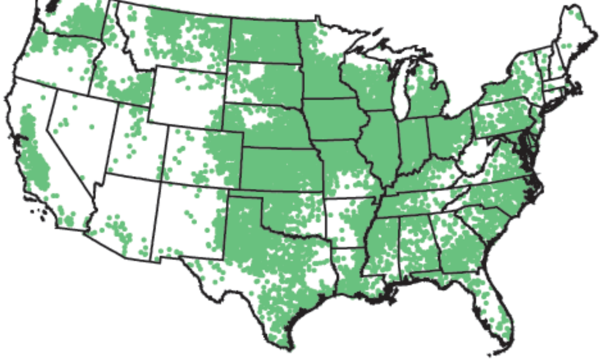
Source: 1997 National Resources Inventory.

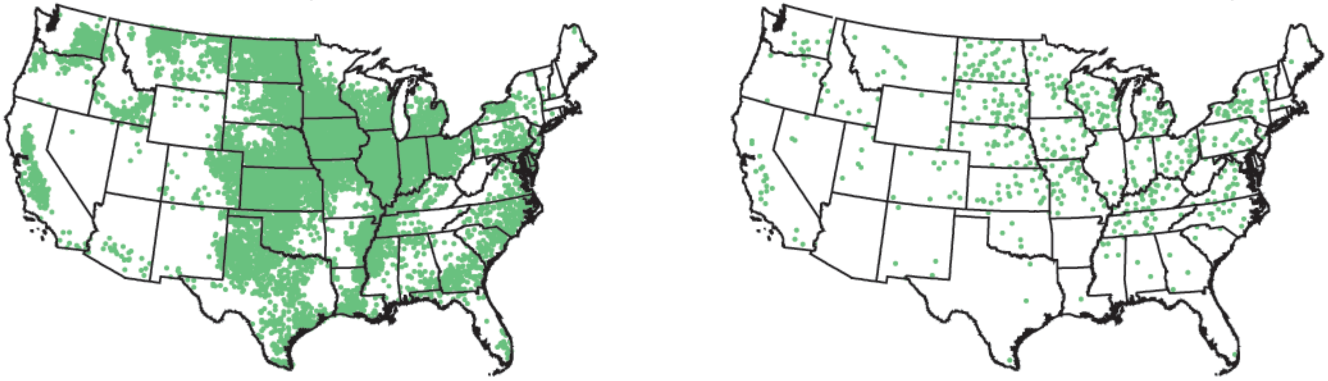
The fact that larger declines occurred in regions with more cultivated cropland does not necessarily indicate that crop production is shifting toward regions with less initial cropland acreage. In fact, the four regions with the largest cultivated cropland acreages (Heartland, Prairie Gateway, Northern Great Plains, and Northern Crescent) experienced the smallest percentage reductions in cultivated cropland area (fig. 2.9). On the other end of the scale, the Eastern Uplands region, which has the smallest acreage of cultivated cropland, experienced the smallest net decline in absolute terms but the largest decline in percentage terms. Reduction in cultivated cropland exceeded 20 percent in three regions: the Eastern Uplands, Southern Seaboard, and Basin and Range. A region's tendency to maintain cultivated cropland (at the margin) likely reflects differences in soil quality, the scale of production, government programs, and other factors affecting the relative profitability of growing crops.

So, the extensive margin of crop production is significantly larger than the net change in land used for cultivated crops. Between 1982 and 1997, cultivated cropland declined by 50 million acres, while more than 100 million acres were shifted into or out of cultivated crops. These shifts (either gross or net) are not evenly distributed across regions, with absolute changes larger in regions with the most cultivated cropland and percentage changes greater in regions with relatively little cultivated cropland.

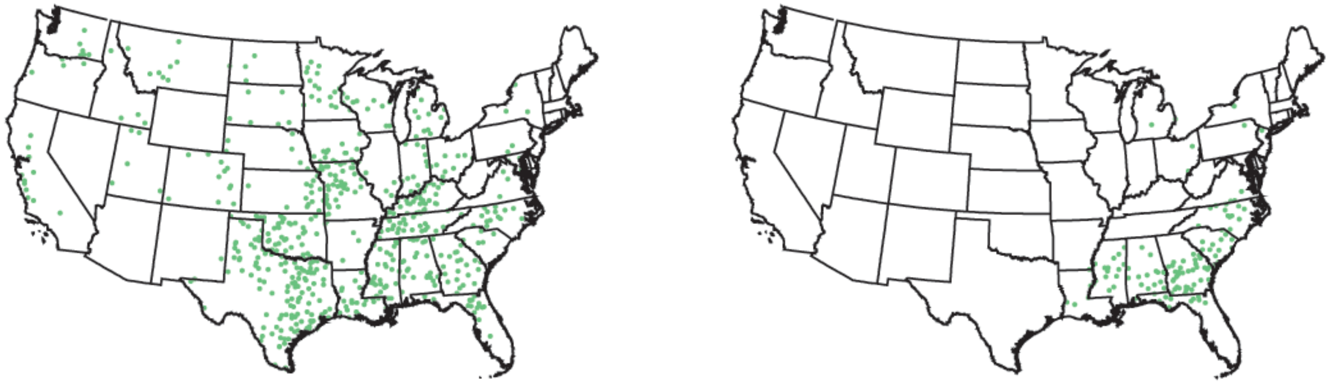
Figure 2.5

Location of land exiting cultivated cropland, 1982-97


All cultivated cropland, 1982


Remained cultivated cropland

Transitioned to uncultivated cropland


Transitioned to grazing land

Transitioned to forest land


Transitioned to CRP

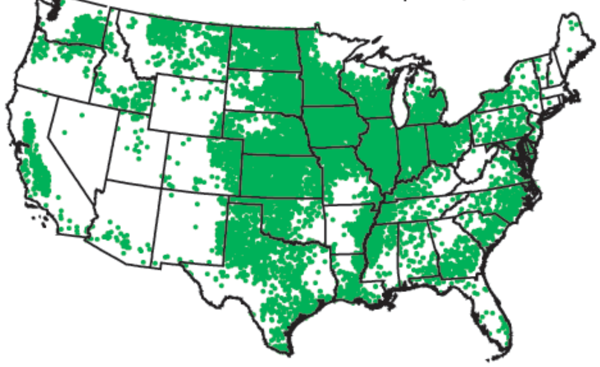
Transitioned to other rural land

Note: Size of dots is not proportional to actual land area.
Source: 1997 National Resources Inventory.

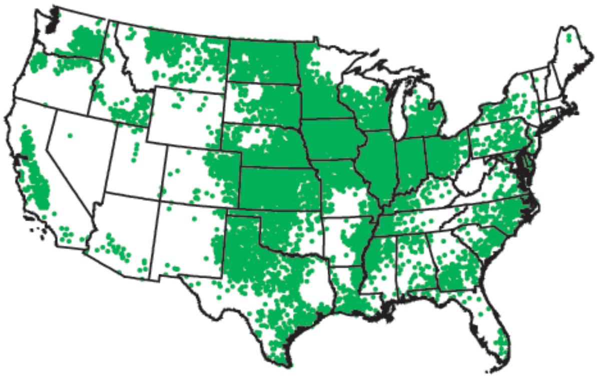
Figure 2.6

Location of land entering cultivated cropland, 1982-97

All cultivated cropland, 1997



Remained cultivated cropland



Transitioned from uncultivated cropland

Transitioned from grazing land

Transitioned from forest land

Transitioned from other rural land

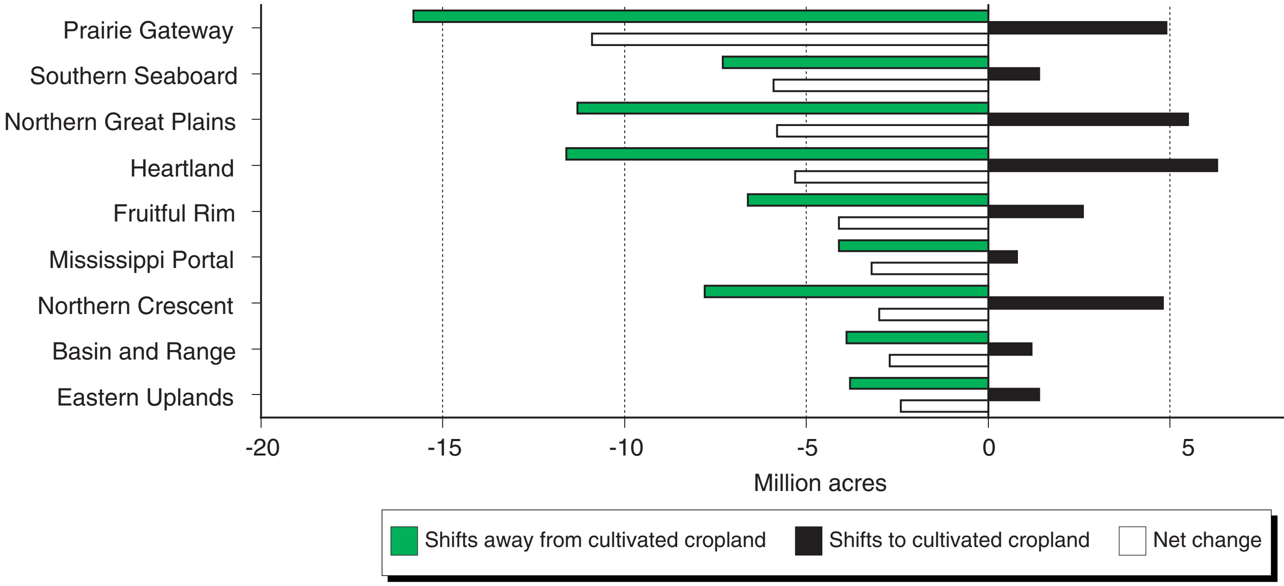
● 1 dot = 25,000 acres

Note: Size of dots is not proportional to actual land area.

Source: 1997 National Resources Inventory.

Figure 2.7

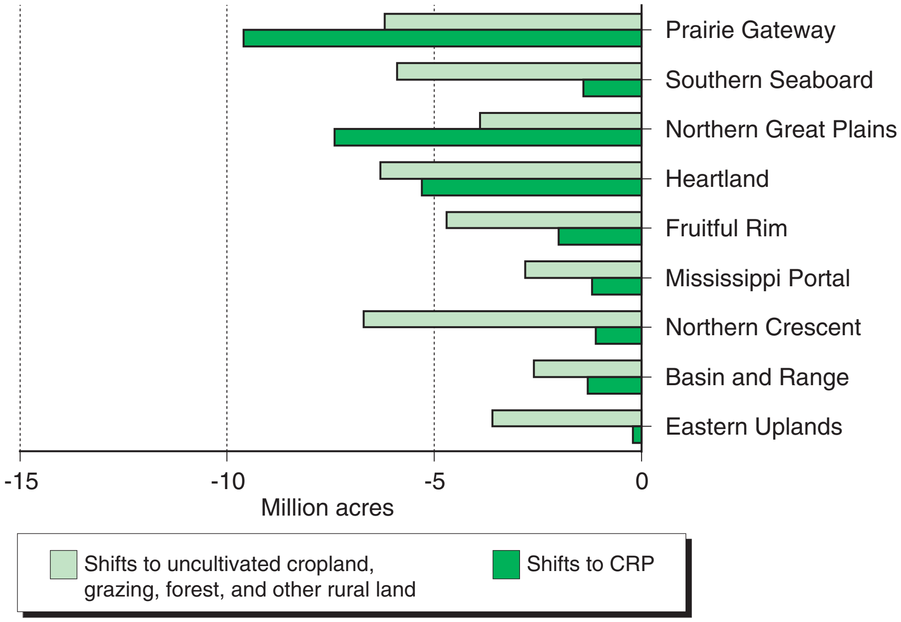
Shifts to and from cultivated cropland (all land uses), by region, 1982-97



Source: 1997 National Resources Inventory.

Figure 2.8

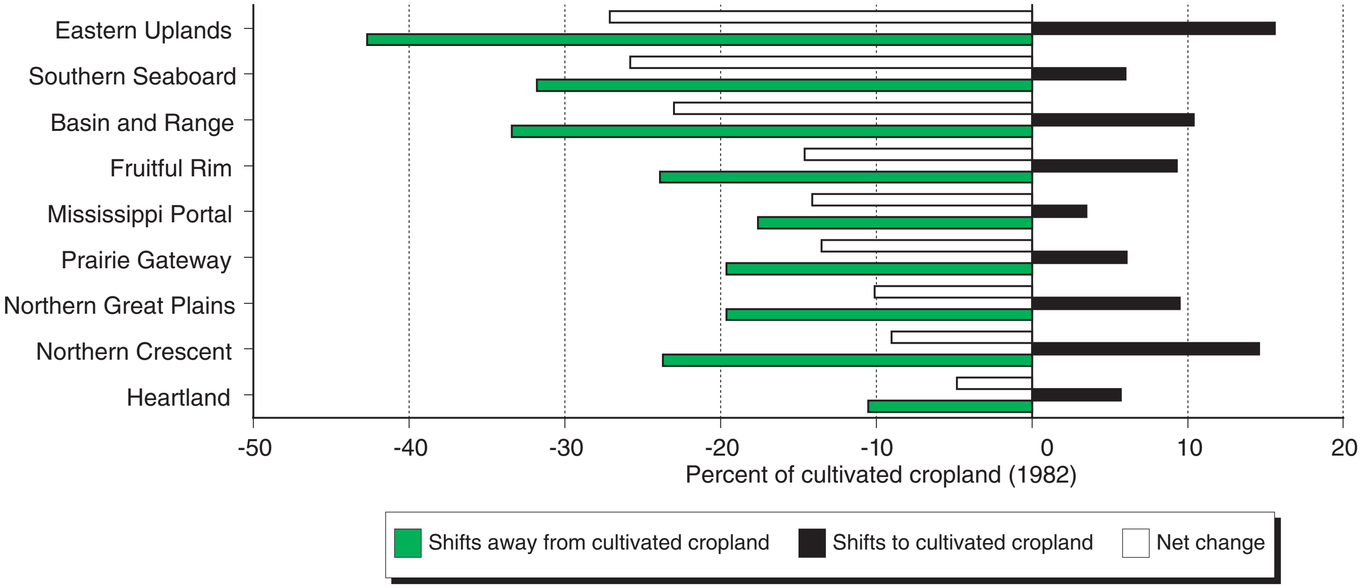
Shifts from cultivated cropland to CRP and other agricultural and forest uses, by region, 1982-97



Source: 1997 National Resources Inventory.

Figure 2.9

Percentage shifts to and from cultivated cropland (all land uses), by region, 1982-97



Source: 1997 National Resources Inventory.

Even if the amount of land used for crop production is relatively stable, the specific land being used for crops is changing. So, have the economic and environmental characteristics of cultivated cropland been changing even while cropland acreage remains constant? And is cultivated cropland at the extensive margin more or less vulnerable to environmental damage than the land that persists in cultivated crop production?

Finally, agricultural policy may affect the environmental characteristics of cultivated cropland through its impact on the extensive margin of crop production. CRP enrollment is critical, given its role in shifting land from crop production in the three regions with most cultivated cropland. How does CRP land compare environmentally with land converted to cultivated crops? Crop insurance may also have affected the extensive margin of crop production, but its effects are more difficult to quantify.

Chapter 3

Land Quality and Land-Use Change

Producers allocate land to the use they expect will yield the greatest benefit over time.[1] In an agricultural context, maximizing benefits entails selecting which commodity to produce (e.g., corn, hay, or timber) and how, using land as an input.[2] The expected return to land depends on the price of outputs and (nonland) inputs, available technology (which can affect the per-unit cost of production), government policies, skills and preferences of the producer, and land quality.

Studies of land allocation, particularly among major land uses, have focused on the role of land quality and policy in determining land use. Policy can affect land-use decisions in a variety of ways. Price supports can alter the relative return between commodities that are supported and those that are not (Wu and Segerson, 1995; Plantinga, 1996). The tax code may favor certain land uses by its treatment of associated investments (Lichtenberg, 1989). Crop insurance, by reducing the risk of crop production, may promote crop cultivation where it is relatively risky (Goodwin et al., 2004; Wu, 1999). Government-funded infrastructure developments, such as flood control projects, may also enhance the economic viability of crop production in particular areas (Stavins and Jaffe, 1990).

In these studies, the effect of market prices, technology, and policy are all considered in the context of the land's ability to produce various goods and services. While there is no single best indicator of land quality, soil productivity—suitability of the soil as a medium for plant growth—is key for agricultural production. Most soil productivity definitions include attributes of the soil, climate, and topography. Existing studies have used a range of indictors, including the Land Capability Classification (Plantinga, 1996; Hardie and Parks, 1997) and one or more specific soil parameters such as water-holding capacity (Lichtenberg, 1989; Wu, 1999; Wu and Brorsen, 1995). As a rule, land quality attributes are fixed or change only slowly. Nonetheless, changes in markets, government policy, or technology may favor some types of land over others.

The characteristics of producers also affect land-use decisions. Producers may assess returns to various land uses differently because of differences in management skills, expectations about future prices or technology, risk aversion, or personal objectives. For example, lifelong crop farmers may be more reluctant to shift from crop production to forestry than individuals who have some expertise in timber production. Likewise, producers whose primary occupation is not farming or forestry may allocate land to agriculture, forestry, or other uses based on preferences that are not centered on potential return.

When a change in land use involves significant upfront costs (e.g., removing trees to begin crop production) or delayed returns (e.g., converting land to

[1] In this report, we use the term "producer" to refer generically to the individual making the land-use decisions for a parcel of land. This decisionmaker may or may not be the owner of the land. Land-use decisions may be made by the landowner, a land manager or operator, or some combination of the two. The ability of an operator renting land to make land-use decisions will depend on the terms of the cash or share lease contract and the ability of the owner to monitor and enforce this agreement.

[2] Land may also be valued for a wider range of goods, including recreational and ecological services. Producers can capture some (but not all) of these values by charging fees for hunting or other recreational activities. Producers may also value services such as recreation, aesthetic beauty, or environmental protection even if they cannot be compensated monetarily for them.

timber production), risk aversion, wealth, and discounting may be important. Producers who are particularly risk averse may be reluctant to make a large, upfront investment or wait many years to receive a return, even when the return is likely to be higher than that of other land uses. Even if they are not risk averse, producers with limited assets may have difficulty financing a long-term investment. Also, the more an individual discounts future returns, the less likely he or she is to undertake a long-term investment. For example, if crop production yields an average annual return (to land) of $40 per acre, the net present value (NPV) of returns discounted at 4 percent per year over 20 years is $544. A pulpwood harvest occurring at 20 years would have to net $1,192 per acre to yield an equivalent NPV (1192*(1+.04)^20=544). If future returns are discounted at 6 percent, however, the timber harvest would have to yield a net of $1,471 per acre to rival crop production.

Over time, market transactions tend to direct land to the owners who value the land most and into the uses they perceive as most valuable. Consider the sale of land that is in grazing use but has some potential for profitable crop production. Some bidders may believe that grazing is the most valuable use of the land and submit bids accordingly. Others may focus on the land's crop production potential and submit bids that reflect returns to crop production (less the cost of converting the land to crop production). If the high bid is from an individual who believes that the land is more valuable in crop production, it is likely that land-use conversion will quickly follow the sale. Because agricultural land markets in certain areas can be "thin" (with only a small proportion of land sold in any given year), reallocation of land use may take many years and be interrupted by changes in economic conditions that alter individuals' views on relative returns.

A Model of Land Allocation and Land Quality

For the purpose of our conceptual model, we assume that land quality can be defined by a single valued index that primarily measures soil productivity. This index captures the potential of land to generate economic returns for the private owner or operator (distinct from an environmental quality index measuring benefits to society). Soil productivity refers to the suitability of the soil and climate as a plant growth medium (see box, "Soil Quality Indicators").

Location may be an important determinant of land quality in several ways. The proximity of land to centers of population and employment is critical in determining the potential value of land for development (Bockstael, 1996). Local amenities, such as open space and rural "character," may also enhance the value of land for residential development (Wu et al., 2004). In terms of commodity production, distance to markets may also be important. For example, local grain prices depend in part on shipping costs. For bulkier commodities such as hay or timber, proximity to markets is even more critical. Distance of land to population centers may also affect the profitability of providing recreational services. In some cases, the value of recreational services that can be captured by the producer may tip the balance in a land-use decision. For example, grassland may provide livestock grazing during the spring and summer, and be used for hunting in the fall and winter

Soil Quality Indicators

In allocating land among agricultural and forest uses, productivity in terms of crop, forage, or timber production is a key indicator of land quality. Productivity refers to the suitability of the soil as a plant growth medium and the favorability of the climate. While productivity itself is complex, some useful proxies include crop yields or yield potential, one or more specific soil attributes such as soil water-holding capacity (e.g., see Lichtenberg, 1989; Wu, 1999), and indices that combine multiple soil attributes into a single number such as the Productivity Index (Pierce et al., 1983) or the soil rating for plant growth (SRPG; Soil Survey Staff, 2000).

Topography can also affect productivity as the loss of soil and nutrients through surface runoff can result in higher input costs and reduced soil depth, reducing soil productivity over time. Highly erodible land, which is often steeply sloping, is less likely to be used for crop production (Miranowski and Hammes, 1984). In at least one index of soil productivity (SRPG), slope reduces the overall soil productivity score. Steeply sloping land can also be difficult to farm efficiently with large machinery typical of modern crop production.

SRPG is an index of inherent soil productivity based on soil's physical, chemical, and biological factors as well as topography and climate. While SRPG is based largely on inherent properties of the soil such as texture and water-holding capacity, the productivity of specific tracts of land can be damaged over time by soil erosion. SRPG was originally developed by soil scientists with USDA's Natural Resources Conservation Service for use in implementing the Conservation Reserve Program (CRP).

While the SRPG rating and other soil productivity measures are indicators of economic potential, they are proxies. A more direct measure is potential yield. Potential yields are estimated in a number of ways, including experimental plots, and are intended to reflect the management practices yielding the highest economic return. Estimated irrigated and nonirrigated yields from the Soil Conservation Service's (now NRCS) Soils 5 data are linked to the National Resources Inventory data set. The Soil Survey Geographic (SSURGO) data from NRCS are the most up-to-date source of yield and soil productivity information, and are being digitized for the entire country.

months. However, given the likelihood that nearby land could also provide similar amenities, the recreational services must be valued by enough people for them to be a viable land use.

Figure 3.1a shows the relationship between land quality and returns for three hypothetical land uses given fixed prices, technology, and policy. The concave shape of the curves (decreasing upward slope as land quality increases) is based on the assumption that the genetic capacity of plants will increasingly become the limiting factor in production as land quality rises. Land use A is best able to use land of very low quality, but also reaches its full potential at a relatively low level of land quality. Land use C, on the

Figure 3.1a

Land quality and relative return to three hypothetical land uses

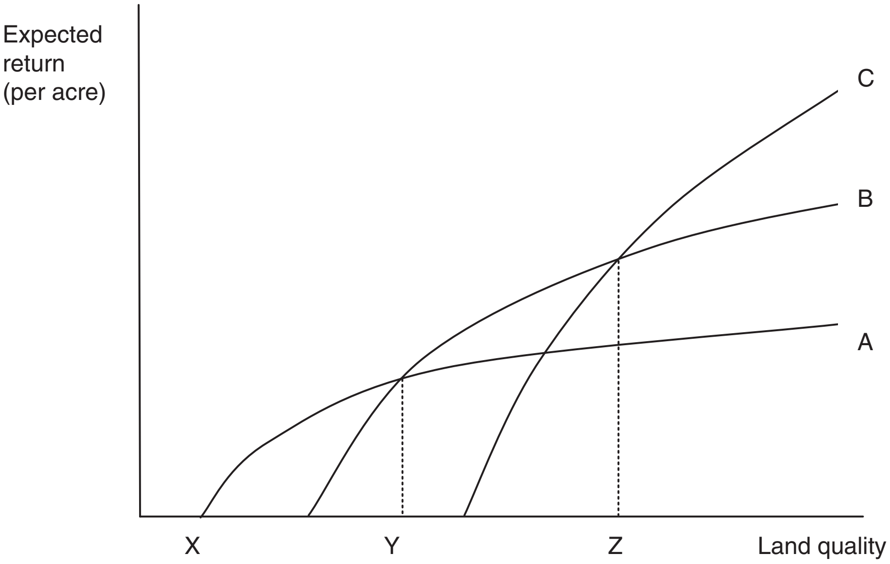
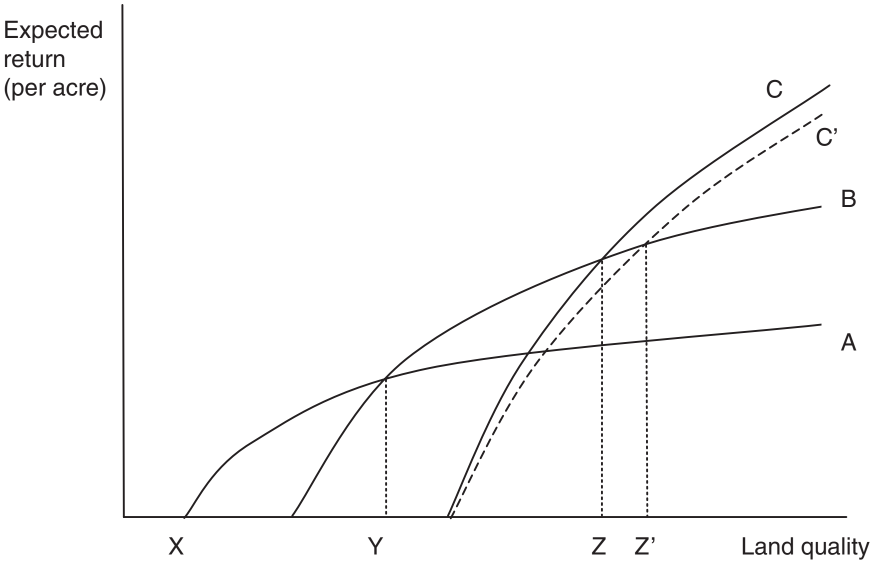


Figure 3.1b

Land quality and relative return to three hypothetical land uses: Effect of decline in output price



other hand, cannot use low-quality soils but is better able to take advantage of the greater plant growth potential on high-quality land.

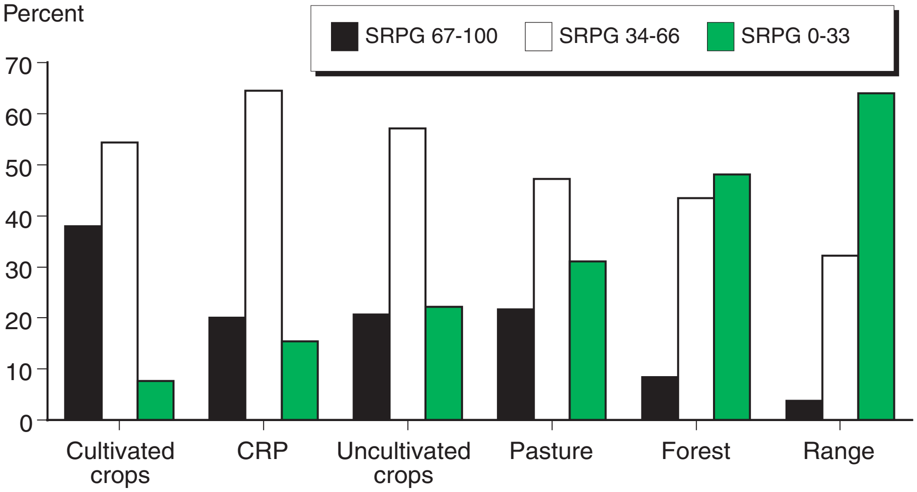
If these curves reflect a market-level assessment of the relative value of the three land uses, land with quality (Q) less than X will be idle (not devoted to any of the three uses considered in figure 3.1a); land with quality between X and Y will be devoted to use A; land with quality between Y and Z will be devoted to use B; and land with quality greater than Z will be devoted to use C. The producer is indifferent between land uses A and B at point Y, and is indifferent between uses B and C for land of quality Z.

These stylized predictions are supported by the data on the distribution of land quality across land uses. Figure 3.2 shows the distribution of land quality, as defined by the soil rating for plant growth (SRPG), by land use, averaged over 1982-97. The SRPG is a measure of soil productivity that can take values of 0-100. While there is land of different qualities devoted to every use, lands in cultivated crops include a greater proportion of high-productivity land (SRPG 67-100) and a smaller proportion of low-productivity land (SRPG 0-33) than any other land-use category. These results imply that cultivated crops are best able to take advantage of high-productivity land but are relatively unprofitable on low-quality land. Uncultivated cropland and CRP include more medium-quality land (SRPG 34-66) than other land-use categories. Finally, pasture, forest, and rangelands include more low-productivity land than the cropland categories or CRP (which is former cropland). Forest and rangeland also include less high-quality land than other land-use categories.

Land enrolled in CRP is likely to be of lower quality than cultivated cropland on average as a result of program-specific objectives and economic incentives for participating. First, USDA targets highly erodible land among other environmental factors in the Environmental Benefits Index (EBI), the selection criteria used for selecting CRP parcels. We show later that highly erodible land is also less productive on average, so the program indirectly targets land with lower soil productivity.[3] Second, the cost of enrolling land is another component of the selection criteria so that, given similar environmental characteristics, producers with less to lose from participating are more likely to be accepted into CRP. Thus, lower value land is directly targeted as well. USDA also sets soil-specific caps (based on SRPG) on the maximum annual rental payments allowed under the program. All else being

Figure 3.2

Distribution of different agricultural uses, by soil productivity index (soil rating for plant growth)



Note: SRPG = soil rating for plant growth. Numbers depict the average share of land in each cell across each soil productivity category from 1982 to 1997, with shares in each cell summing to 100 percent. As seen by moving from left to right across each row, land in more intensive land uses, such as cultivated crops, generally has a higher proportion of high-productivity soils (SRPG 67-100) and a lower percentage of low-productivity soils (0-33) than land in less intensive uses, such as rangeland.

Source: ERS analysis of 1997 NRI and Soil Survey Geographic data set.

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[3] The relationship between soil productivity and erodibility is examined in detail in the next chapter.

equal, for any particular soil type, producers with economic benefits from crop cultivation near (or above) the cap will have smaller incentives to participate in CRP than producers on lower quality land. Because we do not observe all sources of variation in soil productivity, the relative productivity of lands enrolling in CRP may be even lower than our analysis suggests.

Change in market prices, technology, and policy can be depicted as shifts in one or more of the curves in figure 3.1a. If, for example, the price of output(s) produced by land use C decreases, the curve for land use C would shift downward (see C' in figure 3.1b).[4] If returns to other land uses are unchanged, land with quality between Z and Z' would shift from use C to use B. Similar shifts (in the opposite direction) may be observed with technical changes that lower per-unit production costs.

Economic Characteristics of Transitioning Lands

The conceptual model suggests that low-quality cultivated croplands (relative to other cultivated cropland) would be most likely to shift to uncultivated cropland, CRP, and other agricultural and forest uses as market conditions, government policies, or technology change. Similarly, theory suggests that the relatively high-quality land in uncultivated crops and pasture would be on the margin with cultivated cropland while relatively low-quality uncultivated cropland would be on the margin with forest and rangeland. Following the same logic, the relatively high-quality lands in forest and range would be those most likely to transition to crop production.

This pattern is borne out by an examination of land quality for various categories of land-use change over 1982-97. This is the longest period for which the NRI data are available and reveals the largest amount of cropland changes. Land that was cultivated in 1982 and stayed in cultivated crop production (fig. 3.3, row 1, column 1) includes a higher proportion of high-productivity land and a lower proportion of low-productivity land than land that moved to another use by 1997 (fig. 3.3, row 1, columns 2-4). Likewise, land moving to cultivated crop production from another use (row 2 and 3, column 1) includes a higher proportion of high-productivity land and a lower proportion of low-productivity land than noncultivated lands that remained in or moved to another noncultivated use (rows 2-3 and columns 2-4). In general, land that stayed in or moved to cultivated cropland is more likely to be high-productivity land than land in (or moving between) noncultivated land uses.[5]

While the SRPG rating is one indicator of economic potential, it is a proxy. A more direct measure is the potential yield—the amount of a given crop that can be produced per unit of land under the management practices providing the highest economic return (see box, "Soil Quality Indicators"). Figure 3.4 shows potential yields, relative to crop reporting district (CRD) averages, for four major crops (corn, soybeans, wheat, and alfalfa hay) in the cells of the land-use change matrix associated with our four key land uses.[6] The bar in each cell represents the average relative yield for each crop.

By focusing on yields relative to the average for a relatively small geographic area, we compare yields while holding constant other factors that are common

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[4] Curve shifts need not be parallel. If lower quality land has less output (e.g., a lower corn yield), then a change in the output price would have a larger per-acre effect on higher quality land. Technology change may not affect all types of land equally, either. Lichtenberg (1989) showed that soils with greater water-holding capacity in the Nebraska sand hills were more likely to be shifted from small grains and hay to row crops with the development of center-pivot irrigation.

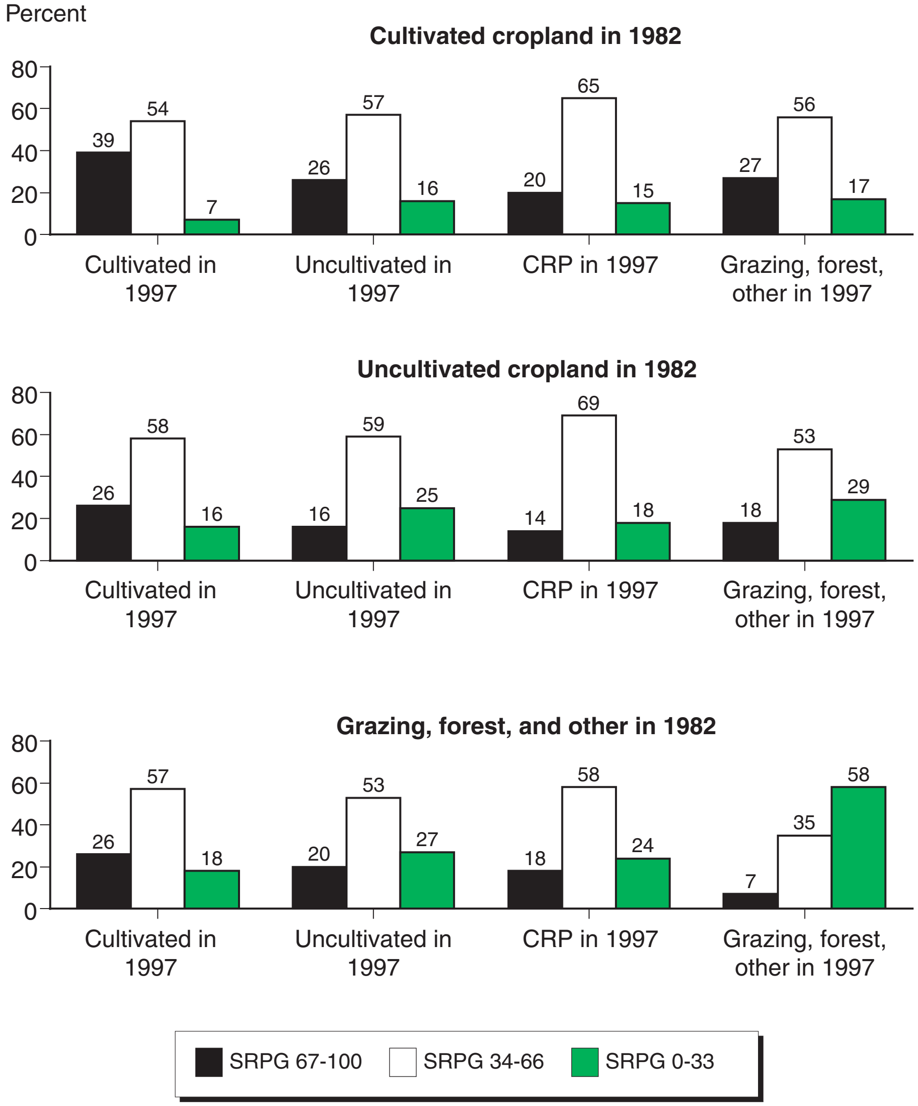
[5] Lands observed in cultivation in both 1982 and 1997 include some lands that shifted out of cultivation and then shifted back over the course of this period. Excluding these lands from our category of lands remaining in crop cultivation would likely strengthen our findings regarding the relative soil productivity at the extensive margin of cultivated cropland.

[6] Most States have between six and nine CRDs, multicounty units used by USDA in gathering data. Each National Resources Inventory point is assigned relative yields, which are the ratio of the point-specific yield to the average yields, for all four land uses in the CRD. Estimated yields are from the Soil Conservation Service's (now NRCS) Soils 5 data. While yields from the Soil Survey Geographic (SSURGO) data have been most recently updated, we used Soils 5 data for this analysis as our focus is on relative (rather than absolute) yield levels, and Soils 5 data had a wider geographic coverage at the time of our study.

Soils 5 yields are also not available for all soils; the less likely land is to be used for crop production, the less likely it is to be assigned a yield in the Soils 5 data series. Because potential crop yields on this land are likely to be relatively low, the exclusion of these lands is likely to bias estimates for average relative yield upward for land in less intensive uses. Thus, differences in relative potential yields may be even more pronounced than indicated in figure 3.4.

Figure 3.3

Land-use change and land quality (Soil rating for plant growth)



Notes: Numbers depict the share of land in each cell across each soil productivity category, with shares in each cell summing to 100 percent. As seen by moving from left to right across each row, land that transitioned to (or remained) in a more intensive land use, such as cultivated cropland, generally has a higher proportion of high-productivity soils (SRPG 67-100) and a lower percentage of low-productivity soils (0-33) than land transitioning (or remaining) in a less intensive use, such as grazing, forest, and other land. As seen by moving from top to bottom along each column, land in more intensive land uses generally has a higher proportion of high-productivity soils (SRPG 67-100) and a lower percentage of low-productivity soils (0-33) than land in less intensive uses.

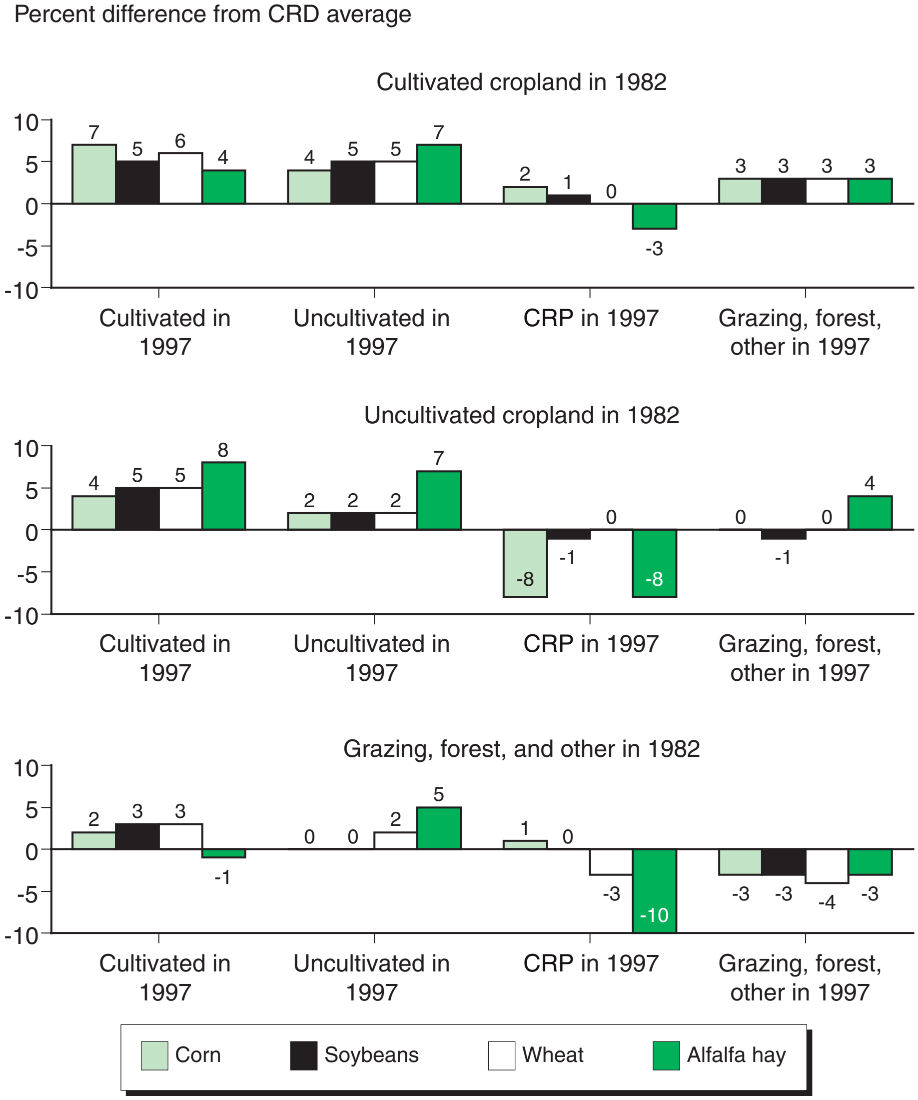
Source: ERS analysis of 1997 NRI and Soil Survey Geographic (SSURGO) data.

to this region. Given that prices for agricultural output and inputs are not likely to vary much within a CRD, estimated differences in yields are strong indicators of differences in the profitability of different subsets of land.

Using relative potential yields gives roughly the same pattern of land use and land quality as SRPG, though it provides some additional insights. In general, land in cultivated crops has higher yield potential than land in other uses (fig. 3.4, compare column 1 to columns 2-4). Average yields for land

Figure 3.4

Land-use change and land quality base on expected crop yields



Note: To account for variations in climate and other nonland quality factors that could cause yields to vary spatially, each NRI point is assigned relative yields that are the ratio of the point-specific yield to the average yields, for all four land uses, in the crop reporting district (CRD). For each cell, the average relative yields are reported.

Source: ERS analysis of 1997 NRI and Soils 5 data.

that was in cultivated cropland in both 1982 and 1997 are generally higher than for land that moved from cultivated cropland to another use. The exception is alfalfa, where potential yields are higher on uncultivated cropland (row 1, column 2). Also, potential yields of corn, soybeans, and wheat on land that moved to uncultivated crops (row 1, column 2) are almost as high as for land that remained in cultivated cropland. Moreover, land that shifted from cultivated crops to CRP (row 1, column 3) had lower yields than all other land moving from cultivated crops (row 1, column 4).

Clear economic differences exist across lands at the extensive margin of crop production. Most strikingly, land enrolled in CRP appears to be the lowest quality land in a crop reporting district across each of the cropland categories considered. Cultivated cropland enrolled in CRP is just slightly above average for corn, soybeans, and wheat and below average for hay. It appears to be less productive than land converting to other agricultural and forest uses. Uncultivated cropland enrolled in CRP follows the same pattern.

Many of the yield differences observed are small. Estimated yields on land in cultivated crops in both 1982 and 1997 are 4-7 percent above CRD averages (fig. 3.4, row 1, column 1), while land that was in grazing, forest, or other uses in both years had yields 3-4 percent below CRD averages (row 3, column 4). The overall pattern is striking given the coarseness of the underlying data. The Soils 5 data do not reflect all of the factors affecting yields on each land parcel. The data are specific to a soil map unit and capture only general variation in potential yields based on soil type. Considering additional parcel-level characteristics would tend to increase the variation in estimated yields within a small geographic area, and thus magnify the departure in yields from the CRD average.

Conclusion

The theoretical model of land allocation provides a framework for analyzing data on the economic characteristics of lands at different extensive margins. Two land quality indicators—SRPG and potential crop yields—suggest clear patterns in the relative profitability of lands at different extensive margins, with higher (lower) quality lands more likely to be devoted to more (less) intensive land uses. The extensive margin of cultivated cropland is largely cultivated cropland that is of lower quality than other cultivated cropland and land in less intensive uses is higher quality than other land in those uses. These results indicate that land quality is, indeed, a critical factor in the allocation of land among agricultural and forestry uses. Lands enrolled in the CRP appear to be of particularly low quality relative to other land in the same geographic area.

The indicators examined do not fully explain land use. For example, some land with high productivity (SRPG 67-100) is in other agricultural and forest uses, while some land in cultivated crops has low productivity (SRPG 0-33). Of course, soil productivity indicators do not capture every dimension of land quality that is important to agricultural land-use decisions. An unfavorable location far from infrastructure and transportation facilities, for example, may make land otherwise quite suitable for crop production unprofitable for this purpose.

In this chapter, land quality was defined narrowly to focus on land characteristics that are of direct economic value in agricultural production. However, the environmental impact of land-use change at the extensive margin of cultivated cropland will depend largely on factors like erodibility and nutrient runoff potential. Some analysts have assumed that land which is economically marginal for crop production is also more environmentally sensitive than other cropland. In the next chapter, we test this assumption by examining the relationship between economically marginal croplands and different indicators of environmental sensitivity.

Chapter 4

Environmental Characteristics of Economically Marginal Cropland

Agricultural production, particularly cultivated crop production, can affect the environment in many ways. But is the extensive margin of cultivated crop production more susceptible to soil erosion or nutrient loss than average cropland? These agri-environmental problems have been a major focus of U.S. agri-environmental policy over the past two decades. We also examine whether changes in cultivated cropland could be affecting habitat that is important to imperiled species of birds and other wildlife. Imperiled species are those classified by NatureServe as either “critically imperiled” or “imperiled” at the national level, receiving a Global Conservation Status (G) rank of 1 or 2, respectively. These data are the most comprehensive measure of U.S. biodiversity conservation status (see Appendix C).

We analyze the relationship between soil productivity, environmental sensitivity, and land use at both the local and national levels. At the local level, we compare differences from averages by Crop Reporting District (CRD). Most States have between six and nine CRDs, which are multicounty areas used by USDA for data-gathering purposes. When environmental sensitivity varies widely at that local level, focusing on small geographic areas ensures that local differences are not averaged out, as they could be in national averages. We look at differences from national averages to capture broader inter-regional differences. For example, wind erosion occurs mostly on semi-arid regions of the Northern and Southern Plains. But at a local level, land may be quite similar in terms of erodibility. Finally, available data are not always sufficient to capture local variations in environmental sensitivity. In these cases, comparisons against national averages are necessary, even if local variation is significant.

Lands With Low Soil Productivity Are More Vulnerable to Erosion Damage

We measure the soil’s sensitivity in terms of erosion using the erodibility index (EI) and the estimated average annual rate of soil erosion. The EI is defined by the ratio of *inherent erodibility* to the *soil loss tolerance*. Inherent erodibility for a given soil is the rate of erosion (tons per acre per year) that would occur on land that was continuously clean tilled throughout the year.[1] The soil loss tolerance is the rate of soil erosion that can occur without significant long-term productivity loss. Thus, while the erodibility index is independent of land use and management, it measures the fragility of the soil in terms of erosion, capturing both the potential of a soil to erode and its resistance to erosion damage.

Actual levels of soil erosion depend greatly on land use and management, making comparisons across different land uses difficult. On land in culti-

[1] Wischmeier and Smith (1978) and Skidmore and Woodruff (1968) provide detailed descriptions of the estimation of inherent erodibility for rainfall erosion and wind erosion, respectively.

vated crop production, soils are frequently exposed to the erosive forces of rainfall and wind, and tend to erode more quickly than land in continuous grass or tree cover. However, meaningful comparisons can be made across lands of different soil productivity levels that are, nonetheless, devoted to the same land use. Average annual rates of erosion are estimated (for NRI data points) using the Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1978) and the Wind Erosion Equation (WEE; Skidmore and Woodruff, 1968).

At the local (CRD) level, lands with lower soil productivity do tend to be more inherently erodible for wind and, especially, rainfall (fig. 4.1, top row). Low-productivity land (SRPG 0-33) is, on average, 40 percent more susceptible to rainfall erosion than the CRD average, while high-productivity land (SRPG 67-100) is 25 percent less erodible. The critical factor behind these differences is the steepness of slopes. On steeply sloping land, water runs off quickly, often carrying soil with it. Topography can also affect soil productivity as the loss of soil and nutrients through surface runoff can result in higher input costs and reduced soil depth. In the SRPG index, slope reduces the overall soil productivity score.

For wind erosion, low-productivity land is, on average, 34 percent more erodible than the CRD average, while high-productivity land is 18 percent less erodible. At a local level, differences in wind erodibility derive from differences in climate (prevailing winds) and the susceptibility of the soil to wind erosion. At a national level, differences in wind erosion are primarily due to regional differences in climate; land in more arid regions is more likely to be eroded by wind.

At a national level, the relationship between soil productivity and erodibility is similar to that observed at the local level, but more pronounced for both rainfall and wind erosion (fig. 4.1, second row). For example, wind erodibility ranges from 62 percent above the national average for lands with low productivity to 47 percent below the national average for lands with high soil productivity.

Potential crop yields also tend to be lower on highly erodible cropland (HEL).[2] Average potential crop yields for HEL range from 77 percent (for oats) to 82 percent (for hay) of non-HEL yields (table 4.1).[3] This suggests that, on average, HEL is about 20 percent less productive, than non-HEL in the same CRD. Still, the productivity of HEL varies considerably. In some CRDs, potential yields on HEL are substantially above—close to double for alfalfa hay—those for non-HEL (maximum yield ratio, table 4.1). In other CRDs, potential yields on HEL are a third or less of those on non-HEL (minimum yield ratio, table 4.1). Despite this variation, at the national level, the highest potential yields always occur on non-HEL for the crops examined.

Soil Productivity and Nutrient Losses

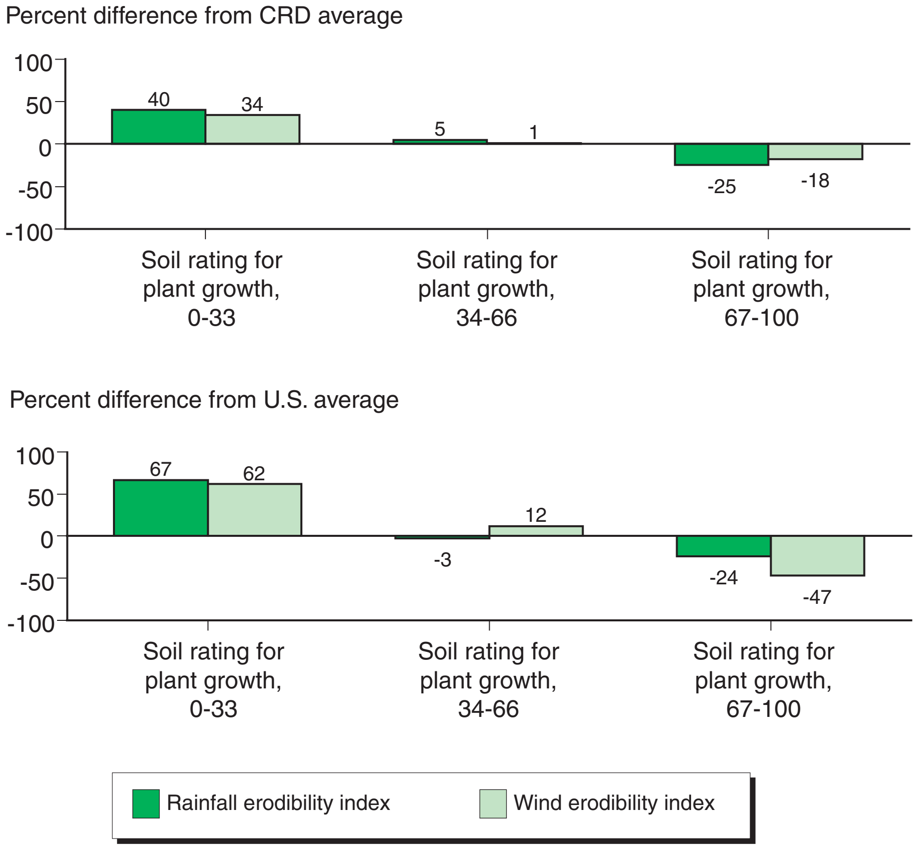
Nutrient runoff depends on both the inherent characteristics of land (including climate) and the way it is used and managed. Lands in crop production tend to have higher rates of nutrient loss because they receive

[2] Highly erodible land (HEL) has an erodibility index (EI) of 8 or more.

[3] Using a Geographic Information System (GIS), estimated yields and HEL designations are overlaid with CRD boundaries to estimate the ratio of yields on HEL and non-HEL land within each CRD. Estimated yields are from Soil Survey Geographic (SSURGO) data, the most up-to-date source of yield and soils information available. We are limited to crop reporting districts that have yield estimates for both HEL and non-HEL, but we have over 200 observations for each of these crops: alfalfa hay, corn, oats, soybeans, and wheat.

Figure 4.1

Erodibility index relative to local and national averages, by land quality classification



Notes: Point-level data are compared with the average for each Crop Reporting District (CRD) and for all agricultural and forest land in the United States. A CRD is a multicounty area defined for data gathering purposes by USDA's National Agricultural Statistics Service (NASS). The soil rating for plant growth is an index of soil productivity based on many biological, chemical, and physical soil properties as well as topography and climate. In 1997, land with SRPG estimates of 0-33, 34-66, and 67-100 comprised 38, 44, and 18 percent of the private agricultural and forest land in the contiguous 48 States.

Source: ERS analysis of 1997 National Resources Inventory and Soil Survey Geographic data.

more fertilizer and, because of tillage, are more susceptible to nutrient transport from rainfall runoff and soil erosion. No indicator of inherent susceptibility to nutrient loss exists. But meaningful comparisons can be made among lands that are in the same use but vary in soil productivity.

Potential nitrogen and phosphorus losses to water are simulated using the Environmental Policy Integrated Climate Model (EPIC) and matched with land-use and soil information from the NRI and SSURGO data sets, respectively. EPIC is a crop biophysical simulation model that is used to estimate the impact of management practices on pollution discharged at the field level (Mitchell et al., 1998). It uses information on soils, weather, land use, and land management practices—including fertilizer rates—and produces estimates of resulting erosion and nutrient loss to the environment (as well as other indicators). Land use and management practices used in the EPIC

Table 4.1

Comparison of average crop yields on HEL and non-HEL, by soil survey unit

Crop	Average non-irrigated yield		Ratio of HEL to Non-HEL yields[1]					
	All land	Highly erodible land (HEL)	Average	Median	Standard deviation	Min.	Max.	No. of observations
Alfalfa hay	3.7	2.7	0.82	0.79	0.22	0.27	1.95	215
Corn	89.2	67.5	0.78	0.76	0.19	0.28	1.62	320
Oats	65.3	47.4	0.77	0.76	0.22	0.33	1.70	222
Soybeans	36.0	28.2	0.78	0.76	0.17	0.33	1.32	219
Wheat	31.5	22.3	0.78	0.78	0.21	0.33	1.73	201

[1] Ratios are for non-irrigated yields within a soil survey unit, a geographic area cutting across counties. Average values are weighted by the amount of cropland within each soil survey unit. Highly erodible land (HEL) is land with an erodibility index (for either rainfall or wind erosion) of 8 or more.

Source: ERS analysis of Soil Survey Geographic (SSURGO) Data set. SSURGO is the most detailed level of soil mapping conducted by USDA's Natural Resources Conservation Service.

management files are based on existing land use, cropping patterns, and management practices for highly erodible (HEL) and non-highly erodible (NHEL) land in 45 farm production regions (see appendix B for details).

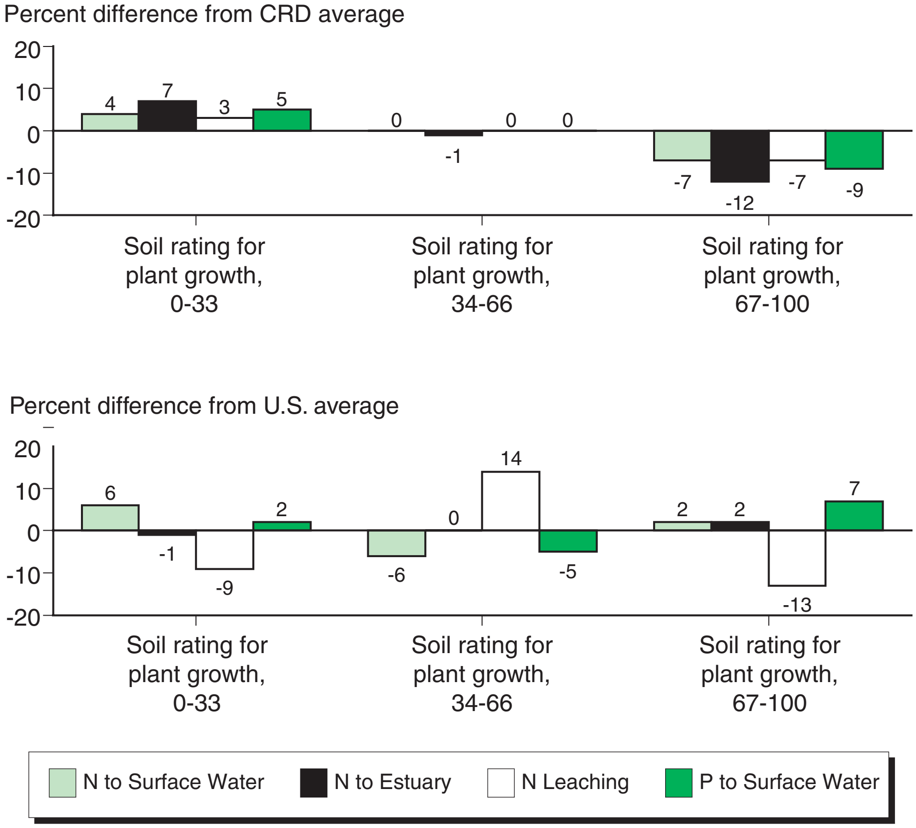
At the local (CRD) level, the potential for nutrient loss to water increases as land quality (SRPG) declines (fig. 4.2, top row). For low-productivity land (SRPG 0-33), potential nutrient losses exceed CRD averages by 3 to 7 percent for all four nutrient loss categories (nitrogen loss to surface water, nitrogen loss to estuaries, nitrogen leaching to groundwater, and phosphorus loss to surface water). On high-productivity land (SRPG 67-100), losses are 7 to 12 percent less than CRD averages for all categories. Potential nutrient loss is very close to CRD averages on medium-productivity land (SRPG 34-66). However, these results are based on environmental modeling in which local variation is limited. Within CRDs, differences in nutrient loss are driven by differences in soil erodibility. Higher erodibility is often associated with lower soil productivity and greater nutrient transport with soil. Also, the available data do not generally capture variations in nutrient applications and cropping patterns within local areas.

At the national level (fig. 4.2, bottom row), differences in nutrient loss across productivity classes are not as uniform as at the local level. Nitrogen loss to surface water is highest (6 percent above average) on low-productivity land but lowest (6 percent below average) on medium-quality land. Nitrogen leaching to groundwater is highest on medium-quality land (14 percent above average), but 9 and 13 percent below average on the other land classes. Nitrogen surface runoff and nitrogen leaching appear to have an inverse relationship: when surface runoff is high, leaching is low and vice versa. Nitrogen runoff to estuaries varies only slightly since this is as much a function of location as soil characteristics. Finally, phosphorus runoff is lowest for lands with medium soil productivity (5 percent below average) and highest for lands with high soil productivity (7 percent above average).

The pattern of nutrient loss across land quality classes may be the product of offsetting trends in inherent susceptibility to nutrient loss and nutrient application. As soil productivity declines, erodibility and land

Figure 4.2

Nutrient runoff potential for cultivated cropland relative to local and national averages, by land quality classification



Notes: Point-level data are compared with the average for each Crop Reporting District (CRD) and for all agricultural, forest, or other rural land in the contiguous United States. A CRD is a multicounty area defined for data gathering purposes by USDA's National Agricultural Statistics Service (NASS). The Soil Rating for Plant Growth (SRPG) is an index of soil productivity based on many biological, chemical, and physical soil properties as well as topography and climate. In 1997, land with SRPG estimates of 0-33, 34-66, and 67-100 comprised 38, 44 , and 18 percent of the private agricultural and forest land in the contiguous 48 States.

Source: ERS analysis of 1997 National Resources Inventory, Soil Survey Geographic data, and nitrogen (N) and phosphorus (P) indicators based on the Environmental Policy Integrated Climate model.

slope tend to increase, potentially increasing the proportion of applied nutrients that are lost to the environment. Because the crop yield potential is generally lower for less productive lands, these lands may receive more fertilizers than higher quality lands so as to compensate for the lower productive capacity of the soil. Alternatively, the relative benefits and costs of fertilizer applications could imply that these lands receive less fertilizer than higher quality lands, reducing the size of the overall pool of nutrients from which runoff can occur. Even if the nutrient pool is smaller, lower crop yields also imply that the crop uses fewer nutrients, perhaps leaving just as much "excess" nutrient, which is susceptible to runoff and leaching.

Our analysis until now has uncovered three relationships:

- Less productive croplands are those most likely to lie on the extensive margin.
- Lands that are less productive for crop production also tend to be more environmentally sensitive in terms of potential erosion damage.
- Less productive lands are often more environmentally sensitive in terms of potential nutrient loss locally and sometimes nationally (although the evidence is not as strong as for erodibility).

Cropland Converted to Other Uses More Prone to Erosion Damage and Nutrient Loss

Rainfall Erosion. Lands that transitioned between cultivated crops and a less intensive land use tend to have a greater potential for erosion damage than land that was cultivated in both 1982 and 1997.[4] At the local level, where variation in rainfall erosion can be large, land that was cultivated in 1982 and 1997 had, on average, a rainfall erodibility index (EI) that was 20 percent lower than the CRD average. Land that shifted to less intensive uses, particularly to CRP, was generally more prone to erosion damage than the CRD average (fig. 4.3). High erodibility on CRP land is not surprising; erodibility is an important factor in CRP eligibility criteria and selection. Similar patterns are observed for land that started out as uncultivated cropland and grazing/forest/other land (fig. 4.3). Similar relationships between rainfall erodibility and land use also emerge on a national scale (fig. 4.4).

Comparisons of estimated erosion rates (rather than the erodibiliy index) across different extensive margin lands can also be made by looking at erosion rates for the year when the land entering/leaving cultivated crops was in cultivation.[5] Land that moved from cultivated crops to another, less intensive use between 1982 and 1997 had relatively high 1982 erosion rates compared with land that stayed in crop production over that period (table 4.2). Land in cultivated crops in both 1982 and 1997 had an average rainfall erosion rate of 4.04 tons/acre/year (TAY), while land moving to uncultivated crops, CRP, or grazing/forest/other uses had erosion rates of 5.08, 5.97, and 6.18 TAY. Land that moved to cultivated crop production from less intensive uses had 1997 rates of rainfall erosion that were roughly equal to or higher than those for land that was cultivated in both 1982 and 1997 (table 4.2). Land cultivated in both years had a 1997 average erosion rate of 3.06 TAY while the 1997 rates on land that moved from uncultivated crops and from grazing, forest, and other uses were 2.99 TAY and 4.34 TAY.

Wind Erosion. For wind-erodible soils, the erodibility index is also higher for land at the extensive margin of cultivated crop production than for land in cultivated crops in both 1982 and 1997. At the local level, however, differences are much smaller than differences for rainfall erodibility (fig. 4.3). Land that was cultivated in 1982 and 1997 was less prone to damage from wind erosion (EI 2 percent below the CRD average) than was transitioning land (EI 4-12 percent above average). Land that moved to cultivated crop production from another use also had higher potential for wind erosion damage than land cultivated in

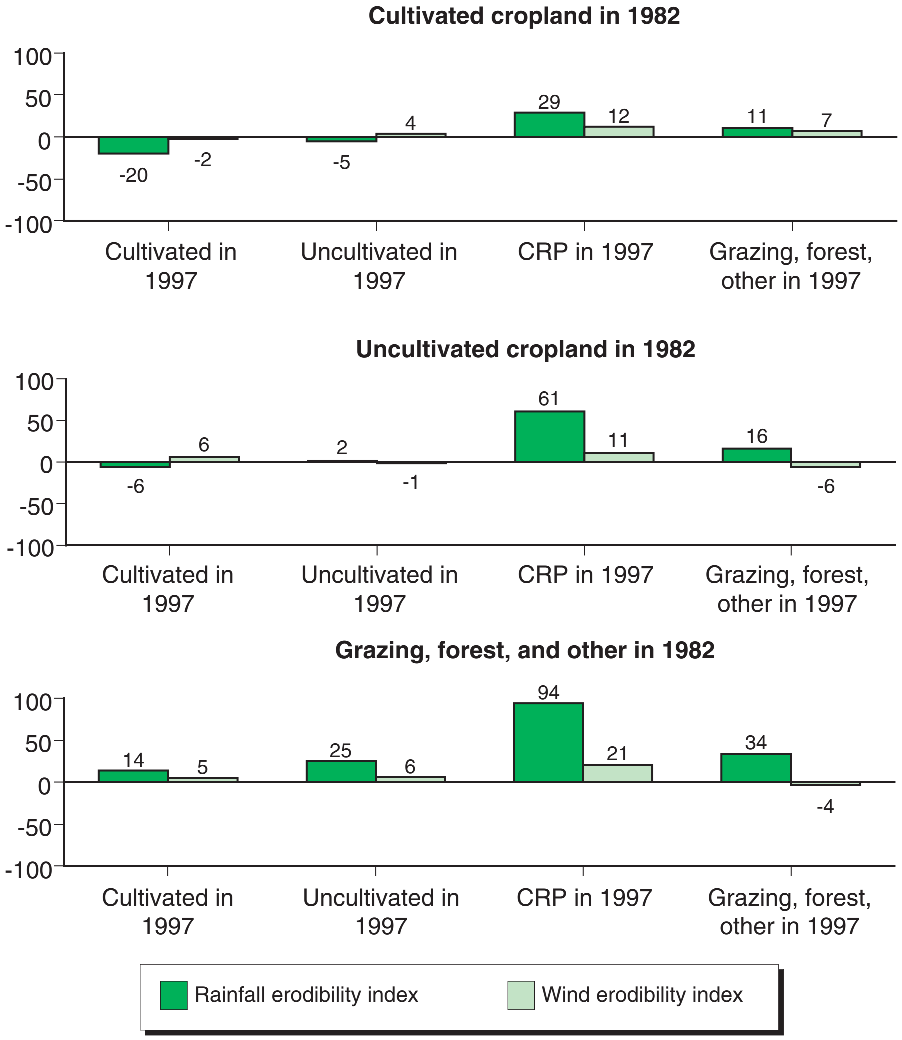
[4] As noted previously, we compare lands transitioning and remaining in cultivation over the 1982-97 period so as to obtain the maximum number of observations of lands transitioning at some point over that period. Comparing lands changing over shorter 5-year periods would capture some lands that shifted out of cultivation and then returned to crop production from 1982 to 1997, but would reduce the overall observations of transitioning lands. Because our group of lands that remained in the same use from 1982 to 1997 includes some lands that transitioned but then reverted back to the starting use, the actual differences in the a characteristics of transitioning and no-transitioning lands are likely to be somewhat greater than our estimates imply.

[5] As land use changes, particularly between cultivated cropland and other less intensive uses, erosion rates change dramatically. Thus, erosion rate change due to land-use change does little to indicate the erodibility of extensive margin land relative to other cultivated cropland. Moreover, soil erosion generally declined between 1982 and 1997 (see table 4 in Claassen et al., 2004), further reducing the usefulness of "before" and "after" comparisons.

Figure 4.3

Erodibility index relative to local averages, by land use and land-use change category

Percent difference from CRD average



Note: Data for each NRI point are compared with the average for each Crop Reporting District (CRD). A CRD is a multi-county area defined for data gathering purposes by USDA's National Agricultural Statistics Service.

Source: ERS analysis of 1997 National Resources Inventory data.

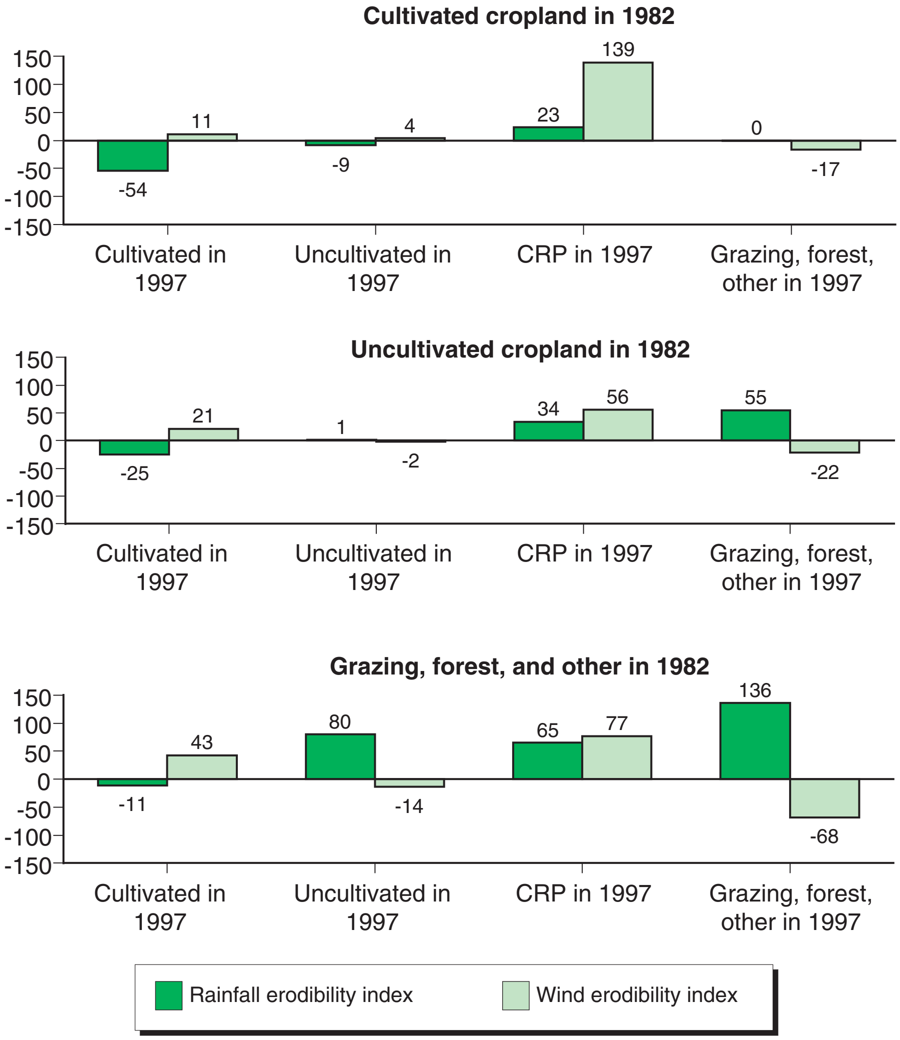
both 1982 and 1997 (fig. 4.3). At the national level, results for wind erodibility are mixed. The wind erodibility index on land that was cropped in 1982 and 1997 (EI 11 percent above national average) is lower than on land that moved from cultivation to CRP (EI 139 percent above national average). On the other hand, land that moved from cultivated crops to uncultivated crops (EI 4 percent above national average) and to grazing, forest, and other uses (EI 17 percent **below** national average) had a lower erodibility rating (fig. 4.4).

Estimated wind erosion rates also yield mixed results regarding the environmental sensitivity of land at the extensive margin of cultivated crop production. The average 1982 wind erosion rates on land converted from cultivated

Figure 4.4

Erodibility index relative to national averages, by land use and land-use change category, 1982 and 1997

Percent difference from U.S. average



Note: Point-level data are compared with the average for all private land in agricultural, forest, or other rural uses in both 1982 and 1997. In 1982, the area of cultivated cropland, uncultivated cropland, and grazing, forest, and other uses comprised 26 percent, 3 percent, and 70 percent of private agricultural and forest land in the contiguous 48 States. In 1997, the area of cultivated cropland, uncultivated cropland; CRP, and grazing, forest, and other uses comprised, respectively, 23, 4, 2, and 71 percent of private agricultural and forest land in the contiguous 48 States (table 2.1).

Source: ERS analysis of National Resources Inventory data.

crops to less intensive uses, except CRP, appear to be lower than the average rate on land that was cultivated in 1982 and 1997 (table 4.3). The average 1997 erosion rate for uncultivated cropland that moved to cultivation was 2.03 TAY, versus 2.51 TAY for land cultivated in both 1982 and 1997.

Nutrient Loss. Comparisons of the potential nutrient losses to water between land remaining cultivated and land moving out of or into cultivated crops can also be made by focusing on years in which lands were cultivated. In general,

Table 4.2

Rainfall erosion, by land use and land-use change category (tons/acre/year), 1982 and 1997

1982 land use	1997 land use			
	Cultivated cropland	Uncultivated cropland	Converation Reserve Program	Grazing, forests, and other rural land
Cultivated cropland	4.04[1] 3.06[2]	5.08 0.77	5.97 0.36	6.18 0.34[3]
Uncultivated cropland	0.75 2.99	0.60 0.52	1.37 0.50	0.86 0.40[3]
Grazing, forests, and other rural land	0.33[3] 4.34	0.66[3] 0.81	0.62[3] 0.46	0.13[3] 0.10[3]

[1] 1982 erosion rates are in the upper left corner of each cell. Erosion rates for rainfall (sheet and rill erosion) are computed using the Universal Soil Loss Equation (USLE).

[2] 1997 erosion rates are in the lower right corner of each cell.

[3] Erosion rate is for pasture only. NRI does not report erosion rates for rangeland, forest, and other rural land.

Source: ERS analysis of National Resources Inventory (NRI) data.

Table 4.3

Wind erosion, by land use and land-use change category (tons/acre/year), 1982 and 1997

1982 land use	1997 land use			
	Cultivated cropland	Uncultivated cropland	Converation Reserve Program	Grazing, forests, and other rural land
Cultivated cropland	3.45[1] 2.51[2]	2.21 0.25	7.57 0.33	2.33 0.07[3]
Uncultivated cropland	0.48 2.03	0.33 0.16	0.68 0.03	0.21 0.10[3]
Grazing, forests, and other rural land	0.08[3] 2.85	0.09[3] 0.15	0.15[3] 0.14	0.01[3] 0.01[3]

[1] 1982 erosion rates are in the upper left corner of each cell. Erosion rates for wind are computed using the Wind Erosion Equation (WEQ).

[2] 1997 erosion rates are in the lower right corner of each cell.

[3] Erosion rate is for pasture only. NRI does not report erosion rates for rangeland, forest, and other rural land.

Source: ERS analysis of National Resources Inventory (NRI) data.

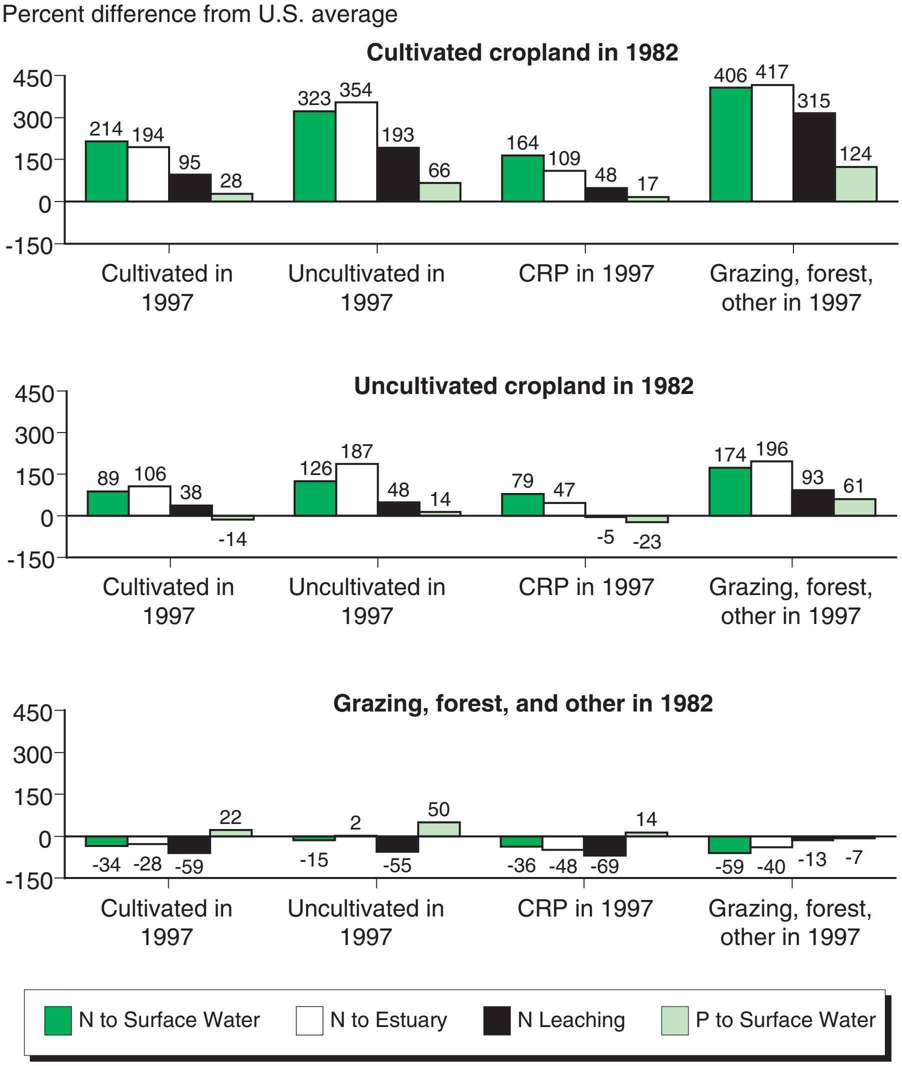
land moving between cultivated crops and a less intensive use had higher potential for nutrient loss (when cultivated) than land that persisted in cultivation in both 1982 and 1997.

Differences are largest for land that moved from cultivation in 1982 to uncultivated crop production or grazing, forest, and other use in 1997 (fig. 4.5).[6] For example, nitrogen runoff to surface water is 214 percent above the national average for land cultivated in 1982 and 1997, but 323 percent above average for land moving to uncultivated crops and 406 percent above average for land moving to grazing, forest, and other uses. Cultivated lands have potential nutrient losses far above the national average because uncultivated lands (the majority of the land base) receive minimal nutrient applications. CRP land appears to be less susceptible to nutrient loss than other lands moving out of cultivation, possibly because the program tends to attract lands with low soil productivity, where nutrient application rates may be lower. Moreover, CRP

[6] Because of data limitations, comparisons are made only to national averages.

Figure 4.5

Potential (1982) nutrient runoff levels, by land use and land-use change categories



Notes: Point-level data are compared with the average for all private land in agricultural, forest, or other rural uses in both 1982 and 1997. Because grazing, forest, and other uses is the largest land-use category, lands in cultivated and uncultivated cropland in 1982 are generally significantly above average in terms of potential nutrient runoff levels. In 1982, the area of cultivated cropland; uncultivated cropland; and grazing, forest, and other uses comprised 26, 3, and 70 percent of the private agricultural, forest, and other rural land in the contiguous 48 States (table 2.1).

Source: ERS analysis of National Resources Inventory data and nitrogen (N) and phosphorus (P) indicators based on the Environmental Policy Integrated Climate model.

land is drawn heavily from arid regions where factors driving nutrient loss—rainfall runoff and rainfall-based soil erosion—are less intense.

Land shifting to cultivated crops from another use also appears to be more susceptible to nutrient loss than land cultivated in 1982 and 1997 (fig. 4.6). For example, estimated potential nitrogen runoff on land converted from uncultivated crops was 288 percent above the national average, versus 239 percent for lands in cultivation in both 1982 and 1997.

Lands Moving In and Out of Cultivation Generally Associated With More Imperiled Species

Erosion and nutrient runoff are indirect indications of how changes in cultivated cropland affect environmental quality and ecosystem health. Also potentially affected is the number of wildlife species at risk of extinction. Previous studies, mainly in the ecology literature, have studied the relationship between land use and wildlife indicators by focusing on a species group, such as birds (O'Connor et al., 1999), or particular habitat types (Hof et al., 1999). Dobson et al., (1997) find a positive relationship between the level of agricultural activity and the density of endangered plants, mammals, birds, and reptiles at the State level. However, their results could reflect the geographic distribution of species and agriculture relative to climate and other factors, rather than the effect of agriculture on species endangerment.

We examine the location of cultivated cropland changes relative to imperiled species counts based on the conservation status assessments in NatureServe's Natural Heritage data set (see Appendix C). These data provide the most comprehensive indication of biodiversity hot spots in the United States (Ehrenfeld et al., 1997).[7] Our species indicator is the number of species in each watershed that are considered to be imperiled throughout their ranges. Hence, these data cannot be used to measure the effects of land-use change on the health of species populations. The presence of an imperiled species in a watershed could reflect the fact that local land-use changes and other conditions in that watershed (or neighboring watersheds) are threatening the survival of that species. On the other hand, the NatureServe measure may simply provide an indicator of the hospitality of a region to species that are imperiled at the national level: the higher the count, the more hospitable that region is to these species given that the species is present in that area. We focus on counts of imperiled vertebrate animal species, imperiled plant species, imperiled birds, and imperiled fish and mollusk species.

Conversion of native prairie to cropland and runoff of sediments and agricultural chemicals are reported to be the major threats to species in the Northern Great Plains and in the rivers and streams of the Southeast (WWF, 2005a; 2005b). The Prairie Pothole region of the Northern Great Plains is an important breeding ground for migratory waterfowl, including more than half of North America's duck population (Kantrud, 1993). The count of imperiled bird species is also one of the most sensitive indicators of biodiversity in a region (Dobson et al., 1997), while counts of imperiled fish/mollusks could indicate the effect of agricultural sediment and chemical runoff on aquatic ecosystems.

On a national scale, cultivated croplands that moved to uncultivated cropland are located in areas with more imperiled species (in all four groups) than lands that remained in cultivated crops or that transitioned to cultivation from uncultivated crops (fig. 4.7, top row). Cultivated croplands that transitioned to grazing, forest, and other rural uses are located in areas with high counts of imperiled vertebrate animals, plants, and fish/mollusks but lower counts of imperiled birds (37 percent below the national average). Lands that moved to

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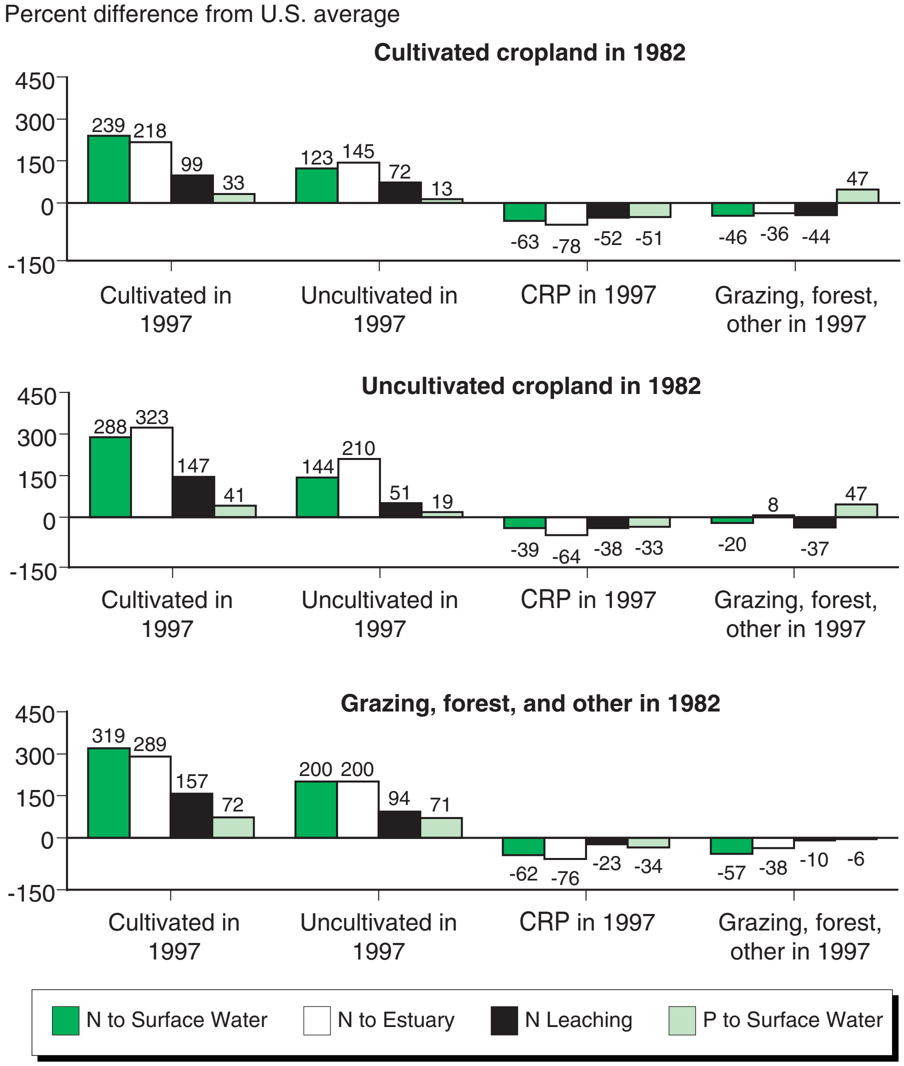
[7] These data may overcount the existence of imperiled species by counting occurrences based on information predating the Natural Heritage program that have since disappeared. On the other hand, the data may generally undercount the existence of very rare species given the difficulty in identifying their occurrences.

Figure 4.6

Potential (1997) nutrient runoff levels, by land use and land-use change categories



Notes: Point-level data are compared with the average for all private land in agricultural, forest, or other rural uses in both 1982 and 1997. Because grazing, forest, and other uses is the largest land-use category, lands in cultivated and uncultivated cropland in 1997 are generally significantly above average in terms of potential nutrient runoff levels. In 1997, the area of cultivated cropland, uncultivated cropland, CRP, and grazing, forest, and other uses comprised 23, 4, 2, and 71 percent of private agricultural, forest, and other rural land in the contiguous 48 States (table 2.1).

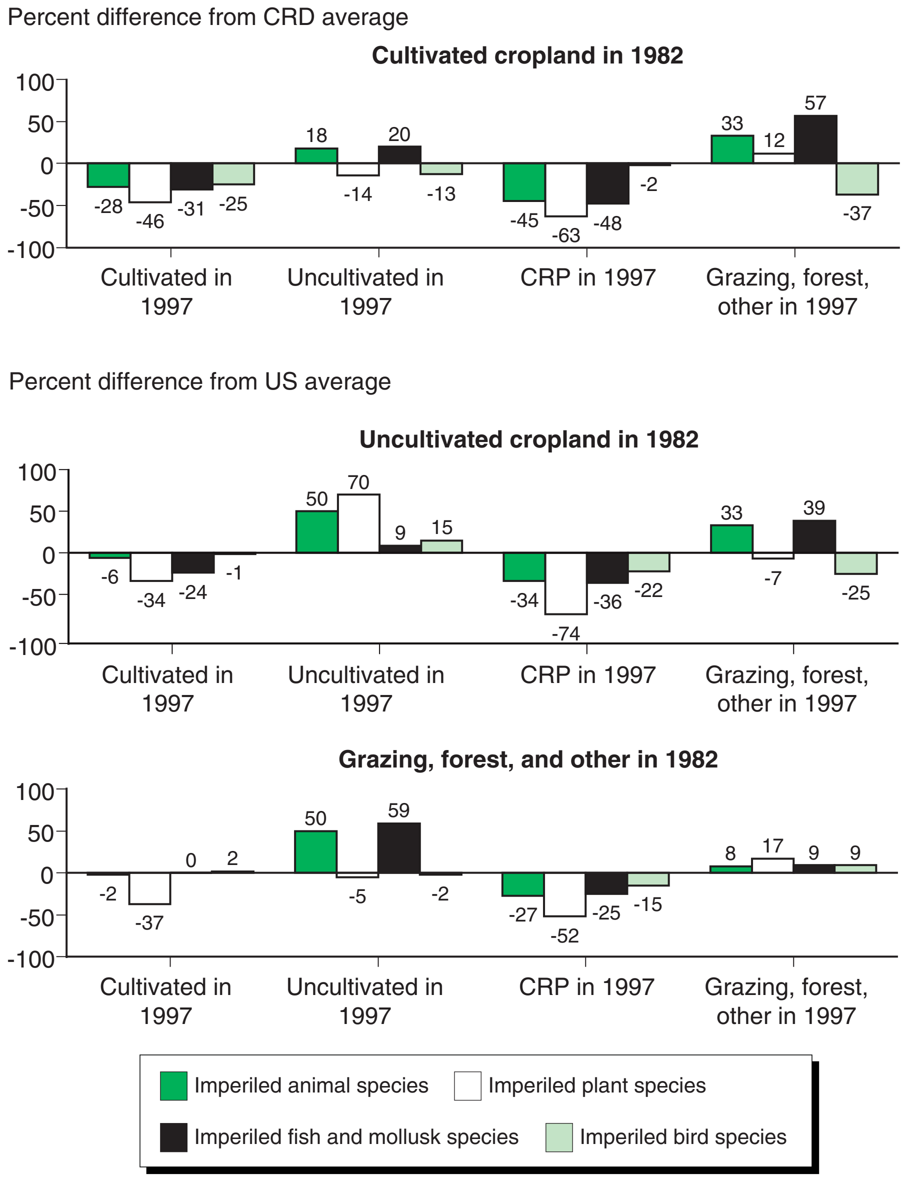
Source: ERS analysis of National Resources Inventory data and nitrogen (N) and phosphorus (P) indicators based on the Environmental Policy Integrated Climate model.

cultivated crops had higher counts in all imperiled species groups than lands that remained in cultivation (fig. 4.7, left-hand column).

The generally negative association between imperiled species counts and cropland transitioning to and from cultivation has various possible interpretations. If the indicator reflects the effect of land use on species imperilment, the observed patterns could suggest that crop cultivation is more favorable for species health, compared with transitions to pasture and forest,

Figure 4.7

Counts of imperiled species, by land use and land-use change categories



Notes: Imperiled species include those classified by NatureServe as either "critically imperiled" or "imperiled" at the national level, receiving a Global Conservation Status rank of 1 or 2, respectively.

Point-level data are compared to the average for all private land in agricultural, forest, or other rural uses in both 1982 and 1997. In 1982, the area of cultivated cropland, uncultivated cropland, and grazing, forest, and other uses comprised 26, 3, and 70 percent of private agricultural and forest land in the contiguous 48 States. In 1997, the area of cultivated cropland, uncultivated cropland, CRP, and grazing, forest, and other uses comprised 23, 4, 2, and 71 percent of private agricultural, forest, and other rural land in the contiguous 48 States (table 2.1).

Source: ERS analysis of National Resources Inventory and NatureServe Natural Heritage data.

grazing, and other uses. Conversely, because the presence of an imperiled species may indicate the hospitality of a local region to a species that is nationally imperiled, the results could also indicate that areas with cultivated cropland tend to be relatively inhospitable for species in general, compared with areas with uncultivated cropland and grazing, forest, and other uses. Although the imperiled species counts reveal associations, these data are insufficient to infer any causal relationships between land-use changes and particular species groups.

Lands converting to CRP (versus remaining in cultivation) tend to be in watersheds with higher counts of imperiled birds but lower counts of other imperiled species. If the species count reflects a region's hospitality for a species, cropland retirement through CRP may well benefit birds more than continued crop cultivation. Or particular bird species may simply take to the regions in which CRP lands are located. Either interpretation is consistent with the fact that habitat protection for imperiled species is an explicit CRP objective and incorporated into USDA's environmental criteria for enrolling land.

Overlaying the species indicators with 1982-97 NRI data on movements of land to and from cultivated cropland reveals many areas with high (low) amounts of extensive margin changes and low (high) counts of imperiled vertebrate animal and plant species (figs. 4.8a and 4.8b). While there is a concentration of cultivated cropland change and imperiled species in the Central Valley of California, no systematic broad-scale relationship is evident between animal/plant species imperilment and the extensive margin of cultivated crop production.[8]

If imperiled species are affected by land-use change, then it may be useful to relate local imperiled species counts to local land-use change. Watersheds with high counts of imperiled birds coincide with areas experiencing changes in the extensive margin of cropland in the Northern Great Plains and Prairie Gateway (fig. 4.9a). These are also areas with the highest concentrations of CRP enrollment. The Appalachian region has high counts of imperiled fish and mollusks (fig. 4.9b) but did not experience particularly high levels of cultivated cropland change. Areas where high levels of cultivated cropland changes overlap with imperiled fish/mollusks are the Central Valley of California, areas along major rivers, and some parts of the Southern Seaboard. To the extent that agricultural runoff poses threats to wildlife, policies that affect land-use changes in these areas might merit special examination. However, other regions with high (low) counts of imperiled fish and mollusk species have low (high) changes in cultivated cropland. Thus, no consistent relationship is apparent between changes in cultivated cropland and imperiled fish/mollusk counts.

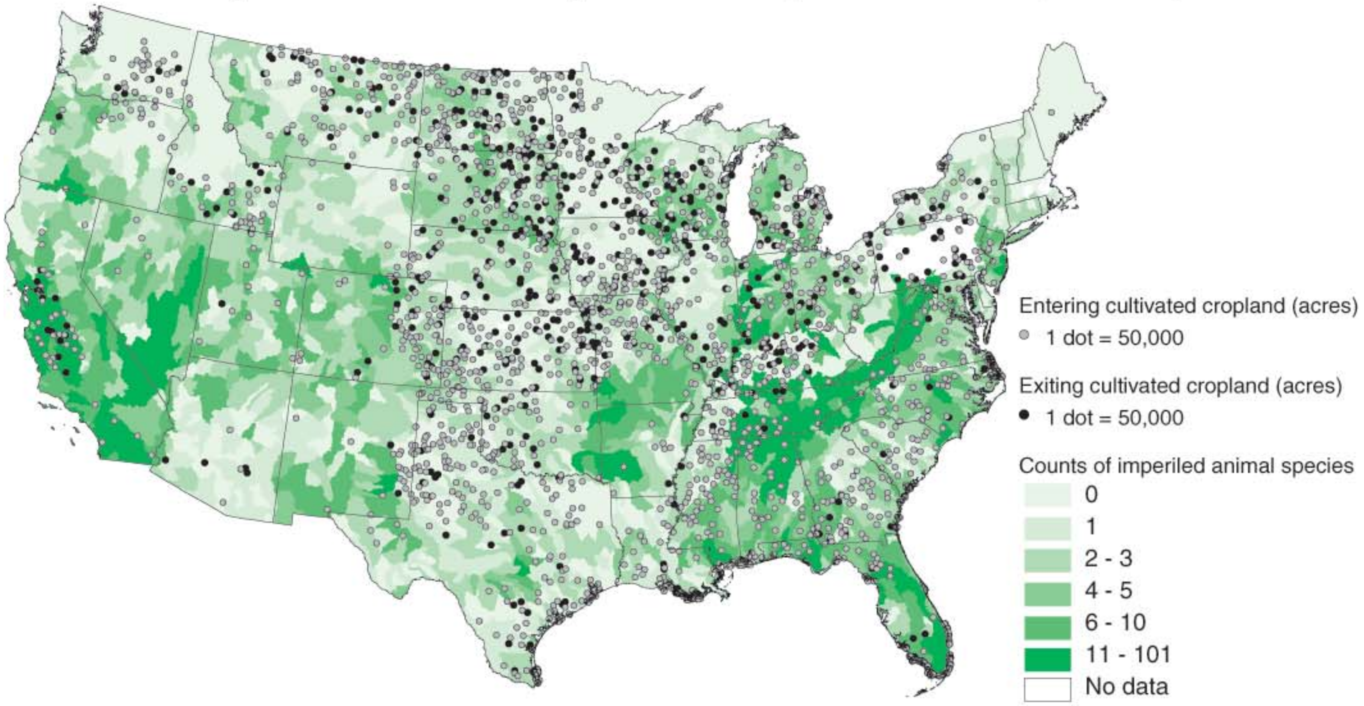
Conclusion

Environmental outcomes depend on land use and land management as well as on the physical characteristics of the land itself and location (e.g., proximity to water). We find that lands transitioning between cultivated cropland and less intensive uses are more prone to rainfall and wind erosion damage than other cropland, both at the national and local level. Except for lands entering CRP, lands at the extensive margin of cultivated cropland are also

[8] Regression analyses did not reveal statistically significant relationships between occurrences of imperiled species and measures of land use and land-use change at the watershed level. The lack of a relationship may be due to the crudeness of the NatureServe data, which obscures variations in the imperilment of particular species across the country. More systematic relationships between cropland changes and the occurrence of imperiled species could emerge through regional analyses, as the factors affecting species may well be different in different regions. For example, while conversion of grasslands might be an important threat to birds in the Midwest, conversion of croplands to urban development could be the principal threat to wildlife in California and Florida.

Figure 4.8a

Counts of total imperiled vertebrate animal species and changes in cultivated cropland area, 1982-97

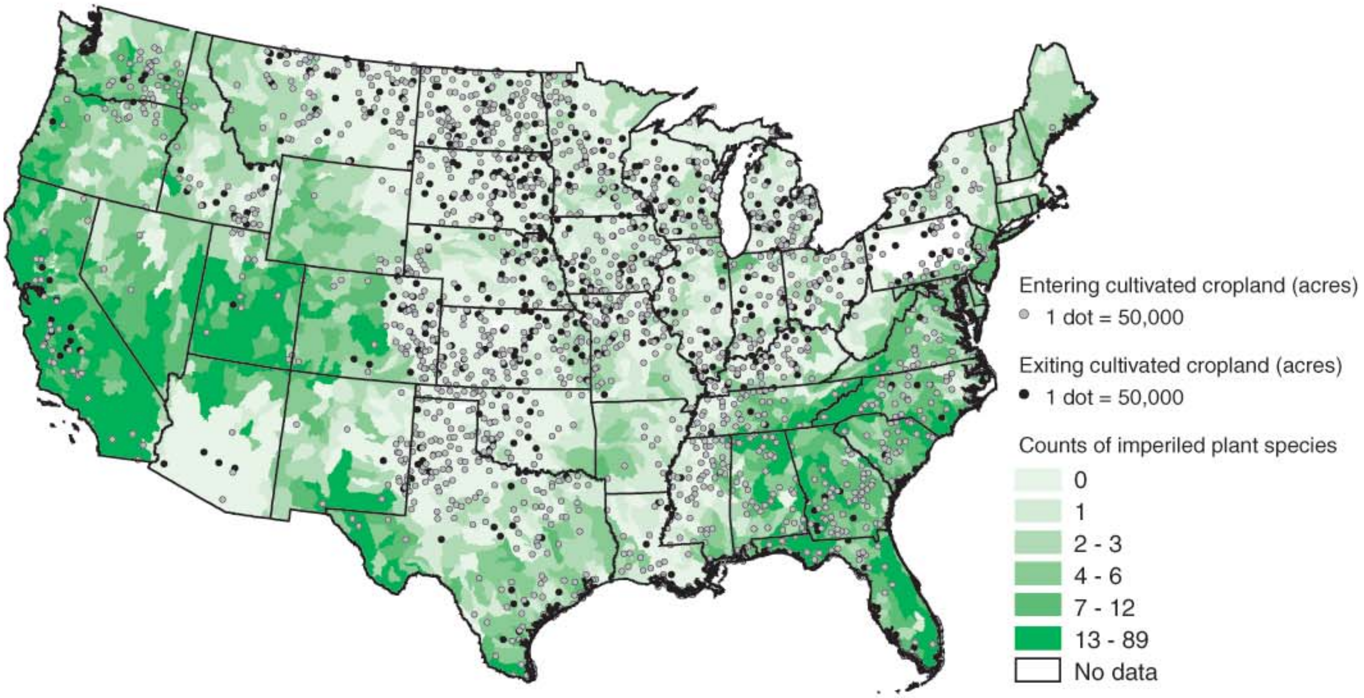


Note: Imperiled species include those classified by NatureServe as either "critically imperiled" or "imperiled" at the national level, receiving a Global Conservation Status (G) rank of 1 or 2, respectively. Size of dots is not proportional to actual land area. Location of dots is assigned randomly within watersheds and may vary slightly across maps.

Source: ERS analysis of National Resources Inventory (NRI) and NatureServe Natural Heritage data.

Figure 4.8b

Counts of total imperiled plant species and changes in cultivated cropland area, 1982-97

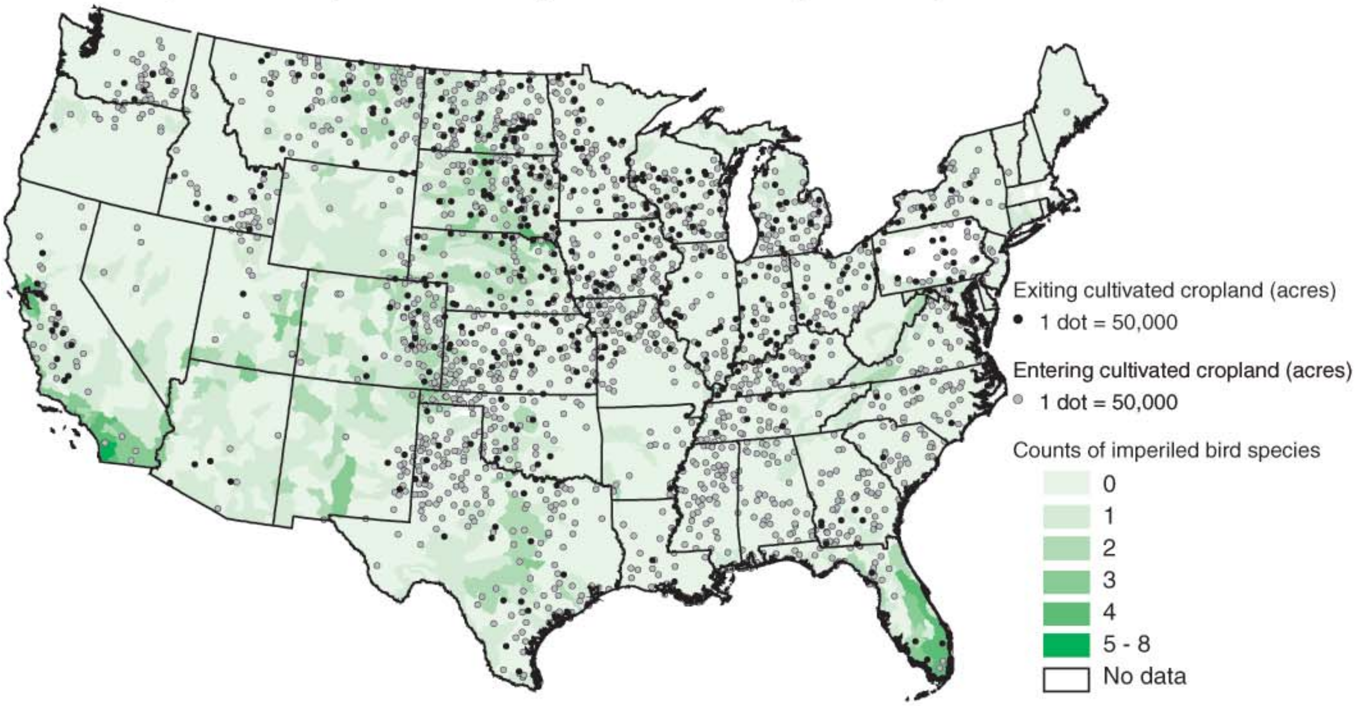


Note: Imperiled species include those classified by NatureServe as either "critically imperiled" or "imperiled" at the national level, receiving a Global Conservation Status (G) rank of 1 or 2, respectively. Size of dots is not proportional to actual land area. Location of dots is assigned randomly within watersheds and may vary slightly across maps.

Source: ERS analysis of National Resources Inventory (NRI) and NatureServe Natural Heritage data.

Figure 4.9a

Counts of imperiled bird species and changes in cultivated cropland area, 1982-97

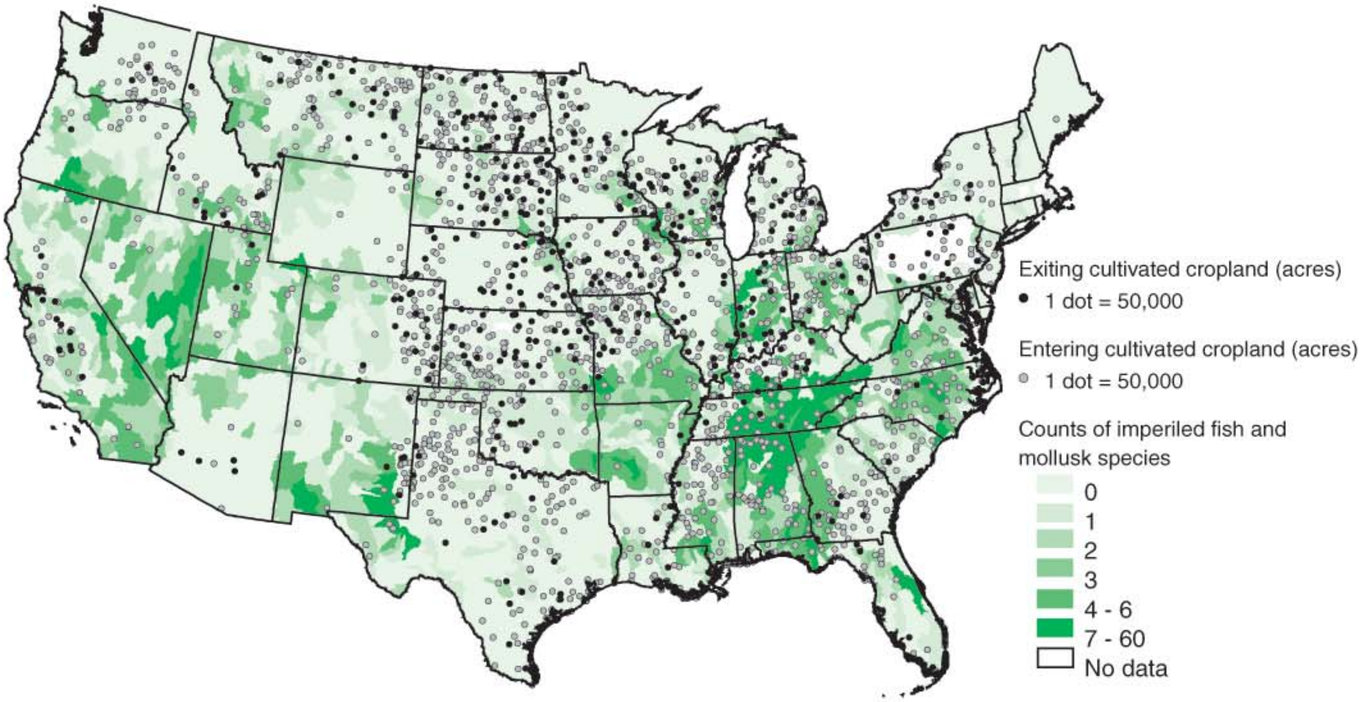


Note: Imperiled species include those classified by NatureServe as either "critically imperiled" or "imperiled" at the national level, receiving a Global Conservation Status (G) rank of 1 or 2, respectively. Size of dots is not proportional to actual land area. Location of dots is assigned randomly within watersheds and may vary slightly across maps.

Source: ERS analysis of National Resources Inventory (NRI) and NatureServe Natural Heritage data.

Figure 4.9b

Counts of imperiled fish and mollusk species and changes in cultivated cropland area, 1982-97



Note: Imperiled species include those classified by NatureServe as either "critically imperiled" or "imperiled" at the national level, receiving a Global Conservation Status (G) rank of 1 or 2, respectively. Size of dots is not proportional to actual land area. Location of dots is assigned randomly within watersheds and may vary slightly across maps.

Source: ERS analysis of National Resources Inventory (NRI) and NatureServe Natural Heritage data.

associated with higher levels of potential nutrient loss than are cultivated croplands that did not change use.

To the extent that particular land-use changes affect particular types of species, a comparison of the location of extensive margin lands and of areas with high counts of imperiled species could help target conservation policies or shape government policies that affect land use. Except for CRP enrollments, land in cultivated crops moving to and from less intensive uses is in areas with higher overall counts of imperiled animal and plant species. Nevertheless, due to the nature of the imperiled species indicator, we cannot infer any causal relationships between land-use changes and the imperilment of species.

The data on cropland transitions from 1982 to 1997 suggest that croplands with lower soil productivity, which are more likely to be at the extensive margin, may be more environmentally sensitive in terms of erosion and potential nutrient loss. Based on soil productivity, lands with lower crop growth potential are more susceptible to damage from erosion than are more productive lands. While greater erodibility contributes to nutrient loss potential, we lack sufficient data on nutrient applications by lands of different quality to reach definitive conclusions on the relationship between soil productivity and nutrient loss.

Lands enrolled in the CRP tend to be different than other lands at the extensive margin of cultivated cropland. CRP lands are located in areas with more erodible land and higher concentrations of imperiled birds (but lower counts of other imperiled species) than other cropland. Again, it is difficult to make direct comparisons of CRP lands to other lands in the same region in terms of nutrient loss or species. Broadly speaking, CRP-heavy areas do not appear to be areas where land characteristics and cropping practices combine to produce above-average nutrient losses.

Chapter 5

Environmental Effects of Policy-Induced Land-Use Changes

Major agricultural programs that are likely to affect land use include price and income support (commodity) programs, subsidized crop insurance, and land retirement programs (e.g., the Conservation Reserve Program). The environmental impacts will depend on the location and physical characteristics of the lands affected by each policy. Lands enrolling in CRP tend to be less productive and to have different physical characteristics, locations, and environmental implications than other lands at the extensive margin of cultivated crop production. The CRP is an example of a policy that expressly offers incentives to take particular types of land out of agricultural production. The next step in our analysis is to identify the particular lands at the extensive margin potentially brought **into** production as an unintended consequence of Federal farm policies.

While other Federal policies and farm programs could have larger effects on cropland area, we focus on federally subsidized crop insurance for two reasons. First, this is a large program, and there has been great concern expressed over the environmental characteristics of lands brought into production due to such risk-reducing farm programs. In a 1999 letter to Congress, 27 conservation and taxpayer groups argued that crop insurance subsidies would encourage farmers to cultivate crops in flood- and drought-prone areas and thus promote the conversion of environmentally sensitive forest and pasturelands to crop production (Environmental Defense, 1999). The contention is that crop insurance tends to encourage the cultivation of lands that provide low or highly variable crop returns, and that these are the precise areas where the environment is particularly sensitive to crop cultivation. For example, in the context of a different Federal policy, Stavins and Jaffe (1990) found that Federal flood control projects had the unintended consequence of promoting cropland expansion onto forested wetlands, which are valuable ecosystems for fish and wildlife and important for water quality.

Second, determining how government policies affect land-use change requires distinguishing the effect of the policy from other factors like changes in commodity prices. CRP, as a land retirement program, directly involves land-use conversion (we considered CRP as a distinct land use and directly examined the characteristics of CRP lands earlier).[1] Participation in crop insurance and other Federal farm programs does not directly require a change in land use. Farmers buying crop insurance for a parcel of land might well cultivate crops there even without the insurance program. About 182 million acres were insured in 1997, or 56 percent of total cultivated cropland in the 48 contiguous States (Glauber and Collins, 2002).

While crop insurance participation does not require land-use conversion, additional analysis might identify unintended land-use impacts from the

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[1] With some caveats, examination of the land-use effects of CRP can be largely restricted to those particular lands participating in the program. One caveat is the possibility of "slippage," the extent to which cropland retirement under the program might be offset by consequent reallocations of other lands outside the program to cultivated cropland uses (Wu, 2000; Roberts and Bucholtz, 2005). This might be expected if land retirement is significant enough to alter commodity prices. Another caveat is that CRP lands that would have left crop production even without the program do not represent cropland retirements directly attributable to CRP. Lubowski et al., (2003) estimate such lands at 8 percent of 1997 CRP acres.

Federal crop insurance program. The large increase in crop insurance subsidies after the 1994 Crop Insurance Reform Act can be used as a natural experiment to observe how land-use conversions change in response to crop insurance subsidies. We identify the impact of this policy change by comparing land-use changes before and after the 1994 Act in response to different increases in the expected return to crop insurance. This approach allows us to isolate the impact of the policy change because the sharp reductions in farmers' insurance costs due to the 1994 Act are likely to be unrelated to other unobserved factors affecting land use locally.

Analytical Model: The Effect of Crop Insurance Subsidies on Land-Use Change

Are the benefits of subsidized crop insurance large enough to affect land-use decisions? Crop insurance can benefit producers by reducing risk or increasing returns. If insurance rates are actuarially fair, expected payouts equal the premiums paid by the beneficiaries. Crop insurance would reduce the variability of returns without changing the average return to crop production. In years without losses, insurance costs would lower returns slightly. In years with indemnified losses, returns would be higher than without insurance due to the insurance payouts. For risk-averse producers, insurance would increase benefits from crop production and could encourage more cultivation.

Because of information constraints, heterogeneous risks, and other factors, some producers may be charged premiums that are below actuarially fair rates, while others are charged rates above actuarial fairness (Serra et al., 2003; Just et al. 1999; Coble et al., 1996; Vandeveer and Loehman, 1994; Goodwin, 1993). Just et al., (1999) suggest that risk reduction is a minor motive for most crop insurance participants and that most participating producers enjoy an increase in average returns over time because subsidies reduce crop insurance premium rates below actuarially fair levels.

By reducing the risk and/or increasing the expected return from crop production, subsidized crop insurance may increase the amount of land in cultivated crops. Almost all studies on crop insurance subsidies have noted the potential for environmental damage due to expanded crop production, particularly if economically marginal land is also more environmentally sensitive. A growing body of literature has focused on the land-use effect of crop insurance (Goodwin et al., 2004; Deal, 2004; Goodwin and Smith, 2003; Keeton et al., 1999; Wu, 1999; Young et al., 2001; Griffin, 1996), as well as agricultural disaster payments (Gardner and Kramer, 1986). This research has chiefly relied on aggregate (county-level) data and has not identified the environmental characteristics of lands affected by the crop insurance policies. Previous studies, including one of the few farm-level analyses (Wu, 1999), focus on subsets of crops and relatively small geographic regions, limiting an assessment of the overall impacts of subsidized crop insurance. Most analyses, moreover, do not examine changes in cropland over time, making it difficult to distinguish the effect of policies from other factors that could drive land-use decisions in different locations. Finally, some studies use simulation models that hinge on assumptions about farmers' responses to changes in risk (e.g., Young et al., 2001).

Since the early 1990s, significant increases in premium subsidies have probably expanded the group of producers with positive expected (average) returns to crop insurance. Our estimates of the impacts of crop insurance subsidies use data on observed changes in land use on individual land parcels before and after 1994. In that year, the Crop Insurance Act increased premium subsidies for all crop insurance products while adding catastrophic coverage and revenue insurance options. Further premium subsidy increases were enacted in 1999-2000. Depending on the level of coverage purchased, subsidies can be as high as 67 percent of producers' insurance costs, up from a maximum of 30 percent prior to 1994, while catastrophic (CAT) coverage is offered for a nominal cost. Crop insurance participation rates rose with the growth in subsidies (Dismukes and Vandeveer, 2001). Insured acreage more than doubled from about 90 million to 197 million acres between 1990-94 and 1995-99, and then rose to 212 million over 2000-03. Program costs roughly doubled to $1.5 billion a year between 1990-94 and 1995-99, and then doubled again (to $3.1 billion) after the Agricultural Risk Protection Act of 2000 (Glauber and Collins, 2002).

Most of the research on crop insurance and land in crop production uses data that pre-date even the 1994 crop insurance subsidy increases.[2] Yet these subsidy increases are a natural experiment from which to measure land-use decisions against an exogenous change in premium rates. Our econometric model of land-use change is based on the parcel-specific data on land use and land characteristics from the 1992 and 1997 National Resources Inventory (NRI). This period spans the change in expected benefits from crop insurance resulting from the 1994 Act and allows us to relate changes in land use to changes in the expected benefits from crop insurance. Because NRI collects data on the same points of land over time, it is possible to define gross land-use changes—rather than just net movements—and to identify the type or quality of land that is actually changing use. Therefore, it is possible to estimate the characteristics, location, and quantity of land brought into and retained in crop production because of the insurance premium subsidy increases.

By estimating responses to changes in insurance benefits, we control for many unobserved factors that might also affect the amount of land in crop production. The underlying assumption is that regional variation in subsidy-induced changes in insurance benefits is unrelated to other, unobserved factors driving land use during 1992-97.[3]

Factors that influence land-use choices include the profitability of alternative land uses, which vary over time and among regions. While we lack information on the profitability of different land uses for each parcel of land in the NRI, we do have information on several physical features of each parcel, including land quality, erodibility, slope, proneness to flooding, and location. These data can be used as proxies for the profitability of alternative land uses, as well as for the costs of converting from one land use to another. The 1996 Federal Agriculture Improvement and Reform (FAIR) Act also introduced changes to farm programs, which likely affected cropland use during our period of analysis. We combine NRI's parcel-specific data with county-level data on insurance returns, government payments, and the profitability of alternative land uses to develop an econometric model of

[2] An exception is the recent study by Goodwin et al. (2004), which includes an analysis of wheat and barley production in the Northern Great Plains over 1997-98.

[3] By studying changes in land use over time, our analysis controls for unobserved factors determining the initial disposition of land use across the country in 1992. Nevertheless, if there were different trends in land-use change in different locations and unobserved factors driving these trends were related to changes in the expected benefits from crop insurance, this could introduce bias into our estimates.

land-use change that covers the contiguous 48 States (appendix D). This model estimates the probability that an NRI parcel used for either cultivated crops or uncultivated crops and pasture moves from its current use to any of six major land-use alternatives (cultivated crops, uncultivated crops and pasture, CRP; range, forest, and urban) between 1992 and 1997. This model should capture the majority of the changes in cultivated cropland, as transitions from uncultivated crops/pasture accounted for 77 percent of the acreage moving to cultivated cropland over 1992-97. (We also estimated models for land used for forests, range, and CRP in 1992, but there were too few observations to achieve convergence during the bootstrapping runs used to calculate confidence intervals for the estimates).

Changes in returns to crop insurance are our key explanatory variable and are measured as the change in crop revenue due to insurance program participation. This is computed as a weighted average across eight major crops (corn, wheat, soybeans, cotton, sorghum, barley, oats, and rice) of the (expected) crop insurance indemnity minus the insurance price faced by the farmer. This price equals the full crop insurance premium minus the premium subsidy, which is paid by the government. The expected indemnity is based on an average of indemnity payments over the previous 10 years, by county (see appendix D for more detail).[4] Crop insurance program data are available from USDA's Risk Management Agency (RMA). Data include total indemnities, total premiums, and the subsidy by crop, insurance product, and county.

The change in crop insurance returns is positively related to the likelihood that land transitioned to cultivated cropland from another use, and to the likelihood that land cultivated in 1992 remained cultivated in 1997. To identify the magnitude of these effects, we use the estimates from our econometric model to conduct a counterfactual simulation of 1992-97 changes in land use and the resulting 1997 land in each use at every NRI point, under the assumption that the change in expected crop insurance returns was zero. The difference between land use under this scenario and land use in reality—which reflects the effects of the actual 1992-97 change in insurance returns—provides an estimate of the land-use effects of the 1994 change in crop insurance premium subsidies.[5]

Higher Insurance Subsidies Increased 1997 Cropland Acreage by Up to 1 Percent

Most researchers who have studied the impact of crop insurance on land use have found that land-use effects are small, on the order of 1-2 million acres (Goodwin et al., 2004; Young et al., 2001). One study—an unpublished manuscript by Keeton et al. (1999)—argues that expansion of crop insurance policies during the mid-1990s led to the introduction of 15 million new cropland acres (50 million if land in CRP is included) or about 5 percent of cultivated cropland.

Our results indicate that the increase in crop insurance subsidies changed land use measurably, but modestly (table 5.1). The change in premium subsidies in the mid-1990s increased cultivated cropland area (1997) by an estimated 2.5 million acres, or 0.82 percent, with the bulk of this land (1.8

[4] We focus on buy-up insurance, but also examined specifications adjusting for changes in catastrophic insurance coverage (see appendix D).

[5] In our analysis, we do not compare land use under the counterfactual scenario of no crop insurance subsidy increase to the observed patterns of land use reported in the 1997 NRI. Rather, we compare the counterfactual scenario to land use under a simulated "factual" baseline predicted from our estimated parameters fitted with the actually observed values for the change in insurance returns and all other variables (see appendix D). In this way, we produce estimates of the land-use impacts of the change in crop insurance returns that are internally consistent within the framework of the econometric model.

Table 5.1
Estimated effect of crop insurance subsidy change (1994) on 1997 land use

Land use	Actual policy 1992-97 (*Subsidy Increase*)	Counterfactual (*No Subsidy Increase*)	Estimated impact of policy	Estimated impact of policy
	A	B	A-B	100*(A-B)/A
	1,000 acres	*——1,000 acres[1]——*		*Percent[1]*
Cultivated crops	300,639	298,161 (297,295-299,034)	2,475 (1,605 to 3,344)	0.82 (0.53-1.11)
Uncultivated crops and pasture	181,257	183,053 (178,819-180,103)	-1,796 (1,154-2,438)	-0.99 (0.64-1.35)
Forest	391,534	391,668 (391,351-391,449)	-134 (85-183)	-03 (02-05)
Urban	69,672	70,092 (69,100-69,405)	-420 (267-572)	-0.60 (0.38-0.82)
CRP	35,721	35,762 (35,660-35,669)	-41 (22-61)	-0.11 (06-0.17)
Range	400,294	400,379 (400,173-400,245)	-85 (49-121)	-02 (01-03)

[1] 95-percent confidence interval for the estimates in parentheses.

Source: 1997 National Resources Inventory and ERS estimates from this study.

million acres) coming from uncultivated crops and pasture. This estimated impact on cultivated cropland area is statistically different from zero, ranging from 1.6 to 3.3 million acres (0.5-1.1 percent), with 95-percent confidence. This estimate rises by about 12 percent (380,000 acres) if shifts from forests, range, and CRP land are also considered, but confidence intervals could not be computed for this additional estimated impact due to insufficient observations (appendix D).

These estimates are not directly comparable with previous studies, as we use more recent data and focus only on the 1992-97 changes in crop insurance subsidies rather than the overall impacts of the crop insurance program. Our estimates likely capture much of the program's overall impact, given that crop insurance participation and total premiums more than doubled over 1992-97.[6] Our estimated effect is in the range of the most recent empirical estimate that a 30-percent increase in premium subsidies (more than twice the 1992-97 change) would increase acreage of major crops from 0.2 to 1.1 percent (Goodwin et al., 2004).[7]

Crop Insurance Has a Disproportionate Impact on Low-Productivity and Certain Environmentally Sensitive Land

While the insurance policy change is estimated to affect just about 1 percent of total cultivated cropland, the increase in insurance subsidies appears to have had the largest effect for low-productivity and certain environmentally sensitive land. Our estimate of land retained in cultivation due to subsidy increases includes land that is lower quality than the national average for cultivated cropland (table 5.2).[8] On the estimated

[6] During these years, insured acreage increased from 83 million to 182 million acres, while total premiums increased from $0.7 billion to $1.8 billion (Glauber and Collins, 2002).

[7] Premium subsidies for the 65-percent coverage level were increased from 30 percent to 42 percent under the crop insurance acts of 1994 (Goodwin et al., 2004).

[8] Given the relatively small numbers of land parcels affected by the change in crop insurance subsidies, local comparisons are not statistically significant and are not reported.

Table 5.2

Characteristics of additional cropland cultivated due to crop insurance subsidy increases, relative to CRP and other cropland

Land characteristic	Predicted land in cultivation in 1997 due to crop insurance subsidy change[1]	All cultivated cropland in 1997[1]	CRP land in 1997[1]
Soil rating for	56.0	60.2	51.3
plant growth (SRPG)	(55.9-56.1)	(60.1-60.3)	(51.1-51.5)
% highly erodible land (HEL)	32.3	24.8	56.4
	(32.2-32.3)	(24.5-25.1)	(55.9-56.7)
Rainfall erodibility index (EI)	4.89	4.34	7.41
	(4.82-4.95)	(4.29-4.38)	(7.30-7.53)
Wind erodibility index (EI)	4.08	3.54	7.24
	(4.05-4.11)	(3.50-3.59)	(7.19-7.28)
% Wetland[2]	2.94	2.44	1.78
	(2.89-3.0)	(2.36-2.52)	(1.69-1.88)
% Frequently flooded	1.97	1.81	0.99
	(1.96-1.99)	(1.73-1.88)	(0.91-17)
Imperiled animal species	3.11	2.61	2.01
(counts/watershed)	(3.09-3.12)	(2.57-2.65)	(1.99-2.03)
Imperiled plant species	3.02	2.14	1.46
(counts/watershed)	(3.01-3.03)	(2.07-2.21)	(1.45-1.47)
Imperiled bird species	0.32	0.31	0.39
(counts/watershed)	(0.32-0.32)	(0.31-0.32)	(0.39-0.39)
Imperiled fish and mollusk	1.29	1.06	0.81
species (counts/watershed)	(1.28-1.29)	(1.05-1.07)	(0.79-0.81
Nitrogen to surface water	11.37	10.57	9.19
(1,000 lbs/acre/year)	(11.29-11.46)	(10.51-10.61)	(9.13-9.26)
Nitrogen to estuary	0.51	0.43	0.32
(1,000 lbs/acre/year)	(0.51-0.52)	(0.43-0.44)	(0.32-0.32)
Nitrogen leaching	8.90	5.82	4.49
(1,000 lbs/acre/year)	(8.89-8.91)	(5.78-5.88)	(4.46-4.52)
Phosphorus to surface water	0.71	0.65	0.61
(1,000 lbs/acre/year)	(0.71-0.71)	(0.65-0.65)	(0.61-0.62)

[1] 95-percent confidence interval for the estimates is in parentheses. Confidence intervals for the predictions (first column) were estimated by bootstrap (see appendix D). Confidence intervals for second and third columns based on NRI's stratified survey design.

[2] Wetlands are defined according to the Cowardin classification system (Cowardin et al., 1979)."

Source: 1997 National Resources Inventory (NRI), NatureServe, EPIC-based nutrient indicators, Soil Survey Geographic (SSURGO) data set, and ERS estimates from this study.

acres in cultivation due to the increases in insurance subsidies, average soil productivity in terms of SRPG was 56, compared with 60 for all cultivated cropland. While 25 percent of all cultivated cropland was classed as highly erodible in 1997, an estimated 32 percent of cultivated acreage due to the increased subsidies was highly erodible land. These differences are statistically significant (at the 95-percent confidence level) and consistent with our earlier finding that extensive margin lands are less productive and more erodible than overall cropland.

Our findings are also consistent with concerns that lands affected by crop insurance are likely to lie in floodplains and, in the case of wetlands, on environmentally sensitive ecosystems. Lands affected by changes in insurance subsidies were slightly more prone to frequent flooding and were more likely to include wetlands than average cultivated cropland (table 5.2). These differences, too, are statistically significant. Total wetlands affected by the 1992-97 subsidy increase are estimated at 37,000 acres, roughly 0.7 percent of the 5.4 million acres of wetlands under crop cultivation. But the affected wetlands represent about a fifth of the net loss (163,000 acres) in non-Federal wetland area between 1992 and 1997 (USDA/NRCS, 2000). Ending crop production and restoring these wetland acres could make a difference in the overall loss of wetland function. Of course, realizing these gains may require more than just discontinuing crop production.

With the 1985 Farm Act, the Government made implementing soil conservation measures on highly erodible land (HEL) and avoiding drainage of wetlands requirements for receiving certain farm program benefits, including subsidized crop insurance (Claassen et al., 2004). Our estimated increase in cultivated wetlands due to the insurance subsidy change could be due to retention of previously cultivated wetland acres, which were grandfathered into the law, rather than to bringing new land into cultivation. The 1996 Farm Act also removed crop insurance from the list of programs subject to conservation compliance. This change potentially encouraged some crop cultivation on wetlands and HEL by reducing the incentives of insured farmers not to cultivate these land types. Because the compliance provisions did not change until April 1996, however, it is not clear how large an effect this could have had on the land-use change over 1992-97. Most insured crop producers also receive commodity payments, which would still have triggered a compliance requirement. As a result, the change in the compliance status of crop insurance may have had little impact on cultivated acreage of HEL and wetlands.

Crop insurance subsidies are also estimated to increase cultivation in areas subject to greater potential nutrient losses to water. While our nutrient loss estimates take into account land erodibility, they may not accurately reflect differences in fertilizer applications on extensive margin lands. All four nutrient loss indicators are higher, on average, for those croplands estimated to be in cultivation due to the increase in crop insurance subsidies than for cultivated croplands overall. In contrast, CRP lands have below-average levels of potential nitrogen and phosphorus losses.

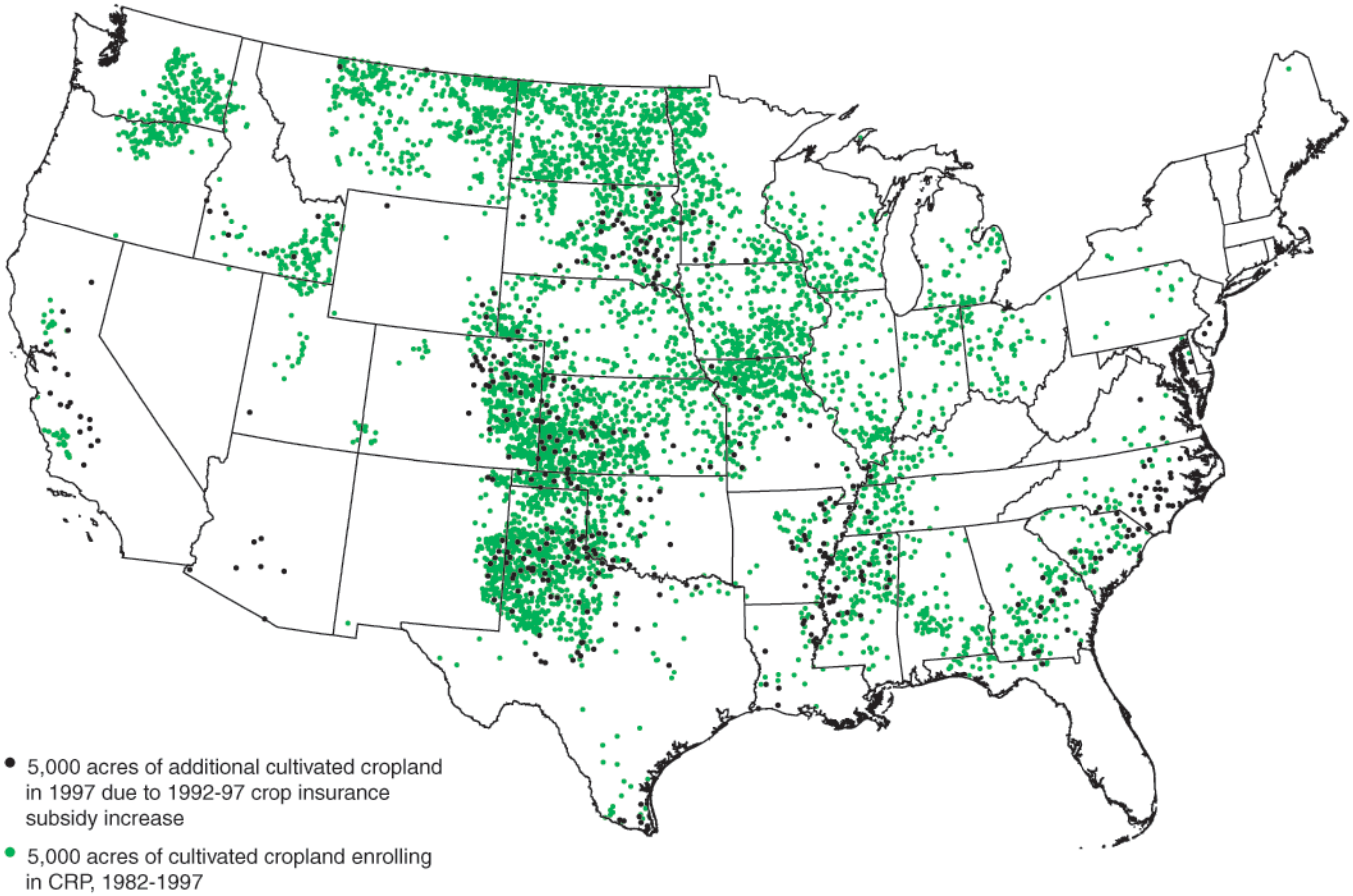
Given the evidence that crop insurance affects land use on land that is both economically and environmentally marginal, larger insurance premium subsidies may be offsetting benefits from agri-environmental programs such as the CRP, as other researchers have suggested (e.g., Goodwin and Smith, 2003). That is true to the extent that the land in cultivated crops due to the crop insurance subsidy increase is also targeted for CRP enrollment. Acres estimated to be in crop cultivation due to crop insurance subsidies and acres enrolled in CRP are both, on average, more erodible and less productive than overall cropland (table 5.2). A different pattern is evident in the case of wetlands and land subject to frequent flooding. While the land cultivated due the increased subsidies is more likely than overall cropland to contain these land types, CRP is less likely to enroll these lands (table 5.2).

Moreover, the location of CRP enrollments differs from that of cultivated croplands added from the 1992-97 increase in crop insurance subsidies (fig. 5.1). Acres estimated to be in crop cultivation due to crop insurance subsidies (the black dots) are clustered in certain regions (Prairie Gateway, Mississippi Portal, and Eastern Seaboard) and not uniformly spread through CRP areas (the green dots).

The Heartland (Missouri, Iowa, Illinois, Indiana, Ohio) has extensive cropland and a fair amount of land shifting in and out of cultivated crops. This region,

Figure 5.1

Location of CRP enrollments and of additional cropland estimated due to crop insurance subsidy increases, 1997



Note: Size of dots is not proportional to actual land area.

Source: ERS estimates and 1997 National Resources Inventory (NRI).

however, has relatively few CRP lands (except for a cluster in Iowa and Northern Missouri) and virtually no estimated lands in production due to the change in crop insurance subsidies. This pattern may be explained by variation in the actuarial performance of the crop insurance program.[9] Lands are estimated to have shifted into cultivation as a result of crop insurance in areas where crop insurance was a better deal for farmers (e.g., the actuarial performance was worse). The Federal crop insurance program has historically performed better for corn and soybeans in the Midwest, and more poorly for cotton in the Southern Plains (Young et al., 2001).

Lands Affected by Crop Insurance Subsidies and Imperiled Species Habitat

Estimated lands in cultivation due to the increase in crop insurance subsidies include some areas with high populations of imperiled wildlife species. In particular, the cluster of added lands in the Plains States coincides with an area of high CRP enrollment and high counts of imperiled birds. Added lands along the Mississippi River and Eastern Seaboard are in watersheds that overlap with habitats of imperiled fish and mollusks. The lands predicted to be in cultivation due to the increase in crop insurance subsidies are disproportionately located in watersheds with higher counts of imperiled vertebrates, plants, and fish/mollusks (relative to the average for cultivated cropland) (table 5.2). In contrast, CRP lands lie in areas with greater counts of imperiled birds (but not of other imperiled species) (table 5.2).

This is consistent with the fact that protecting habitat, particularly for birds, is an express CRP objective. Other areas with relatively high levels of imperiled species, such as Appalachia, have little or no extensive margin changes in cultivated cropland (see chapter 4). Available data are not sufficient to determine whether observed or predicted land-use changes have an impact (positive or negative) on imperiled wildlife populations.

Crop Insurance Effects on Wind and Water Erosion

Changes in cultivated crop acreage prompted by the increase in crop insurance subsidies translate into small aggregate changes in soil erosion, despite higher levels of erosion per acre than other cropland. While the NRI reports erosion levels given 1997 land use, we estimate erosion under the hypothetical scenarios of no insurance subsidy change and no CRP using our econometric estimates and erosion data for lands with similar physical characteristics (see appendix E). While land in cultivated crops is estimated to increase 0.8 percent, wind and water erosion in 1997 are estimated to increase by 1.4 and 0.9 percent as a result of the increase in insurance premium subsidies (table 5.3).

This environmental impact is much smaller than that of the 32.7 million CRP acres enrolled in 1997.[10] CRP is estimated to reduce wind erosion 16 percent and water erosion 7 percent below the 1997 baseline.[11] Since cultivated cropland enrolled in CRP accounted for about 8 percent of total culti-

[9] These estimates account for the fact that the level of participation in the crop insurance program was already high in the Heartland, with less potential for an increase than in regions with historically low participation levels (appendix D).

[10] For the CRP analysis, we assume that land area affected by CRP is limited to the enrolled acres (see Appendix D). Thus, lands not enrolled in CRP in 1997 remain in their observed 1997 use in our simulation of the environmental impacts in our baseline without the program. This assumes no shifts of non-crop lands into crop production in response to CRP. If such "slippage" is significant, the amount of land enrolled in CRP overestimates the actual cropland reduced by the program and our estimated environmental benefits from CRP would thus be overstated. Wu (2000) estimated that about 21 acres have been brought into crop production for every 100 retired through CRP. More recent studies using the same data have found no evidence of slippage, suggesting that the magnitude of slippage remains an open question (Roberts and Bucholtz, 2005).

[11] Our estimates indicate that annual wind and water erosion in the contiguous 48 States in 1997 declined by 135.5 and 86.1 million tons, respectively, as a result of CRP (table 5.3). These aggregate figures are almost identical to estimated 1997 reductions of 134.6 and 89 million tons from Sullivan et al., (2004). The Farm Service Agency (FSA) reports annual wind and water reductions from CRP of 241 and 166 million tons for 2000, when overall CRP enrollment was 31.4 million acres (USDA/FSA 2004a). These reductions are substantially larger on a per acre basis than our estimates. The differences can be accounted for principally by FSA's assumption that CRP land would be cropped under pre-CRP management conditions in the absence of the program. In contrast, our estimates and Sullivan et al. (2004) reflect some CRP lands exiting cultivation without the program as well as 1997 baseline erosion rates, which were significantly lower than 1982 rates for cultivated cropland (see figs. 3.2 and 3.3).

Table 5.3

Estimated erosion impacts of policy-driven land-use changes

Environmental indicator	Crop insurance subsidy increase: Impact on 1997 baseline levels[1]	Crop insurance subsidy increase: Impact as % of 1997 baseline[2]	Crop insurance subsidy increase: Impact per acre	Conservation Reserve Program: Impact on 1997 baseline levels[1]	Conservation Reserve Program: Impact as % of 1997 baseline[2]	Conservation Reserve Program: Impact per acre
Wind erosion	9,311	1.4	3.8	-135,497	-15.8	-4.1
Water erosion	10,931	0.9	4.5	-86,074	-7.2	-2.6

[1] Erosion values are in 1,000 tons/acre/year.

[2] Different 1997 baselines are used for the crop insurance and CRP analyses to generate internally consistent estimates for each policy as described in appendix D.

Source: ERS estimates and data from the 1997 National Resources Inventory (NRI).

vated cropland in 1997, the estimated 16-percent reduction in wind erosion is even more notable.[12]

Lands affected by the change in crop insurance subsidies and by CRP are more susceptible to wind erosion damage than average cultivated cropland, but vulnerability to rainfall erosion appears about average. This is in contrast to other extensive margin lands, which are more susceptible to rainfall and often wind erosion damage than cultivated cropland overall (see chapter 4). Differences in water erosion are driven largely by slope. Wind erosion depends on site-specific conditions as well as climatic factors, which vary regionally. Thus, policy changes, which might target lands in particular geographical areas, could affect lands that are more vulnerable to wind rather than rainfall erosion.

The environmental impacts of the lands affected by the different policies also differ. Lands estimated to be brought into or retained in production due to increased crop insurance subsidies had, on average, higher rates of water erosion but lower rates of wind erosion than lands enrolled in the CRP (table 5.3). This could be due to the greater proportion of acres cultivated due to the crop insurance subsidy change outside of the Plains, a region with above-average wind erosion. This acreage was less vulnerable than CRP lands in terms of potential nitrogen runoff to surface water, but more vulnerable in terms of potential nitrogen leaching as well as runoff reaching estuaries. This is perhaps due to the greater concentration of lands in cultivation due to the increase in crop insurance subsidies along the Mississippi Portal. Different agricultural and conservation policies thus affect different subsets of lands along the extensive margin with different intended—and unintended—environmental implications.

[12] For our erosion calculations, net reductions in cropland for CRP are actually somewhat less than 8 percent as we allow CRP lands to leave crop production in the absence of the program. Thus, the CRP's per acre reductions in wind and water erosion are even larger than the reported numbers.

Conclusions

The links between soil productivity and environmental damages from crop cultivation have important implications for policies that influence land use. The evidence indicates that lands of low agricultural quality are more likely to move into and out of intensive agricultural uses and are also more sensitive environmentally based on some indicators of erosion, nutrient losses to water, and proximity to imperiled species. This suggests that policies that increase incentives for crop cultivation and thereby stimulate production on economically marginal land will have production effects that are smaller—and environmental impacts that are greater—than would be expected if these characteristics of the affected lands were not accounted for. Conversely, environmental benefits could be achieved at lower cost using targeted conservation programs because owners of low-quality and environmentally sensitive land require less payment to remove land from production than owners of higher quality land.

Our findings on the land-use and environmental impacts of crop insurance subsidies and of the Conservation Reserve Program (CRP) are consistent with the view that government farm programs disproportionately affect land use in areas that are less productive and more environmentally sensitive in some ways than other croplands. But we find that the lands affected by the change in crop insurance subsidies and by the CRP differ from each other and other croplands shifting in and out of production. While government policies that alter the incentives for crop cultivation are more likely to influence land use on economically marginal croplands, the subset of lands affected depends on the incentive structure of each program. Which lands are affected determines the size and types of environmental impacts. Identifying the lands changing use due to specific policy incentives could help improve the effectiveness of future farm programs.

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Appendix A—Land-Use Data

To fully investigate the dynamics of land-use change, we use data on **gross** land-use change, obtained from the National Resources Inventory (NRI). The NRI is an area-based survey conducted by USDA's Natural Resources Conservation Service (NRCS), in cooperation with Iowa State University. NRI provides information on land use, land characteristics, and conservation practices for about 800,000 points of nonfederal land across all U.S. counties except for Alaska. Because most of the same points were sampled at 5-year intervals, the NRI allows us to investigate gross land-use changes over time. Since the 1997 survey, the NRI has changed its procedures to sample fewer points annually. Based on the new annual sample, NRCS provides annual estimates of national land use and summary information on selected land-use transitions.[1]

Because NRI is a survey rather than a full enumeration of all land, estimates of land-use change are subject to a small amount of error. For estimates of land use and land-use change at the regional and national level, these errors are quite small and are not reported in tables to avoid clutter. In some cases, however, data presented in the form of maps is aggregated to the 8-digit Hydrological Unit Code (HUC). In these cases, only estimates that are statistically different from zero with 90 percent confidence are displayed.

The NRI places land uses into one of 58 categories, with special emphasis on classifying various categories of cropland. The NRI aggregates these 58 specific land uses into 12 broad land-use categories. We focus on changes between four categories: cultivated crops; uncultivated crops; CRP; and grazing, forest, and other rural land.

Cultivated cropland primarily includes the cropland uses that require more intensive management and have the potential to yield higher values (although summer fallow and set-aside acres are also included). In contrast, uncultivated cropland primarily includes hay with no rotation, a lower value and lower intensity use of cropland. Grazing, forest, and other rural lands include pasture, range, forestland, and other farm lands such as farmsteads.

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[1] Point-level data are publicly available for the 5-year NRI surveys, enabling the analysis of three land-use transitions for each sample point (1982-87, 1987-92, 1992-97). At the time of this study, point-level data were not publicly available for the annual surveys started in 2001.

Appendix table A-1

Land-use classifications in this report based on the National Resources Inventory (NRI)

Classification in this report	NRI broad use categories	NRI specific land-use categories
Cultivated cropland	Cultivated cropland	● Row crops ● Close crops ● Hay with close/row rotation ● Pasture with close/row rotation ● Double-cropped horticulture ● Set-asides, summer fallow, and aquaculture
Uncultivated cropland	Uncultivated cropland	● Single-cropped horticulture ● Hay with no rotation
Conservation Reserve Program (CRP)	Conservation Reserve Program (CRP)	Conservation Reserve Program (CRP)
Grazing, forest, and other rural land	● Pasture ● Rangeland ● Forestland ● Other rural land	● Pasture ● Rangeland ● Forests grazed and ungrazed ● Other farm & rural land
Developed land	● Urban/built-up ● Rural transportation	● Urban/small built-up ● Urban/10 acres or larger ● Rural transportation
Water and Federal land	● Small water areas ● Census water areas ● Federal land	● Small & large streams ● Small & large water bodies ● Federally owned land

Appendix B—EPIC-Based Nutrient Loss Indicators

This appendix describes how indicators for nitrogen and phosphorus loss to water were simulated using the Environmental Policy Integrated Climate Model (EPIC) for different crop production activities, as well as pastured land or land planted to trees. EPIC is a crop biophysical simulation model that is used to estimate the impact of management practices on crop yields, soil quality, and pollution discharged at the field level (Mitchell et al., 1998). It uses information on soils, weather, and management practices—including specific fertilizer rates—and produces information on crop yields, erosion, and chemical losses—including nitrogen losses—to the environment. Cropping and management practices used in the EPIC management files were set consistent with agronomic practices for highly erodible (HEL) and non-highly erodible (non-HEL) land in 45 farm production regions (see app. fig. B-1).

Cropping Enterprises

The National Resources Inventory (NRI) and Agricultural Resource Management Surveys (ARMS) were used to identify 62 crop rotations commonly used throughout the United States and the tillage practices commonly associated with them. This totaled 623 systems, which include rotations of up to four crops differentiated by up to five tillage practices. Rotations were defined based on the number of crops contained in the cropping history. NRI records were divided into regions by overlaying the 26 Land Resource Regions onto the 10 Farm Production regions (fig. app. B-1). Records were then differentiated by HEL or non-HEL. Acreage for each rotation was then recorded. Tillage practices associated with the rotations and the acreage devoted to them were derived from the CPS. Crop rotations as identified through the NRI were used to group the CPS records.

Running EPIC simulations for the predominant systems (and the physical impacts of these systems—yields and environmental effects) required obtaining all the management information needed to mimic the complete production cycle of any crop in a rotation. This included information on all field operations from pre-planting to post-harvesting (i.e., what occurred, when it occurred, with what type of equipment, and how frequently) and input levels (i.e., seeding rates, fertilization and liming rates, pesticide applications, etc.) for each crop within a production activity sorted by rotation, tillage practice, and region.

Fertilizer regimes for each crop in a rotation-tillage system were derived from the fertilizer information contained in ARMS. The means for total quantity of nitrogen (N), phosphate (P), and potash (K) were used to determine how many pounds per acre of N, P, and K to apply to each system. Likewise, liming information was used to determine lime applications. Also, the most frequently occurring month(s) were used to set fertilization date(s).

ARMS data were also used to determine how many field or tillage operations (other than planting, fertilizing, or spraying) occurred for a crop (again, by farm production region, specific to each crop within a rotation-tillage system). The mean number of machinery operations reported in

ARMS for that crop (rounding up or down to an integer, according to convention) was used. Here too, ARMS data determined the most frequently occurring time(s) of field (tillage) operations.

In matching values to NRI observations according to land use, the estimated EPIC values for land in single-hay rotations were used for uncultivated cropland, while values for land in all other rotations (including mixed-hay rotations) were assigned to cultivated cropland. Values for pasture land were used for both pasture and rangeland while values for land in trees were used for forests. Idle cropland and forest values were used for CRP land depending on whether grass/legumes or trees/wildlife cover were reported in the NRI.

EPIC Model Runs

We generate an array of environmental indicators associated with each crop production activity, as well as pastured land or land planted to trees, by running EPIC in two steps. The first step conditions the soil, while the next is used to calculate average rate of discharge. Each step was run to generate separate environmental values for HEL and non-HEL.

The first or conditioning step allows EPIC to rectify any inconsistencies in the soil profile imported from STATSGO data set.[1] It involves running EPIC out for 5 years while keeping its soil erosion module turned off. This step makes the soils profile at the next step consistent with a field that has been subjected to the management practices being simulated. This is important because any particular soil profile used does not necessarily come from a field where the system being simulated has been used.

In the next step, environmental indicators are calibrated by running EPIC out for 60 years, this time with soil erosion turned on. Total discharges for each indicator are tabulated and divided by the length of the simulation to obtain the annual rate of discharge. Running the systems for 60 years does two things: it eliminates the dependence of the discharge from the sequence of weather for any particular period and it provides a consistent base for making comparisons between systems. By eliminating the dependence on weather, we do not have to coordinate weather patterns among the various weather sites. Therefore, all systems are run through two full weather cycles. At the same time, each management regime is run through at least five full management cycles.

Selected Indicators

We categorize the potential impacts of changes in agricultural production on nutrients lost to the environment using several indicators. The indicators we examine are: nitrogen runoff, nitrogen leaching, nitrogen loss to estuaries, and phosphorus loss to water. Excess nitrogen balance is first constructed using data on chemical fertilizer use, manure fertilizer, and nitrogen fixed by legumes. From this, the nitrogen harvested in crop yield is subtracted, which leaves excess nitrogen left on the field vulnerable to leaching or runoff. Nitrogen runoff is the amount of nitrogen in subsurface flow, in solution, and attached to sediment that is estimated to arrive

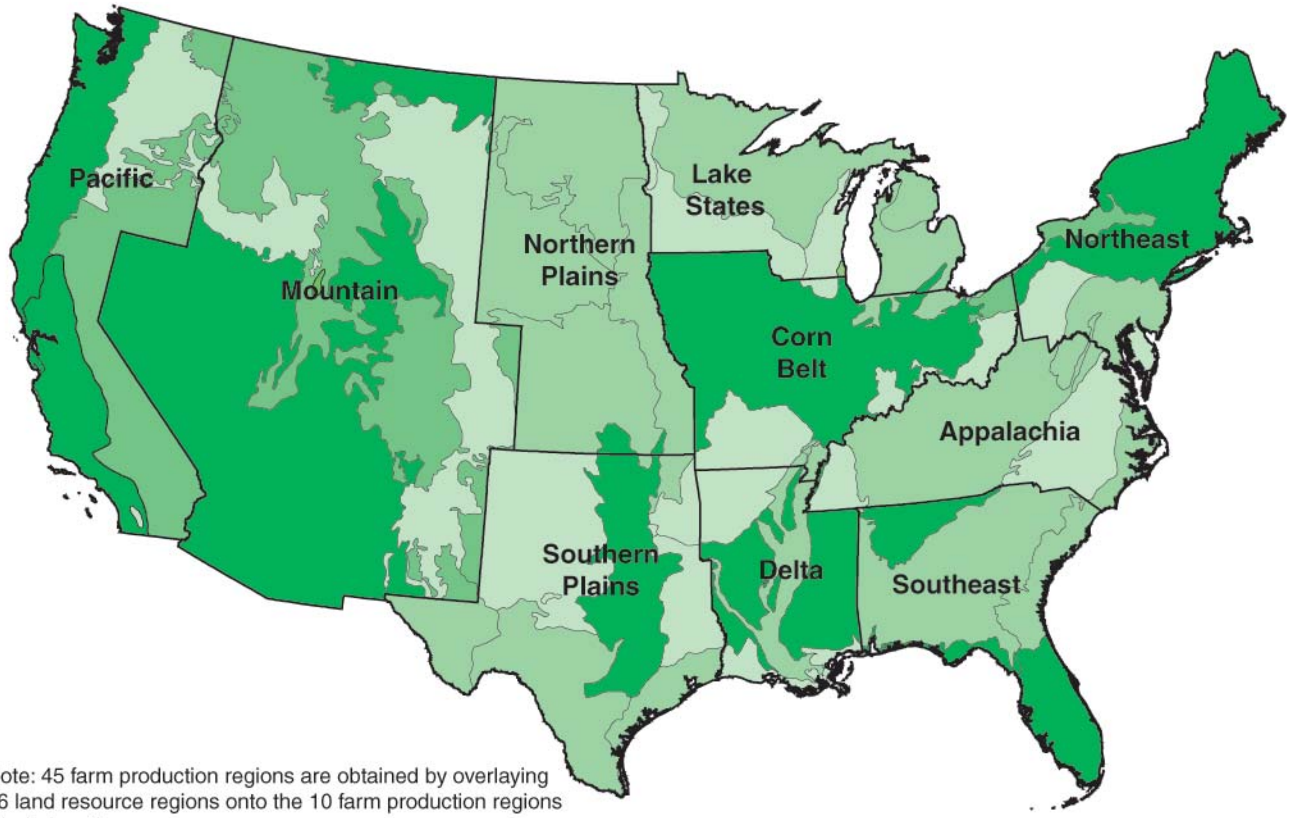
[1] See *http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/metadata/index.html*.

in surrounding streams, rivers, and lakes. USGS forecasts of nitrogen delivery from agricultural sources are used to calibrate nitrogen runoff and the amount of this runoff reaching estuaries (Smith et al., 1997).

Phosphorus loss to water is an indicator that uses EPIC estimates of phosphorus losses to the field edge (in leaching, sediment, and solution and calibrates them to baseline USGS forecasts of phosphorus delivery from agricultural sources (Smith et al., 1997).

Appendix figure B-1

Farm production regions used in environmental simulations



Note: 45 farm production regions are obtained by overlaying 26 land resource regions onto the 10 farm production regions labeled on the map.

Source: USDA/ERS.

Appendix C—Imperiled Species Counts

Counts of "imperiled" species are derived from the conservation status rankings in NatureServe's Natural Heritage data set as of 2000, though data for different States may reflect different levels of updating. NatureServe is a nonprofit network of biological inventories, known as natural heritage programs or conservation data centers, in all 50 U.S. States as well as other countries. The Natural Heritage data set includes conservation status assessments of species from all three taxa (animals, invertebrates, and plants) and their classes. Data on invertebrates is probably the most incomplete of the three as heritage programs tend to assign low priority to collecting species data for this group (NatureServe, 2005).

For each species (or "element") in the Natural Heritage data set, NatureServe assigns a ranking of its risk of extinction.[1] While NatureServe has a wide variety of ranking measures, we use their highest level ranking, their so-called "G" ranking, which rates the element's risk of extinction on a rangewide or "global" basis. For our analysis, we consider "imperiled species" as those classified by NatureServe as either "critically imperiled" or "imperiled" at the national level, receiving a Global Conservation Status (G) rank of 1 or 2, respectively.[2]

Standard ranking criteria and definitions are used to ensure that a particular rank has the same meaning regardless of the species or geographic region considered. Ranking is a qualitative process based on the following factors: total number and condition of element occurrences, population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, environmental specificity, and fragility. According to NatureServe, "The ranker's overall knowledge of the element allows him or her to weigh each factor in relation to the others and to consider all pertinent information for a particular element" (NatureServe, 2005).[3]

The set of species identified by the Natural Heritage network as imperiled or vulnerable provides a more accurate indication of biodiversity hot spots than the federally maintained endangered species list, according to Ehrenfeld et al. (1997). The list of species under the Endangered Species Act includes only species that are formally designated as endangered or threatened as a result of legal proceedings, rather than all species considered by most biologists to be at risk of extinction (Stein et al., 2000). Additionally, the NatureServe data avoid the problems of raw population occurrence data, which overemphasize areas that have been particularly well inventoried. This is overcome by calculating the number of different species within a geographical unit. Counts of imperiled species also help to overcome inconsistencies in inventory intensity.

NatureServe data are available at a national level and in a Geographic Information System (GIS) format. However, these data are often collected with limited *a priori* justification, which limits their usefulness because of variable sampling efforts, inconsistent sampling protocols, small sample sizes, inclusion of opportunistic observations, and a tendency to report unusual observations. In addition, species included in data sets often vary among States (Niemuth, 2004).

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[1] An "element" is defined as a unit of natural biological diversity, representing species, ecological communities, or other nontaxonomic biological entities, such as migratory species aggregation areas. These elements refer to the species records by county and by watershed only. No ecological communities or other significant areas such as migratory stopover points are included in the data sets provided.

[2] An element known or assumed to exist within a jurisdiction is designated by a whole number from 1 to 5, denoting: 1 = critically imperiled; 2 = imperiled; 3 = vulnerable to extirpation or extinction; 4 = apparently secure; and 5 = demonstrably widespread, abundant, and secure (NatureServe, 2005).

[3] See *http://www.natureserve.org/explorer/ranking.htm* for more information.

Appendix D—Estimating Land-Use Changes from Crop Insurance Subsidies

This appendix describes the econometric model used to estimate changes in cultivated cropland area resulting from the large increase in crop insurance premium subsidies during the mid-1990s. Following discrete choice studies on land-use change (e.g., Schatzki, 2003; Lubowski et al., 2003; Irwin and Bockstael, 2002; Claassen and Tegene, 1999), the model builds on traditional rent theory to estimate the likelihood that a parcel of land in a particular land use in 1992 remained in the same use or had moved to a different one by 1997. The land-use impact of the increase in crop insurance subsidies is estimated by exploiting variation in the expected profits from crop cultivation due to the large change in premium subsidies from 1992 to 1997. By examining changes in land use in relation to changes in subsidies, the effect of the subsidies can be identified, controlling for other determinants of land-use change. A critical assumption is that the policy change is largely exogenous and uncorrelated with other, unobserved land-use determinants not included in the model.

The likelihood that land transitions from four initial land-use categories (cultivated crops, uncultivated crops or pasture, range, forest) to any of six broad land-use options (cultivated crops, uncultivated crops or pasture, CRP, range, forest, and urban) is estimated using observation-specific data on land use and land characteristics from the National Resources Inventory (NRI) and county-level estimates of net returns to the different land-use alternatives.[1] One key explanatory variable is the change in expected profitability of crop cultivation in a county resulting from the change in premium subsidies from 1992 to 1997. Estimated parameters from the model are used to simulate 1997 land use under a hypothetical case in which there was no change in crop insurance subsidies over the previous 5 years. The difference in 1997 land-use predictions with and without the change in crop insurance returns provides an estimate for the impact of the 1992-97 subsidy increase at the level of each NRI observation.

Conditional Logit Model

We hypothesize that a producer (or other land-use decisionmaker) will choose to convert a parcel of land from one land use to another based on the profitability (rents) of the alternative land uses (see chapter 3). If land-use patterns are initially in equilibrium, then only changes in the relative levels of profits—and not the profit levels themselves—should drive land-use transitions. Although our focus is on land-use changes over time (1992-97), we include 1992 profit levels (as well as the 1992-97 changes in these levels) in our analysis because the levels will matter if land markets were in disequilibrium initially. Because our measures of profits are not normalized to any one use, we also include profit levels because they indicate the relative profits among alternative uses. Relative profits will matter for land-use changes if hurdles in relative rents must be crossed to induce producers to convert from one land use to another.

Producers presumably compare net returns to alternative uses on particular land parcels. Although we do not observe profits of alternative land uses for

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[1] Uncultivated crops and pasture account for the majority of changes to and from cultivated crops. These categories are combined as our estimates of net returns from these activities are based on similar factors (hay and forage prices and yields). We do not model land starting in urban uses, as these lands are unlikely to transition from development to agricultural land uses. We also do not examine transitions of land exiting CRP, as lands eligible to leave the program represent a small fraction of the land base and depend on government as well as landowner choices. These issues are explored in Sullivan et al. (2004).

each NRI observation, we do observe certain parcel-level attributes and condition our estimates on these attributes as well as on interactions between the attributes and county-level profits and profit changes. We include these interactions because lands with different attributes may be more or less likely to convert from one use to another, especially because our measures of relative profits are based on relatively coarse county-level data. In this way, we model some within-county variation in land-use profits from the different activities. The parcel-level attributes, plus an intercept that varies by land-use transition, also proxy for the costs of converting land from its current use to each of the six land-use alternatives. These attributes include point-level indicators of land quality (Land Capability Class), erodibility, average slope gradient, and flooding frequency.

Land parcels near one another may have unobserved characteristics that are correlated across space. If such characteristics influence land-use decisions or if local land-use choices are interdependent, error terms will be correlated across space, leading to inconsistent and inefficient estimates in a logit model due to induced heteroskedasticity (McMillen, 1992). We deal with spatial autocorrelation in two ways. First, and most importantly, we randomly select only a single point from each sampling cluster of NRI observations because errors within these points located near one another are most likely to be strongly correlated.[2] Second, we use a polynomial spatial trend surface to control for spatial heterogeneity. This approach includes a measure of geographic location as an explanatory variable and is a common approach in spatial statistics (Venables and Ripley 1994). This approach differs from an approach common in the literature on spatial econometrics, which uses a spatially autorcorrelated error structure (Anselin, 1988).[3]

The producer's profit function may be thought of as including both observed and unobserved components. Using a general random utility expression, the one-period expected net profit (utility) to the producer on parcel *i* from switching from use *j* to *k* at time *t* can be specified as:

$$U_{ijkt} = f(X) + \varepsilon_{ijkt}$$

where ε_{ijkt} is a random error term. Assuming that the error terms ε_{ijkt} are independent and identically distributed with the type I extreme value distribution yields, the probability that parcel *i* transitions from use *j* to use *k* between *t* and *t+1* can be written as:

$$\mathrm{Prob}(U_{ijkt} > U_{ijlt}) = P_{ijkt} = \frac{\exp(U_{ijkt})}{\sum_{l=1}^{J} \exp(U_{ijlt})}$$

This is the general formulation of a conditional logit model (McFadden, 1974).[4]

We estimated separate models for four starting land-uses j (cultivated crops, uncultivated crops/pasture, forests, and range) that allow for six land-use alternatives *k* (cultivated crops, uncultivated crops/pasture, CRP, range, forest, and urban).[5] Each model is based on the same specification. After

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[2] The NRI has a stratified sampling design. Data on urban and water areas are collected for about 300,000 primary sampling areas varying from 40 to 640 acres in size. More detailed data on land characteristics and use are collected at two to three sample points randomly selected within each of these areas (Nusser and Goebel, 1997).

[3] The spatial trend surface has an advantage over the spatially autocorrelated error approach for two reasons: First, it may control for omitted factors associated with space, even if they are associated with other covariates, whereas the spatial error model must assume these are not correlated (i.e., a spatial trend may reduce bias in the estimated coefficients, not just the standard errors). Second, it is much easier to estimate. A limited dependent variable model with spatial autocorrelation could be estimated using simulation methods. However, this is very computationally expensive. Remaining spatial autocorrelation, if present, would bias our standard errors, but not our estimates.

[4] The term "conditional" logit or "discrete choice" logit (Greene, 1998) is sometimes used for a logit model in which the independent variables vary only over the choices, in contrast to a "multinomial" logit, in which explanatory variables vary only over the individuals but not over the choices. The more general choice model used here has terms varying over both choices and individuals and is sometimes called "McFadden's choice model" or a "mixed model" (Long and Freese 2001).

[5] While we estimated models for four starting uses, the discussion in chapter 5 focuses on the results based on land starting in either cultivated crops or in uncultivated crops and pasture. We focus on these results since transitions from uncultivated crops/pasture accounted for the majority of transitions to cultivated cropland and because there were too few observations of land-use changes to compute confidence intervals (for the estimates) for land starting in either forests or range. Transitions from uncultivated crops/pasture to cultivated cropland accounted for 77 percent of all land-use transitions from other uses to cultivated cropland between 1992 and 1997.

examining several functional forms for *f (X)* we chose a linear model that considers all possible two-way interactions between a parcel-level indicator of land quality, based on the Land Capability Class (LCC),[6] and estimated levels and changes in levels of land-use profits. Two-way interactions between LCC and the other parcel-level measures are also included, and other explanatory variables (described below) are included without interactions.[7] Dropping the time subscripts, we specify the component of utility that is unique to each alternative *k* (and initial land use *j*) as:

$$f(X) = U_{ijk} - \varepsilon_{ijk} = \alpha^0_{jk} + \alpha^s_{jk} LCC^q_{jk} + \beta^s_{jk} LCC^q_{jk} R^c_{jk} + \theta^s_{jk} LCC^q_{jk} x^s_{jk} + \alpha^s_{jk} x^s_{jk} + \beta^c_{jk} x^c_{jk},$$

where α^0_{jkt} is an alternative-specific intercept; α, β and θ are parameters; R^C_{jk} are net returns (and changes) to use k in county c; LCC^q_{it} is a dummy variable indicating whether parcel i is of quality q at time t; and x^s_{jk} and x^c_{jk} denote other explanatory variables measured at the parcel - specific and county level, respectively.

CRP participation depends on a different set of decisions than other land-use choices, because enrollment depends on both the producer's bid, which includes a proposed rental rate, and the Government's choice of whether to accept the bid, which depends on the environmental characteristics of a parcel as well as the cost. Because the program targets cropland, CRP rental rates are highly correlated with the profitability of cropping in a given locality. We account for the effect of crop net returns on the incentive to remain in cropland. Incentives to enroll in CRP are specified as a function of LCC, the other parcel-level variables, and a spatial trend surface unique to this alternative. Lower land quality as measured by LCC has always been strongly associated with program eligibility. We would thus expect greater enrollment on lower quality lands.

The included variables explain a significant share of the variation in land-use changes, with pseudo R^2 measures ranging from 0.71 to 0.86. The estimated parameters are consistent with economic intuition, with the profit variables (and changes in profits) for each land-use alternative generally significant and positively associated with a greater likelihood of moving to each respective use.[8] The change in insurance returns is positively related, all else equal, to the probability of moving to cultivated crops from 1992 to 1997.

Results from counterfactual simulations in which insurance net returns are set to zero are reported in chapter 5. In these simulations, land-use change probabilities are estimated for each NRI observation in the sample based on the estimated parameters. These probabilities are multiplied by the acreage weight for each observation to estimate the amount of land transitioning from each initial use to each of the six land-use alternatives. These amounts are used as weights in determining mean land characteristics of acres affected by the increase in crop insurance subsidies relative to cultivated cropland overall. Standard errors for the predictions were estimated by bootstrap.[9] We resampled an equal number of NRI point/clusters from our main sample (with replacement) and obtained a new set of estimates and predictions. We repeated this exercise 500 times for each of the model equations.

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[6] The Land Capability Class is a summary measure of the suitability of the land for crop production, based on a ranking of 12 different soil characteristics that are critical for crop production. The overall LCC score consists of the lowest ranking given to any of these 12 soil features based on the principle that this factor will be limiting for crop production (USDA, 1973). Higher LCC ratings indicate poorer soils for crop production. To ensure sufficient observations in each LCC category, we combine the eight categories into three: LCC 1-2; LCC 3-4; LCC 5-8.

[7] The choice of these additional parcel and county-level variables was determined through a process in which terms were dropped and added successively in order to minimize the Akaike (1974) information criterion (AIC).

[8] For brevity, given the large number of variables and equations, individual parameter estimates are not reported but are available from the authors upon request.

[9] This procedure enabled the construction of confidence intervals for the estimates based on points starting in either cultivated cropland or uncultivated cropland/pasture in 1992. There were too few observations to achieve convergence in the bootstrapping runs for the models based on points starting in either forest or range in 1992, so we were unable to compute standard errors for the results from these models. The discussion in chapter 5 focuses on the results for which standard errors could be estimated.

Data

The likelihood that a land unit moves from one land use to another is estimated based on repeated observations of non-Federal land use from the National Resources Inventory (NRI). The NRI is a panel survey of land use and land characteristics on non-Federal lands conducted at 5-year intervals from 1982 to 1997 over the 48 contiguous United States (see chapter 2). Data include approximately 844,000 "points," each representing a land area given by a sampling weight that is inversely proportional to the sampling intensity (Nusser and Goebel, 1997). Our analysis is based on a subset of points drawn from the 657,781 observations that consist of lands that were in cultivated crops; uncultivated crops and pasture; forest; or range in 1992 and any of our six alternative uses in 1997. We randomly sample from these points so as to include only one point in each of our 1982 land-use categories from each of the NRI's primary sampling clusters. This reduces our sample to 83,807 points (23,637 observations in cultivated crops, 25,148 in pasture, 23,723 in forest, and 11,299 in range). This procedure eliminates parcels located near one another in order to purge our sample of potential spatial dependence.

Summary statistics are provided for each of our county- and parcel-specific variables (appendix tables D-1 and D-2). We constructed the land-use profit variables (and changes in these variables) using county-level data derived from a number of sources to approximate revenues less variable costs for each the six land-use activities. In addition to our measure of net returns from urban development, we include the 1990 "urban influence" code for the centroid of each county. This variable is a distance-weighted measure of access to population centers based on the 1990 census and is included as an additional proxy for urban development pressures, given the coarse nature of our urban profit estimates (see Heimlich and Anderson, 2001).[10]

In addition to crop net returns derived from the market, government payments for 1997 are included as a proxy for prior participation in government commodity programs and the effect of the major regime change that decoupled these commodity payments in 1996. The 1996 Federal Agriculture Improvement and Reform (FAIR) Act removed most conditions on plantings and conditioned payments on prior planting histories as opposed to current planting decisions. As a result, payments received in 1997 proxy for program participation prior to 1996.[11]

Our key explanatory variable is the 1992-97 change in expected net returns to crop insurance due to the increase in Federal crop insurance premium subsidies. The construction of this variable is described below. To control for net returns to crop insurance in the initial period (1992), we include the county-level share of insurance program participation for the eight major crops considered. Insurance participation is a revealed preference measure that should reflect initial differences across the country in the relative returns from insurance participation. This also controls for the amount of initial participation, which determines the potential for an increase in participation over 1992-97.

To control for unobserved factors correlated with location, we estimate models with a spatial polynomial surface trend. To estimate this trend, we assign to each point a measure of location, proxied by longitude and latitude

[10] Interaction terms between the urban influence code and the urban net returns (and changes) are also included.

[11] The 1996 FAIR Act also introduced loan deficiency payments (LDPs) and marketing loan gains (MLGs) for grain crops, which had previously only been available for cotton and rice. Our results were not affected by the inclusion of county-average changes in expected LDPs as a separate explanatory variable.

coordinates for the centroid of each NRI polygon.[12] We include these coordinates (interacted with an alternative-specific constant) singly and in all second and third-order interactions.[13]

County-Level Estimates of Profits (Net Returns)

Crop Net Returns. Data on prices, yields, costs, and acres are used to compute a weighted county-level average of the net returns per acre for 21 major crops. State-level marketing-year-average prices and county-level yields are from USDA's National Agricultural Statistics Service (NASS). Producers are assumed to form expectations of future land-use returns based on current prices and the average of yields over the previous 5 years. Data on cash costs as a share of revenue at the State and regional level are from the Census of Agriculture and the Economic Research Service (ERS). County acreage from NASS and the Census of Agriculture provided weights for averaging across individual crops.

Government Payments. County-level estimates of total Federal farm program payments per acre are from the Census of Agriculture and include receipts from deficiency payments, support price payments, indemnity programs, disaster payments, and payments for soil and water conservation projects (USDA/NASS, 1997). Payments under the Conservation Reserve and Wetlands Reserve programs are excluded, as the payments measure is intended to only reflect government payments associated with crop production only, rather than cropland retirement.

Pasture Net Returns. Annual net returns per acre for pasture are estimated using pasture yields from the SOILS-5 data set linked to the NRI, State prices for "other hay" from NASS, and per-acre costs for hay and other field crops from the Census of Agriculture.

Range Net Returns. Annual net returns per acre for rangeland are computed with forage yields from SOILS-5 and State-level grazing rates per head for private lands from ERS.

Forest Net Returns. We use a 5-percent interest rate to annualize the estimated net present value of a weighted average of sawtimber revenues from different forest types based on prices, yields, costs, and acres. State-level stumpage prices were gathered from State and Federal agencies and private data services. Regional merchantable timber yield estimates for different forest types were obtained from Richard Birdsey of the U.S. Forest Service. Regional replanting and annual management costs were derived from Moulton and Richards (1990) and Dubois et al. (1999). The Faustmann formula was used to compute the optimal rotation age, assuming forests start newly planted at year zero. County acreage and timber output data from the Forest Inventory and Analysis (FIA) and Timber Product Output (TPO) surveys of the U.S. Forest Service provided weights for averaging across individual forest types and species, respectively.

Urban Net Returns. Annual urban net returns per acre are estimated as the median value of a recently developed parcel, less the value of structures,

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[12] NRI polygons are land areas defined by the intersections of all counties and 9-digit watershed classifications. To protect the confidentiality of landowners sampled by the NRI, more specific location indicators are not publicly available.

[13] Denoting the location coordinates as x and y, we include x, y, xx, yy, xy, xxx, yyy, xxy, and xyy as explanatory variables.

annualized at a 5-percent interest rate. Median county-level prices for single-family homes were constructed from the decennial Census of Population and Housing Public Use Microdata Samples and the Office of Federal Housing Enterprise Oversight (OFHEO) House Price Index. Regional data on lot sizes and the value of land relative to structures for single-family homes were from the Characteristics of New Housing Reports (C-25 series) and the Survey of Construction (SOC) microdata from the Census Bureau.

Crop Insurance Returns. For the period of years under study, 1992-97, crop insurance was dominated by actual production history (APH) contracts, although revenue insurance products were introduced in selected counties in 1996 and purchase of these products has grown rapidly in the years since. Return to APH crop insurance can be written as:

$$R_{ni} = I_i - r_i + s_i$$

$$E(R_{ni}) = E(I_i) - r_i + s_i$$

where R_{ni} is the **change** in crop revenue due to insurance program participation; I_i is the crop insurance indemnity; $r_i - s_i$ is the (total) crop insurance premium, s_i is the premium subsidy (the premium paid by producers is ri) and E is the expectations operator. Also, catastrophic coverage (APH insurance with a 50-percent yield guarantee and 100-percent premium subsidy) was introduced in 1995. In 1995, producers participating in farm commodity programs were required to purchase at least catastrophic coverage (producers where charged a small processing fee, per crop), but the requirement was dropped for the 1996 and subsequent seasons.

Crop insurance program data for APH contracts, available from USDA's Risk Management Agency, include total indemnities, total premiums, and the subsidy by crop and county. To estimate expected returns, expected indemnity is estimated as the average indemnity over the previous 10 years, by crop and county for eight major crops. A single expected return to crop insurance is estimated for each county as the acre-weighted average of crop-specific expected returns.

Estimates of expected returns were made with and without catastrophic coverage. Because our objective was to estimate the impact of the subsidy increases on expected returns to crop insurance, however, the addition of catastrophic coverage confused the situation. While the introduction of catastrophic coverage significantly increased both liability and enrolled acreage, the low yield guarantee, which made indemnities rare, resulted in a sharp reduction in indemnities per dollar of liability and per unit of land with a crop insurance product. The issues are particularly important given that catastrophic coverage was required for the large share of crop producers who participate in commodity programs. Even when the requirement was removed, renewal was automatic and many producers may have simply allowed the contracts to continue rather than making a conscious decision to continue catastrophic coverage. Thus, we believe that the expected return to buy-up coverage (coverage of 65 percent or higher) best reflects the change in expected returns to crop insurance due to the subsidy increase for those producers who were actually engaged in the crop insurance program.

Appendix table D-1

Summary statistics: County-level variables

County-level variable	No. of observations	Mean	Standard deviation	Minimum	Maximum
Crop net returns in 1992 ($/acre/year)	657,781	16.9	51.1	-829.2	294.3
Pasture net returns in 1992 ($/acre/year)	657,781	-3.0	76.3	-599.8	200.3
Forest net returns in 1992 ($/acre/year)	657,781	6.9	9.8	-1.2	92.6
Range net returns in 1992 ($/acre/year)	657,781	9.0	10.3	0	73.9
Urban net returns in 1992 ($/acre/year)	657,781	2,224	2,892	183	36,944
Urban influence code in 1990	657,781	1.40	0.89	1.0	5.0
Total government payments in 1997 ($/acre/year)	657,781	8.4	5.9	0	47.3
% of eligible crop acres insured in 1992	657,781	0.4	2.6	0	92
Change in insurance net returns, 1992-97 ($/acre/year)	657,781	1.8	4.3	-37.1	40.2
Change in crop net returns, 1992-97 ($/acre/year)	657,781	15.1	62.9	-819.1	939
Change in pasture net returns, 1992-97 ($/acre/year)	657,781	2.2	5.4	-8.2	52
Change in forest net returns, 1992-97 ($/acre/year)	657,781	0.2	2.4	-8.6	12.3
Change in range net returns, 1992-97 ($/acre/year)	657,781	36.2	65.5	-175.2	575.5
Change in urban net returns, 1992-97 ($/acre/year)	657,781	14.1	891	-1,610	10,769

Source: Various sources described in Appendix D.

Appendix table D—2

Summary statistics: Observation-specific variables

NRI point-level variable	No. of observations	Mean	Standard deviation	Minimum	Maximum
Land in cultivated crops in 1992 (yes=1, no=0)	657,781	0.25	0.44	0	1
Land in uncultivated crops/ pasture in 1992 (yes=1, no=0)	657,781	0.13	0.34	0	1
Land in forests in 1992 (yes=1, no=0)	657,781	0.31	0.46	0	1
Land in range in 1992 (yes=1, no=0)	657,781	0.31	0.46	0	1
Land in cultivated crops in 1997 (yes=1, no=0)	657,781	0.25	0.43	0	1
Land in uncultivated crops/pasture in 1997 (yes=1, no=0)	657,781	0.13	0.33	0	1
Land in forests in 1997 (yes=1, no=0)	657,781	0.31	0.46	0	1
Land in range in 1997 (yes=1, no=0)	657,781	0.31	0.46	0	1
Land in CRP in 1997 (yes=1, no=0)	657,781	0	.04	0	1
Land in urban use in 1997 (yes=1, no=0)	657,781	.01	.09	0	1
Land Capability Class 1-2 (yes=1, no=0)	657,781	0.23	0.42	0	1
Land Capability Class 3-4 (yes=1, no=0)	657,781	0.33	0.47	0	1
Land Capability Class 5-8 (yes=1, no=0)	657,781	0.43	0.49	0	1
Highly erodible land (yes=1, no=0)	657,781	0.44	0.49	0	1
Land prone to frequent flooding (yes=1, no=0)	657,781	.04	0.18	0	1
Slope % greater than 15[1] (yes=1, no=0)	657,781	.01	0.11	0	1
Land irrigated (yes=1, no=0)	657,781	.05	0.22	0	1
Acreage weight (NRI xfact in acres)	657,781	1,980	2,368	100	192,200

[1] Lands with slope percentages greater than 15 are considered as having “strong” to “very steep” slopes.

Source: 1997 National Resources Inventory. Observations were included if they were in cultivated crops, uncultivated crops, pasture, forest, or range uses in 1992; and in cultivated crops, uncultivated crops, pasture, forest, range, CRP, or urban uses in 1997.

Appendix E—Estimating Erosion From Policy-Driven Changes in Land Use

This appendix describes the procedures used to estimate environmental impacts in terms of rainfall and wind erosion from the changes in land use induced by: (1) the change in crop insurance subsidies from 1992 to 1997 and (2) the Conservation Reserve Program as of 1997.

Change in Crop Insurance Subsidies. To estimate the impacts from the 1992-97 change in subsidies, we compare erosion under the 1997 land uses with and without the change in crop insurance subsidies, as predicted by the econometric model. Data on rainfall and wind erosion are derived from the NRI. For each NRI point observed in a particular 1997 land use (e.g., crops), the actual 1997 erosion data from NRI are used to calculate 1997 tons/acre of erosion on the fraction of land at that point predicted by the model to be in that particular use in 1997. For the acreage at that point predicted by the model to be in each different use (e.g., pasture), we impute wind (WEQ) and rainfall (USLE) erosion values based on the average 1997 erosion values for similar points in that land use in the same Crop Reporting District (CRD). NRI erosion estimates are only available for land in cultivated crops, uncultivated crops, pasture, and CRP. Erosion on other land uses is assumed to be zero. Given that most changes between the 1997 baseline and no-subsidy-increase scenarios occur at the margin of cultivated cropland with uncultivated crops, pasture, and CRP, these data should account for the majority of the erosion differences due to the simulated changes in land use.

To impute wind and rainfall erosion, points are matched based on erodibility index (EI) quantiles for wind and water, respectively; land capability class (LCC); and 1992 land use. If perfect matches are not available in a particular CRD, we progressively loosen the requirements for similarity—first in terms of erodibility, then LCC, then geographic scale, and then land use—until values are imputed for all points.

Conservation Reserve Program. For the 1997 baseline, given by the observed 1997 pattern of CRP and land use in the NRI, erosion is estimated with 1997 WEQ and USLE erosion values from the NRI. For the counterfactual no-CRP scenario, lands not in CRP are assumed to remain in their observed 1997 use. This assumes that lands not enrolling in CRP did not change use in response to the program (no “slippage”). Lands in CRP in 1997 are assumed to convert to other land uses (or remain in the same use) in the same proportion as similar lands in the same geographic area over 1982-97. We impute 1997 land use—and associated 1997 rainfall and wind erosion—by matching each CRP point to similar points in a CRD based on erodibility, LCC, and pre-CRP land use (1982) through the iterative procedure described above.