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Grassland to Cropland Conversion in the Northern Plains

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Roger Claassen, Fernando Carriazo, Joseph C. Cooper,
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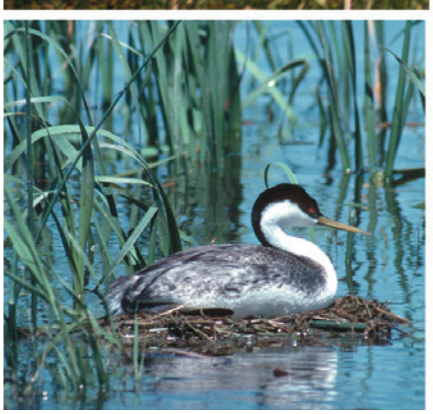

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Grassland to Cropland Conversion in the Northern Plains

The Role of Crop Insurance, Commodity, and Disaster Programs

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Abstract

Native grasslands in the U.S. Northern Plains, particularly those located in the Prairie Pothole Region, are excellent breeding habitat for migratory birds. The conversion of grassland to crop production could damage this habitat and affect bird populations. We focus on three questions: How fast are grasslands being converted to cropland in the United States and especially in the Northern Plains? Can a temporary (5-year) ban on crop insurance purchase for converted grassland slow grassland to cropland conversion? More broadly, what has been the role of crop insurance and other farm programs in grassland to cropland conversion? We find that: (1) roughly 770,000 acres (1 percent) of 1997 rangeland acreage in the Northern Plains were converted to cultivated crops by 2007; (2) a 5-year ban on crop insurance purchase for converted grassland could slow but is unlikely to stop grassland to cropland conversion; and (3) the benefits of crop insurance, disaster assistance, and marketing loans increased cropland acreage by about 2.9 percent between 1998 and 2007.

Keywords: Grassland, cropland, crop insurance, marketing loan benefits, disaster assistance, Northern Plains

Acknowledgments

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Summary

What Is the Issue?

Native grasslands in the Northern Plains, particularly those located in the Prairie Pothole Region (PPR), are used as breeding habitat by migratory birds. The PPR includes parts of Iowa, Minnesota, North Dakota, South Dakota, and Montana. Grasslands in the PPR account for about 50 percent of North American duck production. There is growing concern that the conversion of grassland to crop production is damaging this habitat. Once lost, native grasslands are difficult to re-establish.

Environmental organizations and others have argued that some Federal farm programs are encouraging grassland to cropland conversion. While many farm commodity programs are now decoupled from farmers' crop production decisions, several USDA programs continue to depend on current production, including crop insurance, marketing loans, and disaster assistance. Farmers can expand their eligibility to receive benefits from these programs by converting grassland to cropland.

To address these concerns, the Food, Conservation, and Energy Act of 2008 included the Sodsaver provision. If implemented, Sodsaver would deny crop insurance for the first 5 years of production on native sod (native grassland) converted to crop production. Sodsaver is limited to the Prairie Pothole States (Iowa, Minnesota, Montana, North Dakota, and South Dakota) and would be implemented on a State-by-State basis but only at the request of that State's governor. As of June 2011, none of the governors has requested Sodsaver implementation. The manager's statement accompanying the 2008 Farm Act also directed USDA to conduct a study of the role of farm programs in grassland to cropland conversion.

We focus on three questions: (1) How fast are grasslands being converted to cropland in the United States, especially in the Northern Plains? (2) Can a policy like Sodsaver, if implemented, significantly slow grassland to cropland conversion? (3) More broadly, what has been the role of crop insurance and other farm programs in grassland to cropland conversion?

While concern about grassland conversion is often focused on "native" grassland, available data do not identify grasslands as "native" or "non-native." Native grasslands are most likely to be categorized as part of rangeland. This study considers a wide range of grassland categories including rangeland, pasture, hay, and Conservation Reserve Program (CRP) lands with grass cover.

What Were the Study Findings?

During 1997-2007, grassland-cropland conversion varied by grassland type and region. Compared with other regions, producers in the Northern Plains were more likely to convert grassland to cropland or retain land in crops rather than returning it to grass. In the Northern Plains, about 1 percent of 1997 rangeland had been converted to crop production by 2007 (roughly 770,000 acres), while only 100,000 acres were converted from cropland to rangeland. The Northern Plains accounted for 57 percent of rangeland to cropland conversion between 1997 and 2007. In the United States, there was a net shift between 1997 and

2007 of roughly 10 million acres from cultivated cropland (about 3 percent of 1997 cropland) to hay or pasture. In the Northern Plains, the net shift of cropland to hay and pasture was effectively zero. The gross shift of roughly 3.5 million acres moving from cropland to hay or pasture was exactly offset by acreage moving from hay or pasture to cultivated crops. Through the CRP, however, producers in the Northern Plains moved some land from cultivated crops to grass. Between 1997 and 2007 they enrolled 3.6 million acres of cropland in the CRP, while 1.9 million acres were returned to crop production and 1.7 million acres previously in the CRP became hay, pasture, or range.

The Sodsaver provision of the 2008 Farm Act, if implemented, is likely to have only a modest effect on land use at the grassland-cropland margin. In seven North Dakota and South Dakota counties where evidence suggests that grassland to cropland conversion has been relatively high, Sodsaver would reduce expected crop revenue by up to 5 percent, reduce expected net return by up to 14 percent, and increase the variability of crop production (in terms of annual standard deviation of crop revenue) by up to 13 percent. Land use change depends on how responsive land allocation is to changes in crop revenue, net return, and variability. Using elasticities estimated for this study, we find that crop insurance could have been responsible for shifting up to 0.9 percent of rangeland to cropland in the seven counties we considered. This is an estimate of net change in equilibrium acreage and is not directly comparable to gross rangeland conversion. These counties are located in an area where an annual average rate of rangeland to cropland conversion of 0.6 percent of grassland acreage was observed between 1985 and 2003—indicating total conversion of about 6 percent over a period of 10 years. In comparison, the 0.9-percent change in estimated equilibrium acreage that would result from the withdrawal of crop insurance would be modest and indicates that crop insurance is only one of a number of factors (e.g., market conditions, technology, and other programs) that are driving land use choices.

In a study area that includes 77 North Dakota and South Dakota counties, we use an econometric model to estimate that crop insurance, marketing loans, and disaster payments increased land in cultivated crops by 686,000 acres (the average effect between 1998 and 2007)—roughly 2.9 percent of cultivated cropland acreage. (This is an estimate of the net change in equilibrium acreage. The estimated effect varies over time with economic and policy conditions. The 2.9-percent change is the average estimated effect between 1998 and 2007.) The largest overall effect was from disaster assistance (1.2 percent rise in cultivated cropland; 292,000 acres), followed by crop insurance (1 percent; 235,000 acres) and marketing loan benefits (0.7 percent; 161,000 acres). We estimate that roughly 60 percent of the increase in crop acreage came from hay or pasture (403,000 acres) while the remaining acreage came from range (181,000 acres) and CRP (102,000 acres). The estimated rangeland reduction of 181,000 acres was 1.1 percent of rangeland acreage in the 77 counties considered in this study. In the absence of these programs, farmers could adjust to larger grassland acreages by reducing the rate of grassland to cropland conversion, increasing cropland to grassland conversion, or both. The study period, 1998-2007, largely predates the recent rise in commodity prices, beginning with increased corn prices in 2007. Higher crop prices may be encouraging farmers to expand cropland acreage, prompting them to convert grassland to cropland or retain land in crop production that might have otherwise been returned to grass.

How Was the Study Conducted?

The study has three major components. First, we document trends in grassland to cropland changes using data from USDA's Natural Resources Conservation Service (NRCS) 2007 National Resources Inventory (NRI). A simulation analysis is used to gauge the potential of a Sodsaver-type program to reduce crop insurance indemnities and other payments to crops grown on converted grassland in seven counties, thereby reducing incentives for grassland conversion. Finally, an econometric (statistical) model is developed to help understand the role of farm program payments in the movement of land among cropland, hay and pasture, rangeland, and CRP in 77 counties from 1997 to 2007, while controlling for changes in market prices, crop yields, and other nonpolicy factors that may have also influenced land use decisions.

Introduction

Concern about the effect of Federal agricultural programs on grassland to cropland conversion has been growing over the past decade. Environmentalists, wildlife groups, and some livestock interests are concerned that commodity programs, crop insurance subsidies, and disaster payments are supporting crop production at the expense of grasslands, particularly native grasslands in the Prairie Pothole Region of the Northern Plains (USGAO, Morgan).

Recent concern has focused on federally subsidized crop insurance. Under the Agricultural Risk Protection Act of 2000, subsidy rates for crop insurance premiums were increased sharply to broaden participation and encourage farmers to purchase higher levels of coverage. By 2002, 80 percent of eligible acreage was enrolled (Dismukes and Vandeveer) and most producers paid less than half of the full premium.[1] Crop insurance participation has remained high. In 2009, more than 80 percent of corn, cotton, soybean, and wheat acreage was insured, while rice producers insured nearly 80 percent of acreage and sorghum producers insured nearly 70 percent of acreage (FAPRI).

[1]Farmers who insured at coverage levels of up to 75 percent (i.e., insured against losses that exceed 25 percent of expected revenue or yield) receive premium subsidies of more than 50 percent.

To address concerns about crop insurance and grassland conversion, the 2008 Farm Act included a Sodsaver provision that would, if implemented, deny crop insurance coverage for the first 5 years of crop production on land converted from native grass. Congress limited the program to the Prairie Pothole States of Iowa, South Dakota, North Dakota, Montana, and Minnesota and made program implementation contingent on a request from the governor of each State. As of May 2011, there have been no requests for Sodsaver implementation

A second area of concern is disaster assistance. Although premium subsidy increases and other changes to the crop insurance program were the latest in a series of revisions designed to eliminate the need for ad hoc disaster assistance, Congress has continued to provide regular disaster assistance. Disaster payments were made in every year between 1985 and 2007, totaling $30 billion over those 22 years (Goodwin and Rejesus). Typically, disaster payments have compensated farmers who experience losses of 35 percent or more in any given season.[2] The 2008 Farm Act created the Supplemental Revenue Assistance (SURE) program. The SURE program is a permanent disaster program that functions essentially as a premium-free addition to crop insurance coverage, providing additional assistance to insured farmers in counties where disasters have been declared or to individual farmers who experience losses of more than 50 percent of expected crop revenue in any given year.[3]

[2]Loss thresholds of 35 percent have been typical. For each year between 2001 and 2007 (inclusive), producers were required to document production losses of 35 percent or more to be eligible for disaster assistance. For examples, see http://www.fsa.usda.gov/FSA/newsReleases?area=newsroom&subject=landing&topic=pfs&newstype=prfactsheet&type=detail&item=pf_20080125_distr_en_cdpqty08.html/.

[3]We use the term "revenue" to refer to gross revenue before production costs are considered. We use the term "net return" to refer to revenue less production costs.

Concerns have also been raised about marketing loan benefits. These payments protect producers of subsidized crops (e.g., corn, wheat, and soybeans) from low prices by making up the difference when market prices fall below the commodity loan rate. Assuming that farmers expected commodity prices to sometimes drop below loan rates, these payments may influence producer expectations about the mean and variance of crop revenue. Over time, these payments can increase the average return to program crop production and reduce the variability of returns to crop production.

Are Federal farm programs contributing to the demise of native grasslands? If so, would changes in Federal programs significantly affect the movement of land at the margin between grassland and cultivated cropland? Previous studies of the effect of crop insurance on land use (e.g., Goodwin, Vandeveer, and Deal; Lubowski et al., 2006) have concluded that the overall effect of crop insurance is small. Depending on the study, subsidized crop insurance may have increased land in crop production by 1 million to 3 million acres nationally (0.2 to 1.1 percent of cultivated cropland acreage). More broadly, Lubowski, Plantinga, and Stavins found that farm programs increased overall cropland acreage by about 2 percent while Gardner, Hardie, and Parks estimated that farm programs caused a 22-percent increase in cropland acreage.

Despite previous research on this topic, additional research is needed because previous studies use data from 1997 or earlier, largely predating some major policy changes. The Federal Agriculture Improvement and Reform (FAIR) Act of 1996 (the 1996 Farm Act) mandated marketing loan benefits for wheat, feed grains, and oilseeds; the Agricultural Risk Protection Act (ARPA) of 2000 sharply increased crop insurance premium subsidies; and the new, permanent disaster assistance program (SURE) was created in the 2008 Farm Act. Growth in ethanol production and other demand factors have also led to increased commodity prices since 2007.

For a more up-to-date examination of these programs, we pursued three areas of inquiry. First, what are the historical and more recent trends in grassland to cropland conversions? How does grassland to cropland conversion compare to other land use changes affecting grassland? In the past, the margin between cropland and grassland has been active. Between 1982 and 1997, more than 33 million acres of land moved between, into, or out of cultivated crops along the cropland-pasture and cropland-rangeland margins while another 30 million acres of cropland were enrolled in the CRP (Lubowski et al., 2006). The most recent NRI data provide information on land use and land use change for 1997-2007, allowing estimation of both gross and net movement of land between grassland and other uses, especially cultivated crop production (USDA-NRCS, 2009).

Second, how have farm programs affected crop revenue, and what impact has that result had on grassland to cropland conversion? Farmers face constant changes in markets, technology, and policy that are likely to affect land use and overall agricultural production. Greater demand for corn due to rapid expansion of ethanol production, for example, may be encouraging farmers to expand crop production into grasslands. Genetically modified varieties of corn and soybeans that produce higher yields and are less susceptible to drought also may be playing a role in the expansion of cropland acreage in the Northern Plains. To sort out these effects, we develop an econometric (statistical) model of land use, based on NRI data for 1998-2007, that incorporates the expected mean and variance of market and policy returns and underlying land quality including soil productivity, erodibility, propensity for flooding or wetness, and the availability of irrigation. Using the model, we estimate the number of acres that are likely to have been in crop production between 1998 and 2007 largely because of farm program benefits.

Finally, we estimate the potential effect of Sodsaver in reducing the role of farm programs in grassland to cropland conversion. Because Sodsaver has not been implemented, we develop a simulation model using 2008 as a base year for the development of a series of representative farms. Because crop insurance and other farm programs protect producers against low revenue, we develop a model of farm revenue that accounts for variability in prices and yields. The joint distribution of crop yields and prices, along with actuarial parameters obtained from USDA's Risk Management Agency (RMA), are used to estimate producer returns from crop insurance purchases, including SURE payments on recently converted land. Using elasticities drawn from the literature and from our econometric model, we estimate the potential effect of Sodsaver on land use.

Grassland and Grassland-Cropland Conversion, 1997-2007

Grasslands have been defined by land cover and by land use (Sanderson, Wedin, and Tracy). Grasses are the dominant vegetation, but grasslands also include legumes, forbs, and, depending on the climate in a specific location, may be dotted with trees. (A forb is an herb or nonwoody flowering plant that is not a grass.) In terms of land use, grasslands are also defined by grazing, haying, and other forms of forage harvest. By these definitions, grassland encompasses a wide variety of grassland types from minimally managed natural or native grasslands to grassland that is extensively managed for forage production to feed livestock. While concern about grassland conversion is often focused on native grassland, we consider the full range of grassland types: hay, pasture, rangeland, and CRP lands that are in grass cover.

The market value of grassland is derived largely from forage production. In terms of forage value, pasture and rangeland are grazing lands and can be close substitutes. Hay is also a key source of livestock forage. These grassland types are often distinguished by the mix of grass and other plant species present and by the level of management they receive in agricultural use. Rangeland, for example, may include many grasses, forbs, and other plants while pasture and hay land are more likely to include a single domestic species or a small number of domestic species. Rangeland is less likely than pasture or hay land to be fertilized or periodically re-seeded. Some rangeland has never been cultivated, while hay and pasture land are likely to have been used for cultivated crops at some time in the past. Although hay (particularly

Grassland Types

Hayland. Land managed for the production of forage crops that are machine harvested. The crop may be grasses, legumes, or a combination of both.

Pastureland. Land managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the National Resources Inventory, pastureland includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

Rangeland. Land on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs, or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland.

Source: USDA, Natural Resources Conservation Service, NRI glossary.

alfalfa) is often grown in rotation with cultivated crops, hay and pasture are often grown on land of similar productivity and may involve a mix of grasses and legumes. In some cases, the difference between hay and pasture is the method of harvest—some grassland may be used for pasture in some years and for hay in others.

By virtue of land cover, a large share of land in the CRP can also be considered grassland. More than 20 million of the 31.2 million acres enrolled in the CRP (as of May 2010) are in grass cover, not counting grassed waterways, field-edge filter strips, and other grass-based conservation practices (USDA-FSA). Although CRP land is sometimes referred to as "retired," CRP grassland can be used for hay or grazing in certain circumstances (e.g., severe drought) and can generate recreational and ecological value (Feather, Hellerstein, and Hansen).

Grasslands can provide a range of ecological services under light or moderate grazing (Conner et al.). Grasslands in the Northern Plains are a highly productive breeding habitat for ducks. Grasslands habitats produce about 50 percent of U.S. ducks while accounting for only 10 percent of breeding territory (USDOC-NOAA and others). Ducks are particularly drawn to small wetlands surrounded by grasslands—a key feature of the Prairie Pothole Region of the Northern Plains. Fragmentation of grasslands, overgrazing, and the spread of invasive species are damaging the quality of habitat for duck and other species of grassland animals (Conner et al.) When compared to cultivated cropland, grasslands store substantial amounts of carbon (Eve et al.) and tend to produce runoff that is relatively free of sediment, nutrients, and pesticides.

By any definition, grassland covers a large part of the United States. In 2007, rangeland, pasture, hay, and CRP lands accounted for 606 million acres in the contiguous 48 States, 63 percent of the 900 million acres of U.S. agricultural land and more than 25 percent of the 1.9 billion acres that make up the conterminous United States (USDA-NRCS, 2009). Roughly 67 percent of grassland, 408 million acres, is classified as rangeland. Pasture and hay together account for 27 percent of grassland (160 million acres), while 5 percent of grassland is in the CRP.

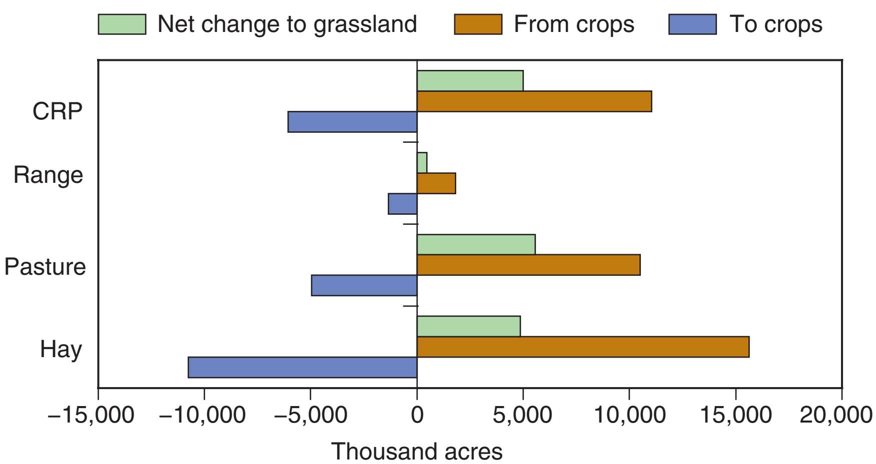
Grasslands once covered a larger share of U.S. land area. Between 1850 and 1950, an estimated 260 million acres of grassland were converted to other uses, mostly cropland (Conner et al.). Between 1950 and 1990, grassland area declined by another 27.2 million acres. Of the post-1950 loss, 36 percent was converted to nonagricultural use. Only about 4 percent of tall-grass prairie, which once covered large portions of Illinois, Iowa, Missouri, Western Minnesota, and Eastern Oklahoma and Texas, remains today (USDOI, USGS). On the Eastern edge of the prairie (e.g., northern Illinois, Southern Iowa, northern Missouri, and parts of Kansas, Oklahoma, and Texas), the broad savannas and tall grasses that once existed have been replaced almost entirely by cultivated crop production. Of the mixed-grass and short-grass prairie that once blanketed the High Plains (roughly the area west of the 100th meridian and east of the Rocky Mountains), remaining grassland ranges from 20-80 percent depending on the State.

The Grassland-Cropland Margin

Land that moves between grassland and cultivated cropland is, by definition, at the margin between these uses. Activity along the margin between cultivated cropland and grassland varies regionally and by grassland type. Initially, we consider the margin between cultivated cropland and four types of grassland: range, pasture, hay, and CRP.

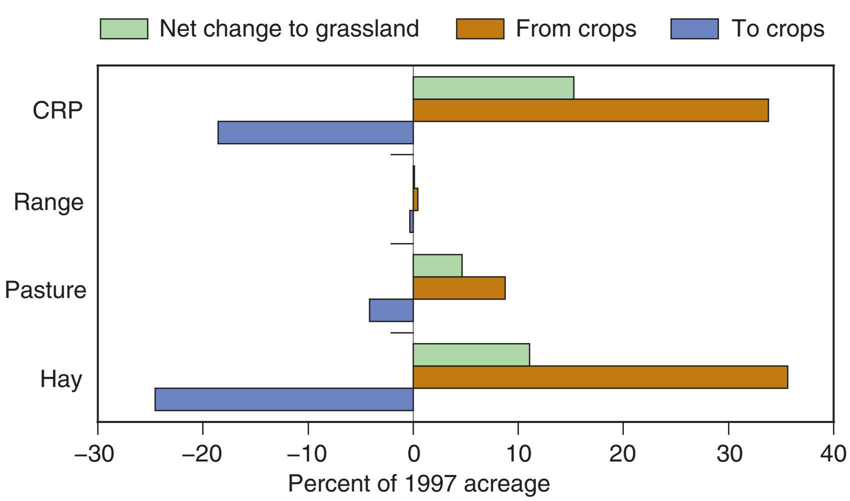
Nationally, the most active grassland-cultivated cropland margin between 1997 and 2007 was for hay (fig. 1). More than 26 million acres moved between cultivated crops and hay, resulting in a net shift of 4.8 million acres from cultivated crops to hay. More than 15 million acres moved between cultivated cropland and pasture, resulting in an overall shift of 5.5 million acres from cultivated crops to pasture. In contrast, the margin between crop-

Figure 1a
U.S. grassland-cropland conversion, 1997-2007



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

Figure 1b
U.S. grassland-cropland conversion, as a percentage of 1997 land use



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

land and rangeland involved less than 3.1 million acres. Roughly 1.3 million acres of range (0.33 percent of 1997 range) were converted to cultivated cropland, while 1.8 million acres went the other way for a net conversion from cultivated crops to range of about 500,000 acres (0.11 percent of 1997 rangeland).[5]

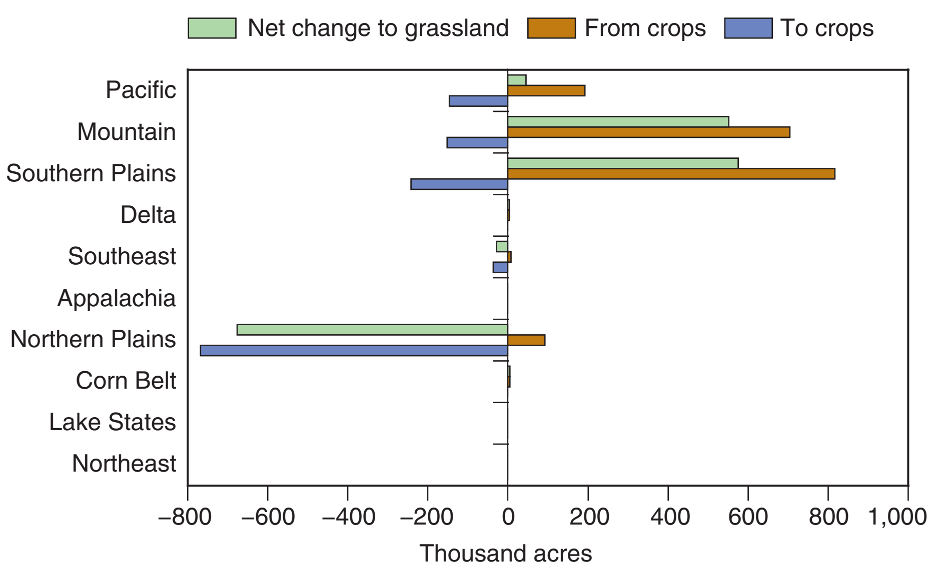
The CRP appeared to serve as a transitional land use between cultivated crop and forage production (see figure 1). Total CRP enrollment was roughly 32 million acres in both 1997 and 2007. During this period, however, 11.1 million acres of cultivated cropland were enrolled in the CRP for the first time while only 6.1 million acres were returned to cultivated crops. Most of the other 5 million acres leaving the CRP were used for hay or grazing in 2007.

In sum, U.S. farmers and landowners shifted a net total of 16.5 million acres of cultivated cropland to pasture, hay, range, or CRP between 1997 and 2007. The net shift included gross conversion of 23.7 million acres of grassland to cropland and 39.0 million acres of cropland to grassland. Cultivated cropland in the United States declined by more than 21 million acres (6.6 percent) while hay, pasture, and rangeland, combined, grew by just under 3 million acres (0.5 percent).

Activity along the grassland-cropland margin is not evenly distributed across the United States. In the Northern Plains region (Kansas, Nebraska, North Dakota, and South Dakota), the movement of land between grassland and cropland favored cultivated crops when compared with other regions. The Northern Plains States accounted for 57 percent of U.S. rangeland to cropland conversion between 1997 and 2007, an estimated total of more than 770,000 acres (fig. 2) and roughly 1.1 percent of 1997 rangeland acreage. While some land was converted from cultivated crops to range, net conversion of range to cropland was more than 680,000 acres—roughly 0.8 percent

[5] Not statistically different from zero.

Figure 2
Rangeland-cropland conversion, 1997-2007, by USDA Farm Production Region



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

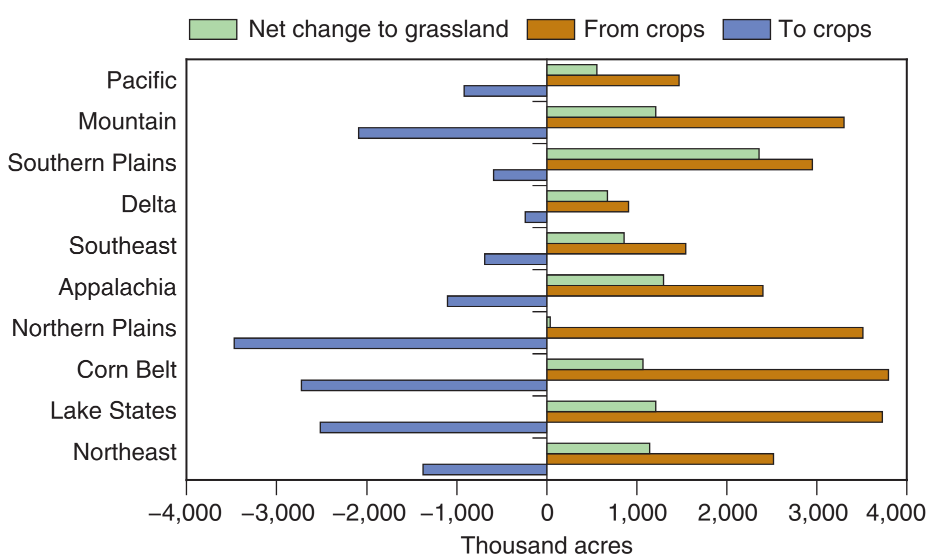
of 1997 range acres. During the same period, other Western regions, including the Mountain and Southern Plains States, were experiencing a net shift of land from cropland to range.

Unlike the rest of the country, the land use decisions of Northern Plains' farmers and ranchers produced no net movement of land from cultivated crops to hay and pasture (fig. 3). While 3.5 million acres (27 percent) of hay and pasture land was converted to cultivated crop production, these changes were roughly offset by conversion of cultivated cropland to hay and pasture. During the same period, the land use decisions of farmers and landowners in every other U.S. region created a net shift of land from cultivated crops to hay and pasture.

Through changes in CRP enrollment, however, farmers and ranchers in the Northern Plains shifted a net total of 1.8 million acres from cultivated crops to grass between 1997 and 2007 (fig. 4). Here, the Northern Plains largely reflects the national trend. A total of 3.6 million acres of cultivated cropland was enrolled in CRP for the first time, while 1.9 million acres of CRP land were returned to crop production after contracts expired. The balance of land leaving the CRP—just under 1.7 million acres—was in hay, pasture, or range in 2007.

For context, we compare grassland-cropland conversion for 1987-1997 and 1997-2007. During the earlier period, Northern Plains producers converted more than 1.1 million acres of rangeland to cropland (fig. 5a) compared with 770,000 acres during 1997-2007 (fig. 5b). Considering hay and pasture land combined, there was a substantial net movement from cropland to grassland during 1987-1997 (see figure 5a) but almost no net conversion either way during 1997-2007 (see figure 5b). So, considering all three types of forage

Figure 3
Hay and pasture-cropland conversion, 1997-2007, by USDA Farm Production Region



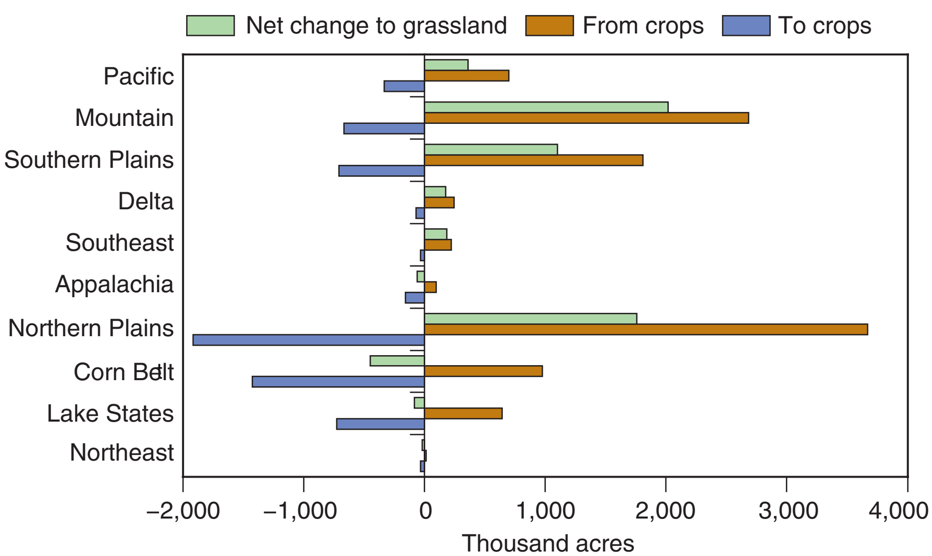
Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

(range, pasture, and hay), there was essentially no net movement of land between grass and crops during 1987-1997, while there was a modest shift toward crops (roughly 640,000 acres) during 1997-2007. When CRP land is also considered, there was a net shift from cropland to grassland during both periods. Because CRP enrollment was large during 1987-1997—more than 6 million acres—the net shift from crops to grass (including CRP) was much larger during 1987-1997 (about 6.2 million acres) than during 1997-2007 (roughly 1.1 million acres).

While our study is focused on grassland-cropland conversions, grasslands also are being lost to nonagricultural uses. On a national level, while there was a net movement from cropland to grass for each of our major grassland categories (range, pasture, hay, and CRP), there was also a net conversion from grassland to nonagricultural use for every grassland category (fig. 6a). Nonagricultural uses include forest, roads, and development for housing or commercial purposes. In the Northern Plains, on the other hand, the grassland-cropland margin is still primary. For example, net conversion of range and hay to cropland is much larger than conversion to nonagricultural uses for the grassland categories (fig. 6b). For all three forage categories combined, grassland loss to crop production was larger than grassland loss to nonagricultural uses.

While the Northern Plains differs from the overall United States in terms of land use and land use change, there is also a great deal of diversity in growing conditions, crop mix, and land use within the Northern Plains. To investigate this diversity, we look more closely at land use and cropping patterns for portions of Land Resource Regions (LRR) M, F, and G located within the Northern Plains (figs. 7a and 7b). LRRs are areas of relatively uniform climate and soil conditions (USDA-NRCS, 2006). The intersection of the Northern Plains with LRR F, G, and M covers all of North and South Dakota

Figure 4
Conservation Reserve Program-cropland conversion, 1997-2007, by USDA Farm Production Region

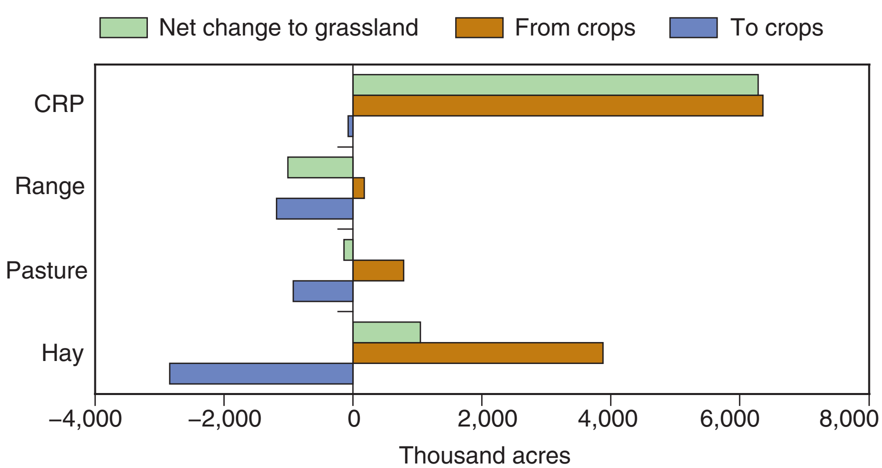


Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

and much of Nebraska. These areas are selected for further scrutiny because they include a large portion of the Prairie Pothole Region where concern about grassland to cropland conversion has been greatest.

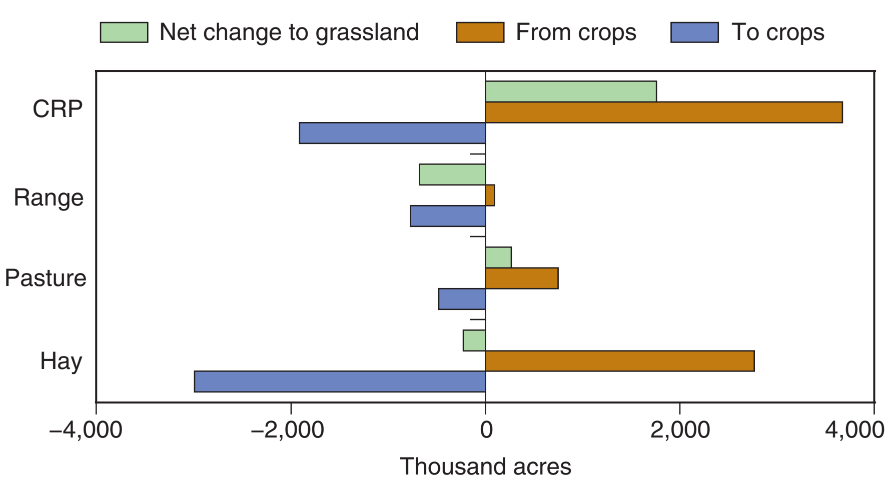
We refer to LRR M as the Western Corn Belt because a high proportion of land is cropped (70 percent; see figure 7b) and corn and soybeans are the predominant crops, accounting for roughly 90 percent of all cultivated acres. LRR F, which we refer to as a "transitional" region, covers large portions of central and Northwestern South Dakota and all of North Dakota. About 70 percent of LRR F agricultural land is cropped (see figure 7b). Although wheat still covers a majority of cultivated crop acres, corn and soybean production doubled between 1997 and 2007 (from 20 percent to 40 percent of crop acreage). Finally, land in LRR G, which we refer to as a rangeland region, is largely devoted to livestock grazing; rangeland accounts for about

Figure 5a
Grassland-cropland conversion in the Northern Plains, 1987-1997



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

Figure 5b
Grassland-cropland conversion in the Northern Plains, 1997-2007



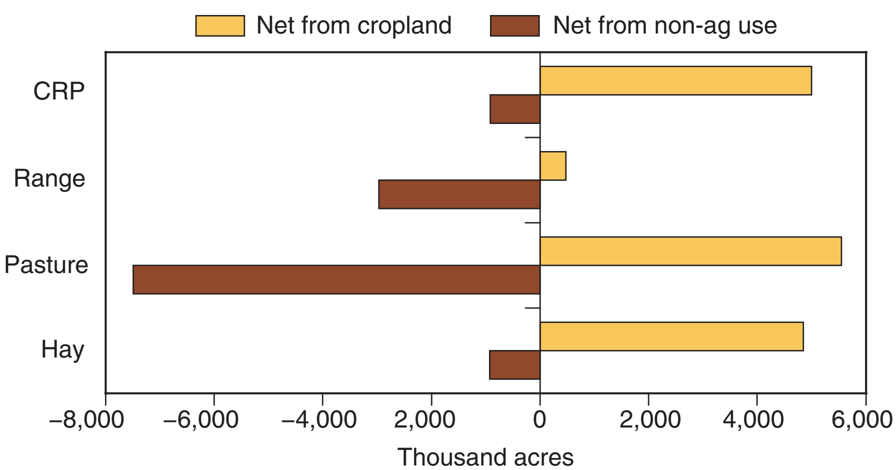
Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

80 percent of agricultural land. Cropland is largely devoted to wheat but irrigated corn is grown where water is available.

Overall, land use change in the portion of the Northern Plains defined by these three LRRs is similar to that observed over the entire region. Estimated rangeland to cropland conversion during 1997-2007 was roughly 370,000 acres, roughly 0.9 percent of 1997 rangeland acreage (fig. 8). Net rangeland conversion was roughly 0.7 percent. While gross conversion of hay and pasture in LRR F, G, and M, was large in both directions, net conversion of hay and pasture to cropland was 350,000 acres, about 5 percent of 1997 hay and pasture acreage, as compared with zero net conversion observed for the

Figure 6a

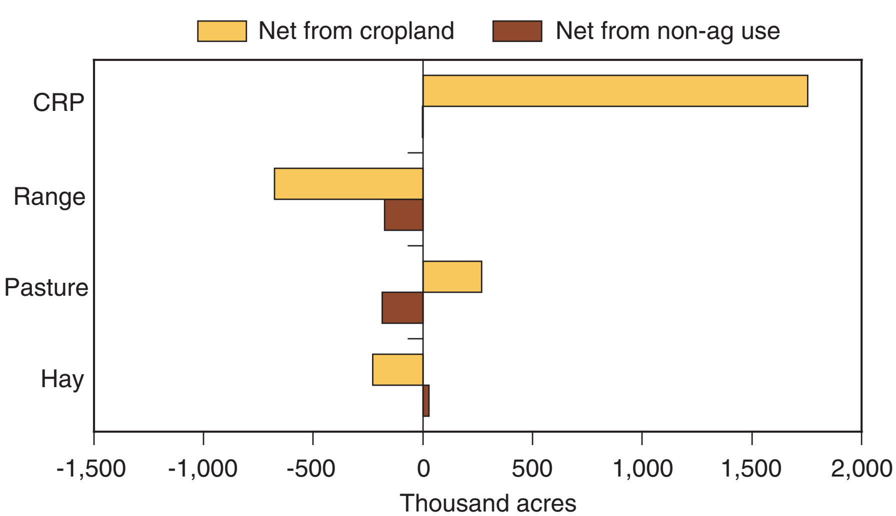
Net grassland change vs. cropland and nonagricultural land uses in the United States, 1997-2007



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

Figure 6b

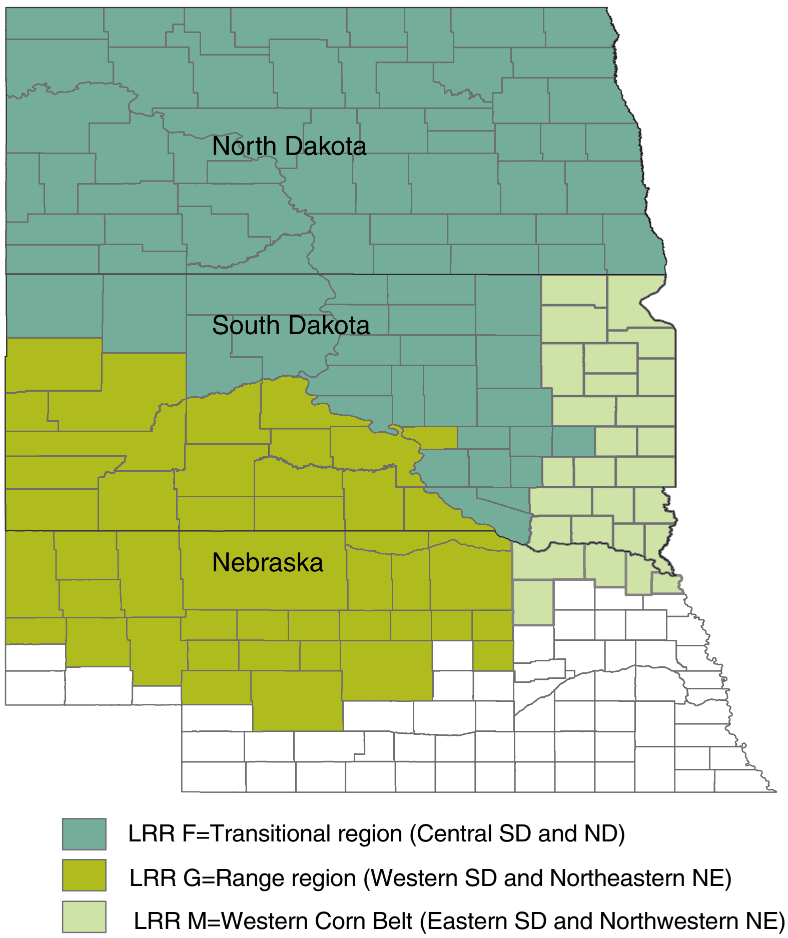
Net grassland change vs. cropland and nonagricultural land uses, in the Northern Plains, 1997-2007



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

Figure 7a

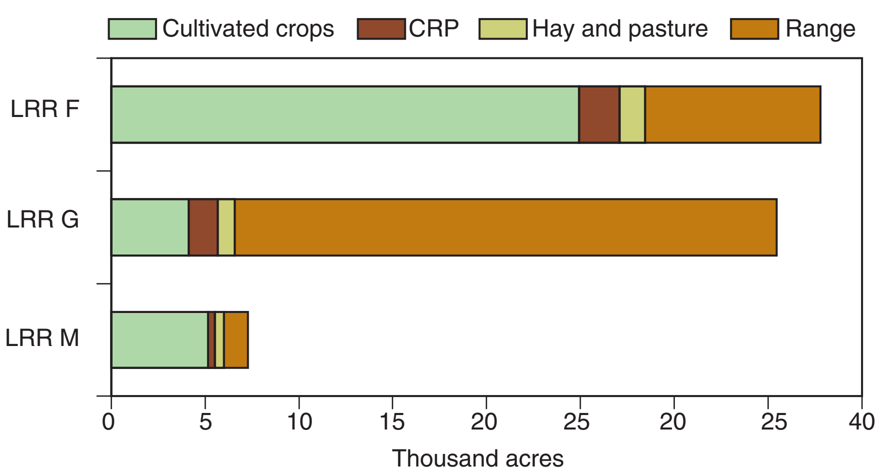
Land Resource Regions (LRR) in the Northern Plains



Note: Boundaries shown are approximate.
Source: USDA, Economic Research Service, based on USDA, Natural Resources Conservation Service, 2006.

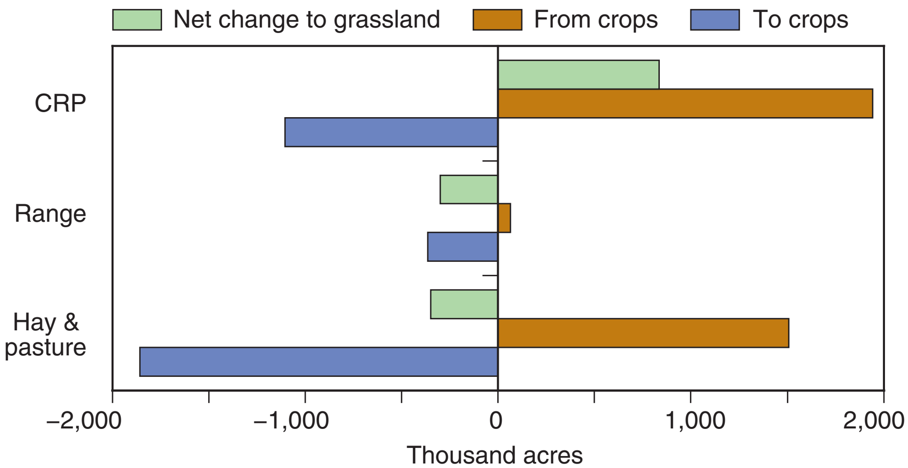
Figure 7b

Land use in the Northern Plains, by Land Resource Region



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

Figure 8
Grassland-cropland conversion for the Northern Plains, LRR F, G, and M, 1997-2007



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory, 2007.

entire Northern Plains region. Overall gross conversion of range, hay, and pasture to cropland in this area was 2.22 million acres for 1997-2007, about 4.4 percent of 1997 range, hay, and pasture acreage. Net conversion of these grasslands to cropland was about 650,000 acres, or 1.4 percent. While a great deal of land moved between cultivated crops and enrollment in the CRP, enrollment decisions resulted in a net shift of more than 800,000 acres from cultivated crops to CRP. Overall, land use change resulted in a small net shift of cultivated cropland to grassland (range, pasture, hay, and CRP).

Although the NRI sample is not dense enough to make reliable estimates in smaller areas (e.g., counties), other studies suggest that grassland to cropland conversion was concentrated in smaller areas. In a study of grassland to cropland conversion for 1985-2003, Stephens et al. use satellite imagery with ground truth data[6] to document annual grassland conversion rates ranging from 0 to 1.5 percent in three areas of the Missouri Coteau[7] region of North and South Dakota. Average annual grassland loss across the three study areas was 0.4 percent per year. Grassland loss averaged 0.6 percent in the Hyde-Hand area of South Dakota, a region that includes all of Hyde, Hand, and Faulk counties in East-Central South Dakota and parts of surrounding counties, including Sully and Edmunds.

Grassland to Cropland Conversion More Likely in Northern Plains

Available data suggest that grassland to cropland conversion was much more likely in the Northern Plains than in other regions. The entire Northern Plains region (Kansas, Nebraska, South Dakota, and North Dakota) accounted for 57 percent of gross rangeland to cropland conversion between 1997 and 2007. The portion of the Northern Plains located in LRRs F, G, and M, which includes a large share of the Prairie Pothole Region, accounted for 27 percent of rangeland to cropland conversion. While other regions have, on average, shifted land from cultivated crops to hay and pasture, Northern Plains

[6]Satellite imagery was from the Land-Sat V and VII satellites. Field visits were made to verify the correctness of interpretations.

[7]The Missouri Coteau is a narrow band of land running from South-Central South Dakota through central and Northwestern North Dakota and into Saskatchewan, Canada. The three study areas considered are relatively small, each encompassing all or part of 5 to 10 counties

producers have not. In the sub-region defined by LRRs F, G, and M, there was a net movement of land from hay and pasture to cultivated crops.

There is some evidence to suggest that grassland to cropland conversions were more likely in the areas that form the transition from the Corn Belt to the High Plains. In the Hyde-Hand region studied by Stephens et al., observed average annual native grassland conversion of 0.6 percent was much higher than the regionwide average of roughly 0.1 percent indicated by the NRI. The Hyde-Hand area is also part of LRR F, where farmers have been shifting from wheat to corn and soybeans. In the next chapter, "Land Use and Land Use Change: Conceptual Issues," we investigate possible land use drivers and contrast conditions and trends found in LRR F (the transitional region) with those of LRR M (the Western Corn Belt) and LRR G (the rangeland region).

Land Use and Land Use Change: Conceptual Issues

Private land is generally allocated to the use that maximizes landowner value. Land can be valued for many reasons. The market value of land is derived from the direct or onsite benefits of land ownership. These include any benefits that can be captured directly by landowners or through market transactions, including the value of agricultural production, recreational activities such as hunting or fishing (through fees, for example), and residential or commercial development. Offsite or indirect benefits (or damages) are realized only downwind or downstream. These are often referred to as "nonmarket" benefits (or costs) because their value or cost is generally not captured (paid) by the landowner through market transactions.[8] For example, water quality damage due to nutrient runoff from crop or livestock production does not necessarily affect the landowners applying nutrients, who may not even be aware of the damage.

[8]There are rare exceptions. One example is payment made by New York City to Hudson River Valley farmers for the adoption of best management practices for water quality. Reducing upstream pollution was designed to reduced water treatment costs.

The realized mix of benefits (and costs) depends largely on how land is used.[9] In the U.S. Northern Plains, a large majority of land is used for agricultural production. Both grassland (used for grazing or hay) and cropland provide economic returns that can be captured directly by landowners. Which of these broad land use categories is more profitable for the landowner depends on the underlying quality of the land, market prices for production inputs and outputs, and policy incentives. Grasslands often provide a higher level of offsite benefit (or lower level of offsite costs). When compared to cultivated land, grasslands typically (1) offer better wildlife habitat, (2) are less susceptible to soil erosion and sediment runoff, and (3) receive lower levels of fertilizer application, which often translates into less nutrient runoff to water. Some landowners may value nonmarket benefits even if they cannot be compensated monetarily for them. Nonetheless, private land allocation decisions will not necessarily reflect these benefits and, therefore, may not reflect an optimal allocation of land between crops and grass from the perspective of the broader society (Lubowski et al., 2006).

[9]The mix of benefits and damages may also depend on the spatial arrangement of land uses. For example, the value of grassland as wildlife habitat may be reduced if grasslands become fragmented because of grassland to cropland conversion.

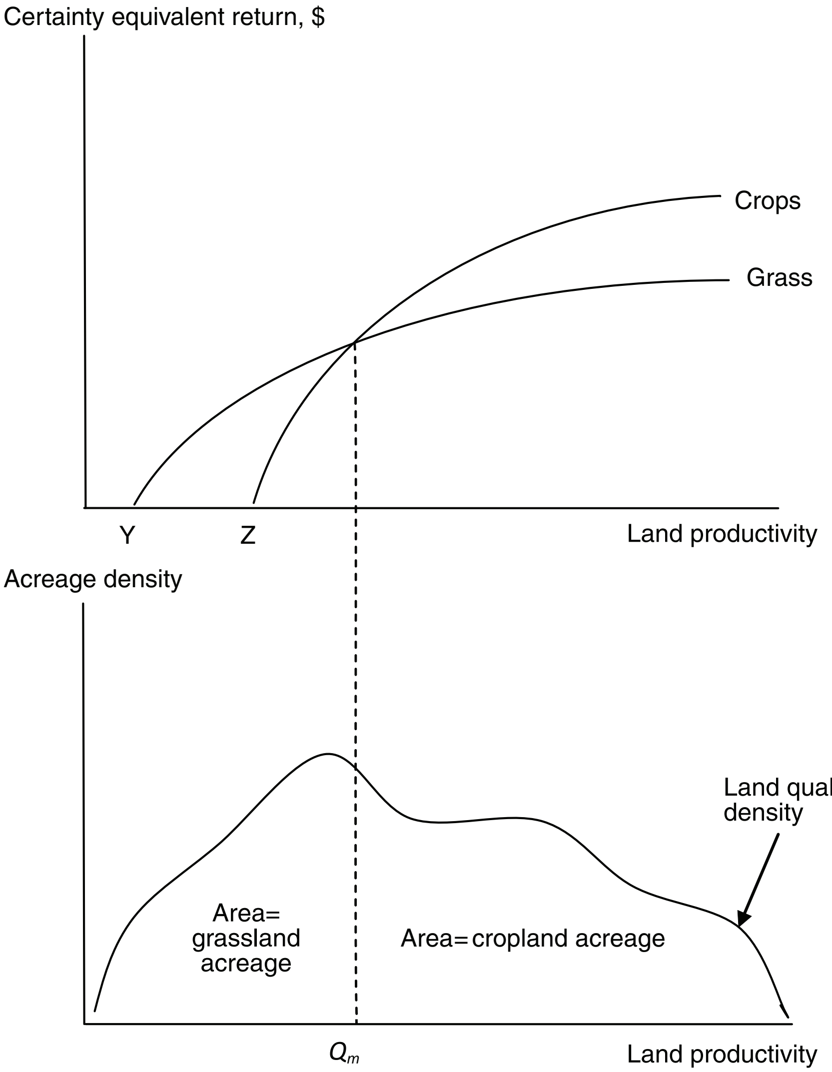
Federal agricultural policies can affect the mix of benefits (and costs) by affecting the mix of grassland and cropland used in agricultural production. The CRP compensates farmers for converting cropland to grassland or trees and making only limited use of the land for a period of 10 years or more. The CRP is designed, in part, to increase wildlife habitat and reduce water quality damage due to nutrient runoff and sediment. Other Federal agricultural programs support crop farmers. While the payments associated with many of these programs have been "decoupled" from production—that is, current production decisions cannot affect current or future payments—some payments continue to depend on current production. Over time, programs designed to protect farmers from low prices or low yields can increase the expected return and decrease the variability of returns to crop production. If payments are available for crops grown on converted grassland, they may encourage grassland to cropland conversion and work at cross purposes with agri-environmental programs, including the CRP.

A Model of Land Use and Land Quality

Land quality is a key determinant of land use. Many previous studies have used a range of land-quality indicators in explaining land use. Indicators have included land capability classification (Lubowski, Plantinga, and Stavins; Lubowski et al., 2006; Plantinga), potential crop yields (Claassen and Tegene; Wu and Adams), soil water-holding capacity (Lichtenberg), land topography including slope and elevation (Nelson and Hellerstein; Turner, Wear, and Flamm; Muller and Zeller), and flooding potential (Chomitz and Grey). Most land-quality indicators (or sets of indicators) used to represent the quality of land for agricultural use attempt to capture the suitability of the soil as a medium for plant growth, suitability of the climate for crop production, and suitability of the topography for cultivation.

In general, high-quality or high-productivity land is more likely to be in cultivated crop production than is medium- or low-productivity land. The top half of figure 9 shows a hypothetical, but plausible, relationship between land

Figure 9
Conceptual model of land use and land quality



Source: USDA, Economic Research Service.

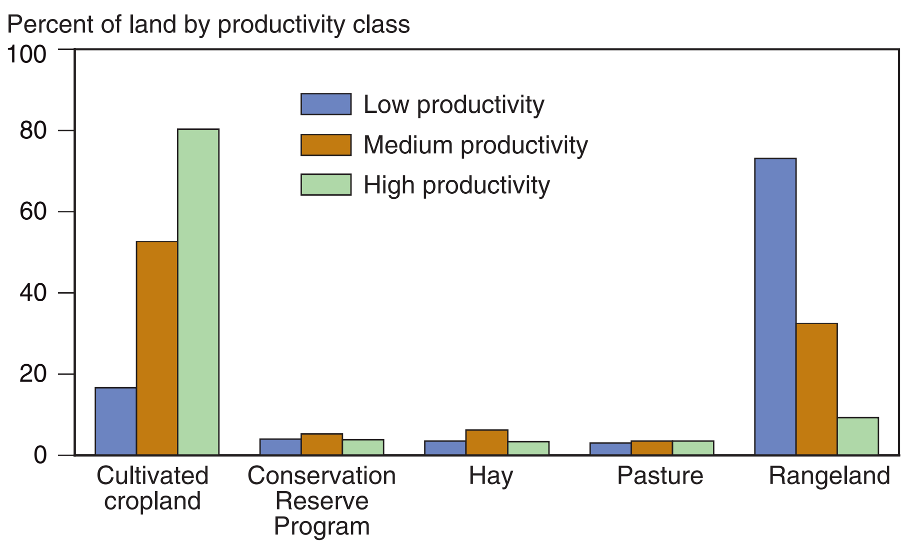
quality and returns to grass (hay or grazing) and crop production, given that prices, technology, and policy are fixed and producers are uniform in their degree of risk aversion and their overall assessment of returns to various land uses. The concave shape of the curves is based on the assumption that plant genetic capacity will increasingly become the limiting factor to production (yields) as productivity rises, and is consistent with Lichtenberg's empirical findings (Lichtenberg). Grass for grazing or hay is best able to utilize low-productivity land and reaches its full potential at a relatively low level of productivity. Cultivated crops, on the other hand, are better able to take advantage of high-productivity land. In the situation depicted in figure 9, land with productivity greater than Q_m will be used for cultivated crop production, while land with productivity less than Q_m will be used for grazing or hay.

The amount of land devoted to cultivated crops and grass depends on the productivity distribution of land. A hypothetical density function for land quality is shown in the bottom half of figure 9. The area under the density function and to the right of Q_m represents the amount of land that would be used in crop production while the area under the density curve to the left of Q_m represents the area devoted to hay and grazing. When the level of return to either land use changes, represented by a shift on one or the other curve in the top half of figure 9, it is land with productivity characteristics that place it near on the productivity scale that is most likely to change use. We refer to this medium-quality land as "economically marginal" land.

Empirical evidence generally supports this model. While we do not observe a sharp, land quality-defined land use margin, available data suggest that medium-quality land is more likely to be at the economic margin between cultivated crops and grass when compared to high- or low-quality land. Figure 10 shows the distribution of land productivity by land use in LRRs F, G, and M in the Northern Plains.[10] Most high-productivity land is used for

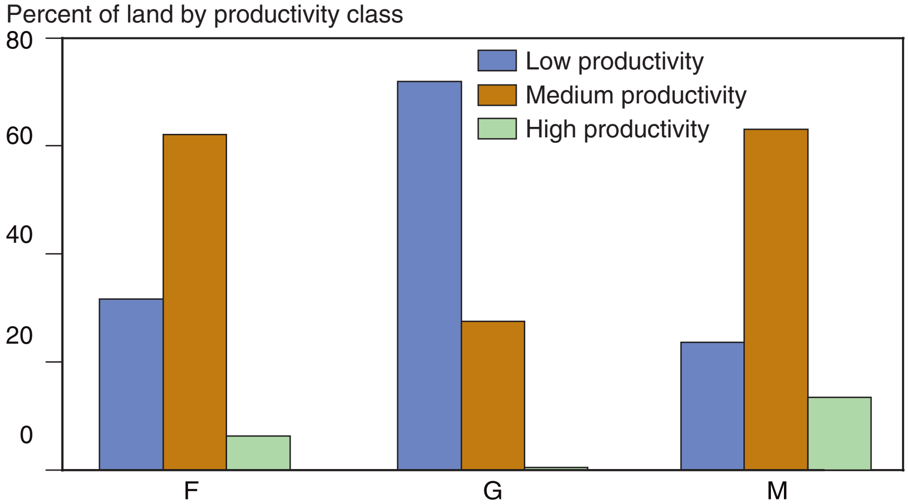
[10]This is based on the 1997 National Resources Inventory (NRI), linked to the National Commodity Crop Productivity Indicator (NCCPI; Dobos, Sinclair, and Hipple, 2008) to describe the joint distribution of land use and land productivity. NCCPI captures the effect of both climate and soil properties on plant growth.

Figure 10
Distribution of land by productivity class and use, LRR F, G, and M, Northern Plains



See figure 7a for map of LRR F, LRR G, and LRR M.
LRR F=Transitional region; LRR G=Range region; LRR M=Western Corn Belt.
Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory data, 1997.

Figure 11
Distribution of grassland by productivity class, LRR F, G, and M, Northern Plains



See figure 7a for map of LRR F, LRR G, and LRR M.
LRR F=Transitional region; LRR G=Range region; LRR M=Western Corn Belt.
Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service, National Resources Inventory data, 1997.

cultivated crop production (80 percent) while most low-productivity land is rangeland, used primarily for grazing (73 percent). Medium-productivity land is spread across all land uses including cultivated crop production (52 percent), forage production (hay, pasture, and range; 42.5 percent), and CRP (5.5 percent). In aggregate, we observe medium-quality land devoted to a wide range of uses because individual landowners differ in their risk aversion and overall judgments about the best or most valuable use of land. Nonetheless, the amount of medium-quality grassland available for conversion to cropland may be an important determinant of potential conversion.

The amount of medium-quality grazing land varies widely across LRRs within the Northern Plains (fig. 11). More than 60 percent of grassland (hay, pasture, and range) located in LRR F and M has medium productivity while less than 30 percent of grassland in LRR G has medium productivity. Potential for conversion in LRR M is limited because grassland accounts for only a small portion of overall land (see figure 7b). Conversion potential in LRR G may be large because it encompasses a huge area of grassland, even though 70 percent of it has low productivity, which is generally not suited to crop production. Finally, LRR F has a large area of grassland and a large share of that area has medium productivity, representing high potential for conversion to crop production.

Market Returns, Policy, Technology, and Land Use

Given the availability of grassland with land quality characteristics that place it on the margin with cultivated cropland, changes in the relative profitability of cropland and grassland may prompt producers to convert land from one use to the other. In terms of figure 9, an increase in crop returns would shift the crop curve up and shift the margin between cropland and grassland to the left, into lower quality land. The magnitude of the land use change would depend on the size of the change in crop returns and the amount of land with productivity between the old margin and the new margin.

Market returns are the most important source of value for agricultural lands. Higher demand for corn due to increased ethanol production and other factors led to a large increase in corn prices, beginning in 2007. Other crop prices increased as farmers shifted land to corn from other crops. Higher prices also may be prompting farmers to expand cropland into grassland or other land not previously used for crop production. Farm commodity payments, crop insurance, and disaster assistance payments complement market returns by protecting farmers from unexpectedly low yields or an abrupt drop in crop prices while allowing them to benefit during periods with high prices or high yields. Over time, these payments will increase average returns of program crop production and reduce the variability of those returns. New technologies that increase crop yields or lower production costs also can increase the net return to crop production relative to other land uses.

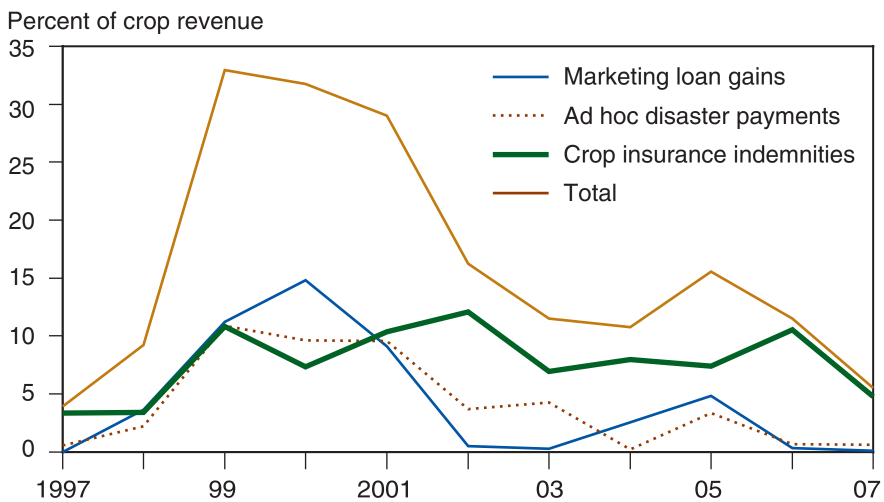
We focus on marketing loans, crop insurance, and disaster assistance because these payments depend on current production.[11] Farmers can increase the number of acres eligible for these programs by converting land from grass to cultivated crops. Marketing loans protect producers against low prices. When the market price of a covered commodity (e.g., corn, wheat, soybeans, and cotton) drops below a fixed "loan rate," the Federal Government pays producers for the difference between the loan rate and the market price. Crop insurance can protect farmers against crop yield or crop revenue loss due to unfavorable weather, pests, adverse price movements, etc. Because the premiums are subsidized, producers may realize a net gain to their crop insurance purchase over time. As already noted, disaster assistance payments have been made on an ad hoc basis but have been substantial in recent decades.

[11]Beginning in 1996, most farm program payments were decoupled from current production decisions. For decoupled programs, decisions about the use of land or other inputs do not change program benefits.

Figure 12 shows marketing loan benefits, crop insurance indemnities, and disaster payments for the Northern Plains during 1997-2007. Figure 13

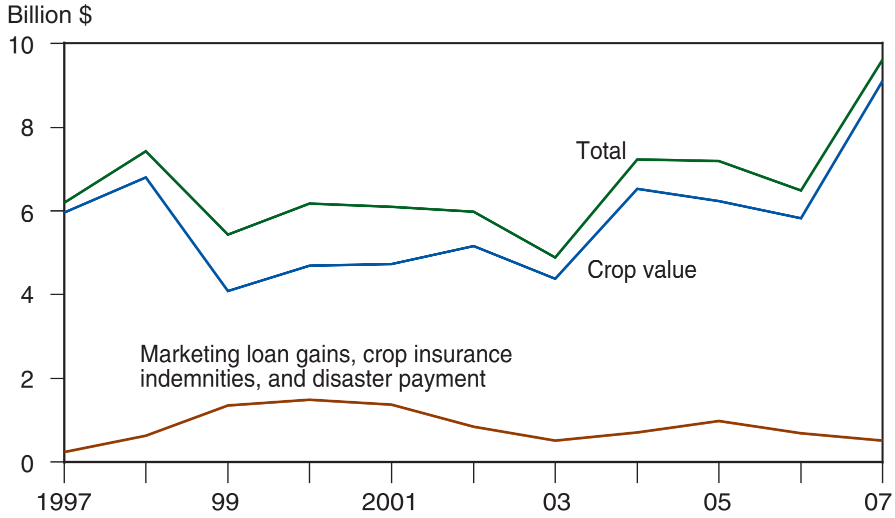
Figure 12

Marketing loan benefits, crop insurance indemnities, and disaster payments in the Northern Plains, 1997-2007



Source: USDA, Agricultural Resource Management Survey, National Agricultural Statistics Service and Economic Research Service, 1997-2007.

Figure 13
Marketing loan benefits, crop insurance, disaster assistance and the value of crop production in the Northern Plains, 1997-2007



Source: USDA, Agricultural Resource Management Survey, National Agricultural Statistics Service and Economic Research Service, 1997-2007.

shows how these payments affected crop revenue over time. The spike in marketing loan benefits for 1999-2001 was driven largely by payments to soybeans. From 1997-2001, the soybean loan rate was $5.26 per bushel while season average prices hovered around $4.50 between 1999 and 2001. The soybean loan rate was lowered to $5.00 beginning in 2002, while loan rates for corn and wheat were adjusted upward. Indemnities increased sharply in 1999 as a result of higher premium subsidies, which triggered broader participation in the crop insurance program. Subsidies were also designed to encourage purchase of high levels of coverage, increasing indemnities. We note, however, that producers must pay premiums on crop insurance. Even though premiums are highly subsidized, the net value of crop insurance indemnities would be considerably less than the full value of the indemnity, which is shown in figure 12.

Less attention has been given to the role of technology in land use change, although technology adoption can lead to changes in cost structure and new cropping patterns (e.g., Lichtenberg)—things that may increase the value of cropland relative to grassland and could trigger land use change. Adoption of herbicide-tolerant (Ht)[12] soybeans and corn has been swift, rising from roughly 20 percent in 1998 to nearly 100 percent for soybeans by 2006, while adoption of Ht corn was over 50 percent by 2006 (fig. 14). Previous research has shown that Ht varieties did little to reduce production costs, but did significantly reduce labor requirements in the busy spring planting season (Fernandez-Cornejo and McBride). Timely planting, particularly in corn, is critical to achieving optimal yields.

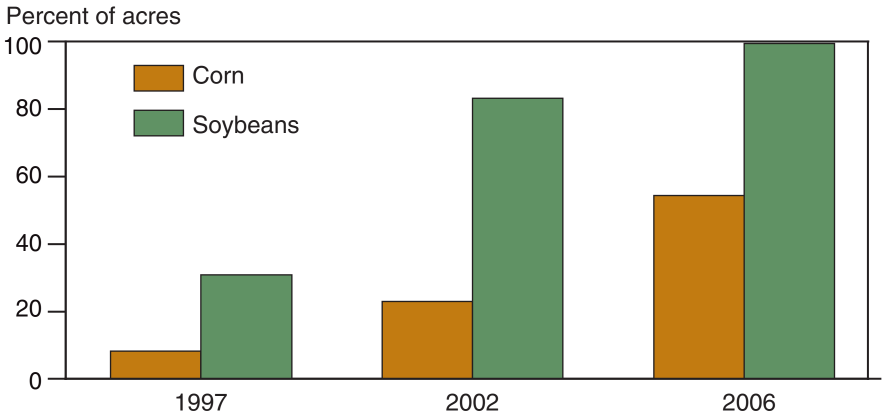
Adoption of no-till methods (fig. 15) may also facilitate land use conversion. Where soil and climate conditions are suitable, switching from conventional to no-till production can save labor and fuel (fewer field operations are needed) and reduce machinery requirements (tillage machines and large

[12]Herbicide-tolerant varieties are modified to withstand contact with the herbicide glyphosate. While glyphosate is nonselective (it kills most plants), producers planting herbicide-tolerant varieties can control weeds by spraying fields after the crop has emerged.

tractors needed to pull them are no longer necessary). No-till also may reduce the barrier to land use change posed by the "sodbuster" provisions of U.S. agricultural policy. Under these provisions, producers who convert highly erodible land to crop production must adopt a soil conservation system that prevents a "significant" increase in soil erosion or risk loss of all Federal agricultural payments, not just payments on the converted land. In many instances in the Northern Plains no-till methods satisfy this requirement (USGAO).

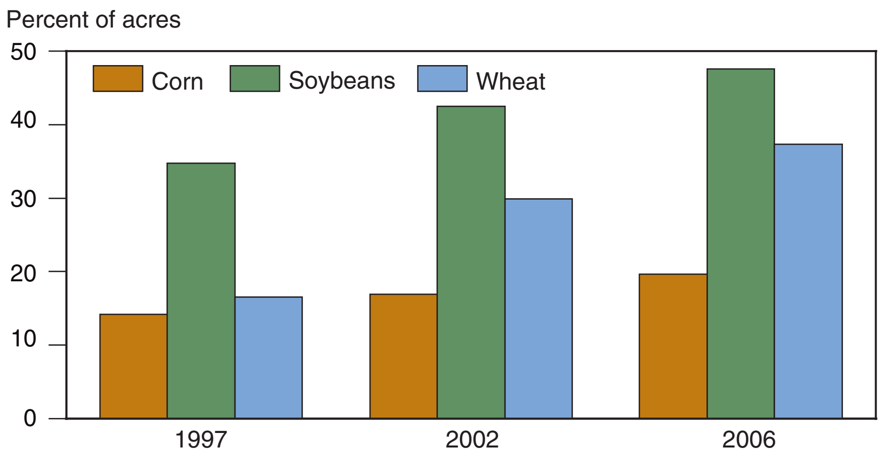
Changes in crop mix do not yield direct information on returns to crop production, but may be an indicator of changes in returns. A shift to more profitable crops may also encourage farmers to convert land not planted to a crop to cultivated crop production. Figure 16 shows how the mix of corn, soybeans, wheat, and other crops changed between 1997 and 2007 for LRRs

Figure 14
Adoption of herbicide-tolerant crop varieties, in the Northern Plains, for selected years



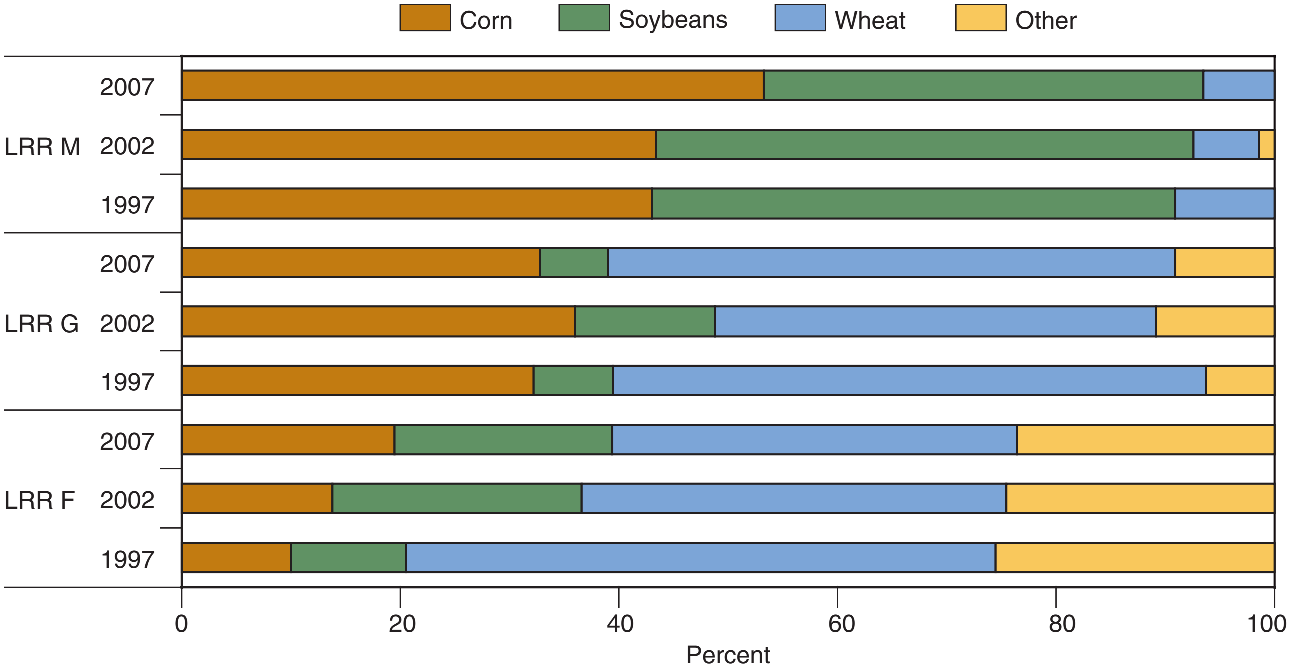
Source: USDA, Agricultural Resource Management Survey, National Agricultural Statistics Service and Economic Research Service, 1996-2006.

Figure 15
No-till adoption in the Northern Plains, by crop, for selected years



Source: USDA, Agricultural Resource Management Survey, National Agricultural Statistics Service and Economic Research Service, 1996-2006.

Figure 16
Changes in cropping patterns, Land Resource Regions F, G, and M, 1997-2007

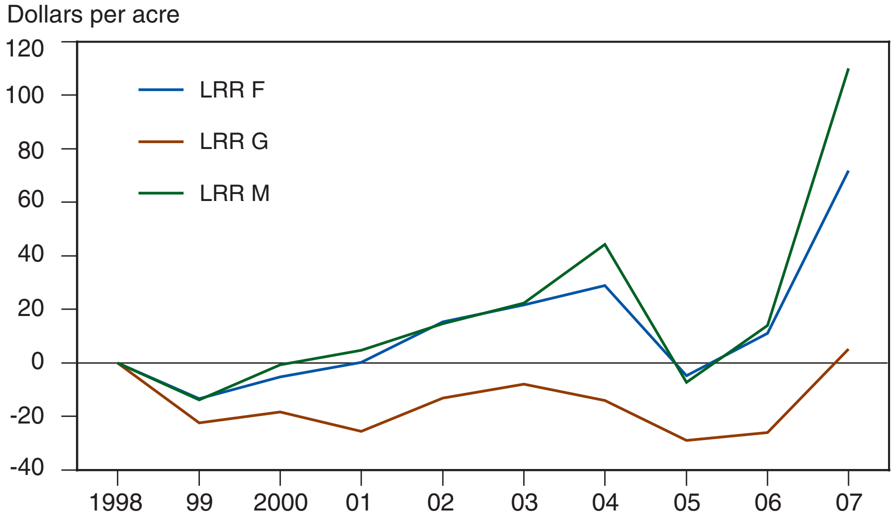


LRR F=Transitional region; LRR G=Range region; LRR M=Western Corn Belt.
See figure 7 for total cropland acreage by LRR.
Source: USDA, National Agricultural Statistics Service, Census of Agriculture, 1997, 2002, and 2007.

F, G, and M in the Northern Plains. Cropping patterns have been stable in LRRs M (Western Corn Belt) and G (Rangeland Region). Cropland in LRR M is largely devoted to corn and soybeans while in LRR G a majority of cultivated cropland is devoted to wheat production. In LRR F (Transitional Region), however, there was a major shift from wheat to corn and soybeans between 1997 and 2007. Corn and soybean acreage roughly doubled, going from just over 20 percent to almost 40 percent of cultivated cropland. A crop-mix shift of the magnitude observed in LRR F would have been less likely under U.S. farm commodity policies that existed before 1996, when producers were prevented from expanding plantings of corn, soybeans, wheat and other crops, while also continuing to receive farm program payments. Since 1996, farmers have been (mostly) free to change crop acreages with risking the loss of farm programs benefits.

Figure 17 shows the difference in average net returns to crop production and grazing (normalized to zero for 1998) by LRR. The value of marketing loan benefits and net crop insurance indemnities (indemnities less producer-paid premiums) are included. Upward slopes represent an increase in returns to cultivated crops, relative to livestock grazing. A downward slope indicates a relative increase in returns to grazing. Returns to crop production are an acre-weighted average of returns for three major crops: corn, wheat, and soybeans. Acreage weights are based on the average acreage of each crop in the 3 previous years, as the shift to higher value crops may have played an important role in changing crop returns. These returns also include the effect of farm program payments that depend directly on current production: marketing loan gains and federally subsidized crop insurance.

Figure 17
Change in difference, expected return to cultivated crops and grazing, by Land Resource Region



See figure 7a for map of LRR F, LRR G, and LRR M.
LRR F=Transitional region; LRR G=Range region; LRR M=Western Corn Belt.
Source: USDA, Economic Research Service.

On average, returns to crop production are increasing in LRR M (Western Corn Belt) relative to LRR F (Transitional Region) or G (Range Region). For most of the period (7 of 10 years), relative returns to crop production in LRR M were higher than in 1998. In LRR G, on the other hand, relative returns to crop production were higher than 1998 returns in only 1 year (2007). Relative returns to crop production in LRR F were higher than relative returns in 1998 for only 3 of 10 years, but higher than relative returns in LRR G in every year after 1998. So, the evolution of returns over time suggests that the probability of converting grassland to cropland (for comparable tracts of land) would be larger in LRR M and F than in LRR G.

Many Factors Affect the Cropland-Grassland Margin

There is evidence to suggest that land quality is an important factor in determining the economic margin between cropland and grassland. There are large areas of low-productivity rangeland that seem to have little chance of being converted to cropland in the absence of water for irrigation. There are also large areas of high-productivity cropland that are unlikely to become grassland in foreseeable future.

Nonetheless, evidence also suggests that economic factors do matter. The margin between cropland and grassland is active. A significant share of land, particularly medium-quality land, may shift back and forth between cropland and grassland depending on the net returns expected from each use. The concentration of grassland to cropland conversions in LRR F (particularly the portion that intersects South Dakota), as shown in the chapter, "Grassland and Grassland-Cropland Conversion, 1997-2007," corresponds roughly to the broad availability of medium-productivity grassland and changes in crop mix that may signal a larger shift in the relative profitability of grassland and cropland. These changes may have roots in changing market prices, policy, technology, or all three.

In the next chapter, “Simulation Analysis of Sodsaver: Can It Save Native Grasslands?” we focus on county-level variation in the level of farm program payments that could be affected by Sodsaver, if it were implemented. We consider the difference in payments and its effect on revenue for counties experiencing high levels of grassland conversion and counties that are not.

Simulation Analysis of Sodsaver: Can It Save Native Grasslands?

If implemented, the Sodsaver provision could deny crop insurance for a period of 5 years on native grassland converted for crop production. Because the SURE program depends on the purchase of crop insurance (where available), these payments would also be denied if Sodsaver were implemented. After 5 years, the land would become eligible for crop insurance coverage and SURE payments.

How much difference would Sodsaver make in grassland to cropland conversion? The answer depends on the size of net crop insurance indemnities and SURE payments that would be affected by Sodsaver and the extent to which producers respond by altering plans for grassland conversion. To gauge the potential effect of Sodsaver, we devise seven representative farms based on seven North Dakota and South Dakota counties where there is information to suggest that grassland to cropland conversion has been high. Specifically we focus largely on counties located in and near the Hyde-Hand area studied by Stephens et al. (Beadle, Edmunds, Faulk, Hand, Hyde, and Sully in South Dakota and Stutsman County in North Dakota; all are located in LRR F (Transition Region)). For comparison, we develop farms representing two Southeastern South Dakota counties (Turner and Union; located in LRR M (Western Corn Belt) where most land is already cropped and conditions are similar to those in the Western Corn Belt (we refer to these as "comparison" counties).

For each representative farm, we develop a joint distribution of prices and yields for three major crops (corn, soybeans, and wheat) and forage harvested through grazing. We use these distributions along with data on crop and grazing acreage to estimate the effect of crop insurance and SURE payments on the mean and variance of crop revenue, net returns (revenue net of production costs), and the producer's willingness to pay to avoid greater revenue variability under Sodsaver. Elasticities of grassland to cropland conversion drawn from the literature are used to estimate the potential change in the rate of land use conversion under Sodsaver. The elasticity of grassland to cropland conversion with respect to crop returns is an estimate of the change in grassland to cropland conversion given a 1-percent change in net return to crop production.

Policy Scenarios

The effect of Sodsaver on crop revenue depends on crop insurance indemnities, net of premiums, and SURE payments that would be received without Sodsaver. We estimate the mean and variance of these payments for two scenarios based on variations in crop insurance eligibility and calculation of the actual production history (APH) yield. The APH yield is a key determinant of premium rates (USDA-RMA, 2000) and is used along with the producer-selected coverage level to determine the level of yield or revenue guaranteed by a crop insurance policy. The APH yield is also a factor in the calculation of SURE revenue guarantee. In most cases, the APH yield is an average of the most recent 4 to 10 yields on a crop insurance unit, depending on the availability of yield history. On land that has been in crop production but has not been previously insured (for a specific crop), "transitional" yields, based on historic county yields, are used to fill out the yield history until four actual yields are available. On land that has not been previously cropped, USDA's RMA uses a special set of "New Land" rules to determine the APH yield.

Our New Land scenario is patterned after current RMA policy with respect to land that has no history of crop production. To be eligible for crop insurance, RMA requires at least 1 year of actual production history (i.e., crop insurance is not generally available in the first year of production).[13] On land that has been cropped for fewer than 4 years, the yield history is filled out using a percentage of county transitional yields. If land is first insured in the second year of crop production (with 1 year of production history), transitional yields are reduced by 20 percent. For land that is first insured in the third year (with 2 years of actual yield history) transitional yields are reduced by 10 percent. If the reduced transitional yields are lower than the producer's expected yield on new land, the producer will pay a higher effective premium rate and will be less likely to collect an indemnity than if a yield history were available.

[13]Crops could be insured during the first year of production through written agreements between RMA and the producer. Written agreement are developed (or denied) on a case-by-case basis and, therefore, cannot be effectively modeled.

As a benchmark, we create the No Restriction scenario, which considers the effect of dropping the New Land rules: crop insurance can be purchased in the first year of production and the APH yield in the first 4 years of crop production is calculated using county transitional yields, as needed, without the reductions required by the RMA New Land rules.

Simulating the Effect of Crop Insurance and SURE on Crop Revenue

Depending on the crop insurance product purchased, indemnities are paid when either yields or revenue (for a specific crop) fall below a guarantee level. In the Northern Plains, revenue insurance is the dominant product. For 2007, RMA Summary of Business data show that revenue assurance (RA) accounted for 74 percent of insured corn acreage (most insured for 70- or 75-percent coverage), 82 percent of insured soybean acreage (mostly 70- and 75-percent coverage), and 44 percent of insured wheat acreage, almost all of it at 65-, 70-, or 75-percent coverage. For this analysis, we assume that all three crops are covered by an RA policy at 70-percent coverage. When revenue for an individual crop falls below 70 percent of revenue expected at the beginning of the season (as determined by RMA rules) the insurance indemnity is the difference between 70 percent of expected revenue and actual revenue.

By law, RMA must attempt to set premiums at actuarially fair rates. Actuarially fair premiums are equal to expected losses over time so that insurance protects farmers against low revenue years, but does not increase average net returns to crop production over time. The premiums actually paid by farmers are heavily subsidized by the Federal Government. At 70-percent coverage, 59 percent of the premium is paid by the Government. So, if the full premiums are actuarially fair,[14] farmers will realize a gain over time equal to the amount of the subsidy, in addition to the revenue-stabilizing effect of crop insurance. In our analysis, we assume that crop insurance premiums are actuarially fair so that the full premium is equal to the expected

[14]A number of authors have argued that premium rates are not actuarially fair and that some producers benefit from asymmetric information (pay premiums that are lower than actuarially premiums while others are charged premiums that are higher than actuarially fair (e.g., Just, Calvin, and Quiggen; Makki and Somwaru)). RMA data show that crop insurance losses are persistent in the Northern Plains (Glauber), suggesting that our estimates of the crop insurance subsidy may be conservative, on average.

indemnity and expected net return to crop insurance purchase is equal to expected indemnity less the farmer-paid premium. We refer to this expected net return as the expected net indemnity. Our model of crop revenue insurance is detailed in appendix A.

SURE payments provide additional support to farmers who also purchase crop insurance (where it is available). Like crop insurance, SURE payments are triggered when revenue is low. Unlike crop insurance, however, SURE payments depend on whole-farm revenue rather than single crop revenue and do not require the payments of an additional premium. Payments can be made only to producers who are located in counties where a disaster has been declared (for our analysis, we assume that the Secretary of Agriculture determines that there has been a weather-related production loss of 35 percent or more in at least one crop[15]), counties contiguous to disaster counties, or to any producer who experiences production 50 percent or more below normal levels. SURE payments are based on formulas that account for actual revenue, expected revenue, and the level of crop insurance coverage purchased. Our model of SURE payments is also detailed in appendix A.

[15]Thirty-five percent is typical of past disaster assistance programs. For each year between 2001 and 2007 (inclusive), producers were required to show production losses of 35 percent or more to be eligible for disaster assistance, as noted in footnote 2. See web link, footnote 2, for examples.

To estimate crop insurance indemnities and SURE payments, we devise joint probability distributions for crop prices and yields for each of our representative farms. Using these distributions, we determine the probability that revenue for specific crops will fall below the crop insurance or SURE revenue guarantee (assuming the conditions for a disaster declaration have been met), the size of indemnities or payments that would be made when revenue dips below the guarantee, and the effect of these indemnities (net of crop insurance premiums) and payments on crop revenue.

The crop yield distributions are based on county crop yield data collected by USDA's National Agricultural Statistics Service and national and State crop price data, with two adjustments. First, grassland is less productive, on average, than cropland (see figure 10). In the seven "high conversion" counties we consider, average rangeland productivity is 18 percent lower than average cropland productivity.[16] Because relatively high-productivity rangeland is most likely to be converted to crop production, we assume that crop yields will be about 10 percent lower on converted land than on average cropland. Second, some farm-level yield variation will be averaged out of county data. To reflect farm-level conditions, we inflate crop yield variances using a method similar to that of Coble, Dismukes, and Thomas. Means and standard deviations, along with transitional yields for corn, soybean, and wheat yields, are shown in table 1. A similar procedure is used to estimate the distribution of prices and yields for grazing. We assume that grasslands are used as part of a cow-calf operation. A joint distribution of cow-calf revenue (the "price") and stocking rates (the "yield") is developed in conjunction with the crop price and yields distributions. Development and use of the price-yield distributions are detailed in appendix A.

[16]Average productivity based on land use information from the 2007 National Resources Inventory (USDA, Natural Resources Conservation Service) and the National Commodity Crop Productivity Indicator (Dobos, Sinclair, and Hipple).

Table 1
Expected yields, standard deviations, and county transitional yields

County	Corn			Soybeans			Wheat		
	Expected yield	Yield standard deviation	County transitional yield	Expected yield	Yield standard deviation	County transitional yield	Expected yield	Yield Standard Deviation	County Transitional yield
Stutsman	94.2	45.2	81	28.8	10.3	22	33.8	14.3	34
Beadle	95.8	46.9	94	30.0	14.7	30	39.8	15.9	38
Edmunds	99.8	44.3	99	27.2	12.7	28	40.7	16.3	39
Faulk	103.5	48.1	100	28.3	12.3	29	41.8	17.7	41
Hand	84.1	44.7	80	26.2	14.9	25	35.0	18.3	34
Hyde	76.6	46.2	68	25.6	15.3	25	32.8	21.3	32
Sully	67.5	38.0	71	31.6	15.9	29	32.4	20.4	**31**
Turner*	119.7	42.6	121	34.3	11.3	34	na	na	na
Union*	131.7	49.1	132	38.7	12.7	36	na	na	na

*Comparison counties.
Source: USDA, Economic Research Service analysis of USDA, National Agricultural Statistics Service and USDA, Risk Management Agency data.

Simulation Results: The Sodsaver Effect

Sodsaver would deny crop insurance and could—by extension—SURE payments, over a period of 5 years. The 5-year net present value (NPV) of expected net crop insurance indemnities (the expected indemnity less the producer-paid premium) and SURE payments on converted grassland for the New Land scenario (in the absence of Sodsaver) are shown in figure 18. Expected payments (the sum of expected net indemnities and SURE payments) are what producers could reasonably expect to receive, on average, over a period of years given the likelihood of yields and/or prices low enough to trigger these payments. Expected payments are not necessarily what producers receive over any given 5-year period—in a series of particularly high (or low) revenue years, producers could realize lower (or higher) payments. In calculating net present values, we discount future payments at a rate of 7 percent.[17]

In high-conversion counties, the net present value of net crop insurance indemnities and SURE payments ranges from $26 per acre (Stutsman County) to $58 per acre (Hyde and Sully Counties) (see figure 18). In the comparison counties, the payments range from $29 per acre to $36 per acre. SURE accounts for 19-26 percent of the estimated payments that would be affected by Sodsaver in high-conversion counties and roughly 23 percent of Sodsaver-affected payments in each of the comparison counties.

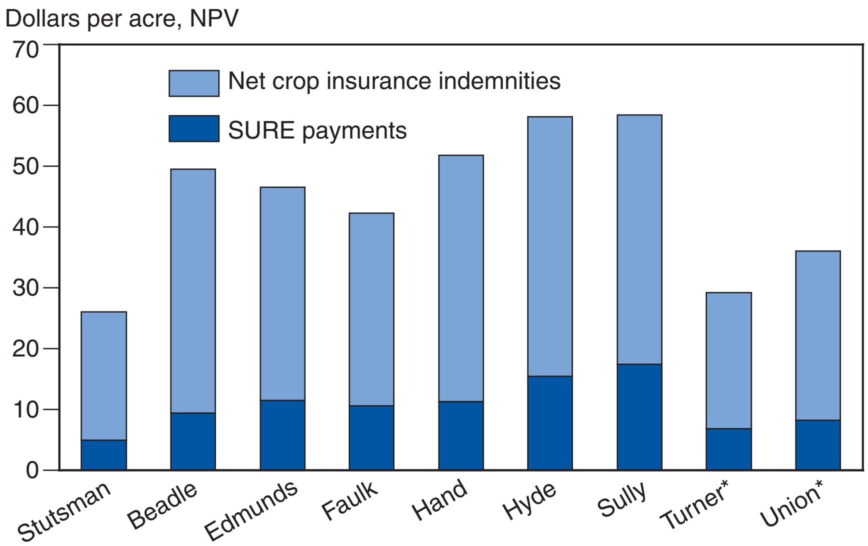
As a percentage of the net present value of expected crop revenue, these payments are modest. In high-conversion counties, they represent between 2 percent and 5.5 percent of total expected crop revenue and less than 2 percent of total revenue in the comparison counties (see figure 18). As a percentage of net returns (revenue less crop production cost), net crop-insurance indemnities and SURE payments are somewhat larger, representing 9 percent to 14 percent of net returns in high-conversion counties and roughly 3.4 percent of net return in both of the comparison counties (not shown).

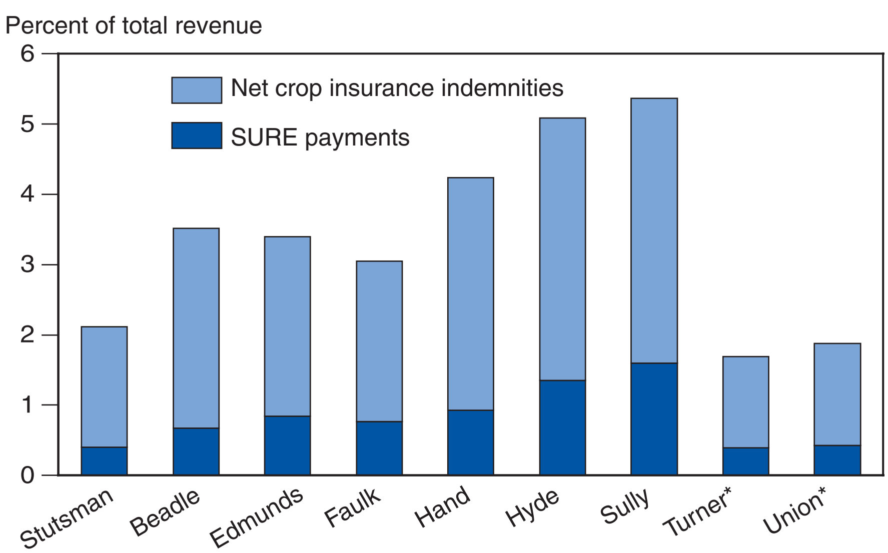
Stutsman County is somewhat of an outlier among high-conversion counties —expected payments in all other high-conversion counties are considerably

[17]We tested the sensitivity of the model to lower discount rates. The NPV of crop insurance indemnities and SURE payments increased by 5 percent and 10 percent when the discount rate was reduced to 5 percent and 3 percent, respectively. In Hand County, for example, the NPV of expected indemnities would rise from roughly $40 per acre to $44 per acre when the discount rate was reduced from 7 percent to 3 percent. Payments as a percentage of revenue or net return, however, would be largely unchanged and the NPV of revenue and net return would also rise.

higher both in absolute dollars and relative to total revenue. A key difference between Stutsman and other high-conversion counties is that crop insurance transitional yields are low relative to expected yields (table 1). For most counties and crops, our expected yields (which are 10 percent less than county average expected yields) are very close to the transitional yields. For corn and soybeans in Stutsman County, however, transitional yields are 13 and 21 percent less than expected yields, respectively. Lower transitional yields lead to lower APH yields which, in turn, mean higher premium rates and lower guarantees for both crop insurance and SURE, leading to less frequent and smaller net crop insurance indemnities and SURE payments.

Figure 18
Expected NPV of net crop insurance indemnities and SURE payments in the New Land scenario over 5 years

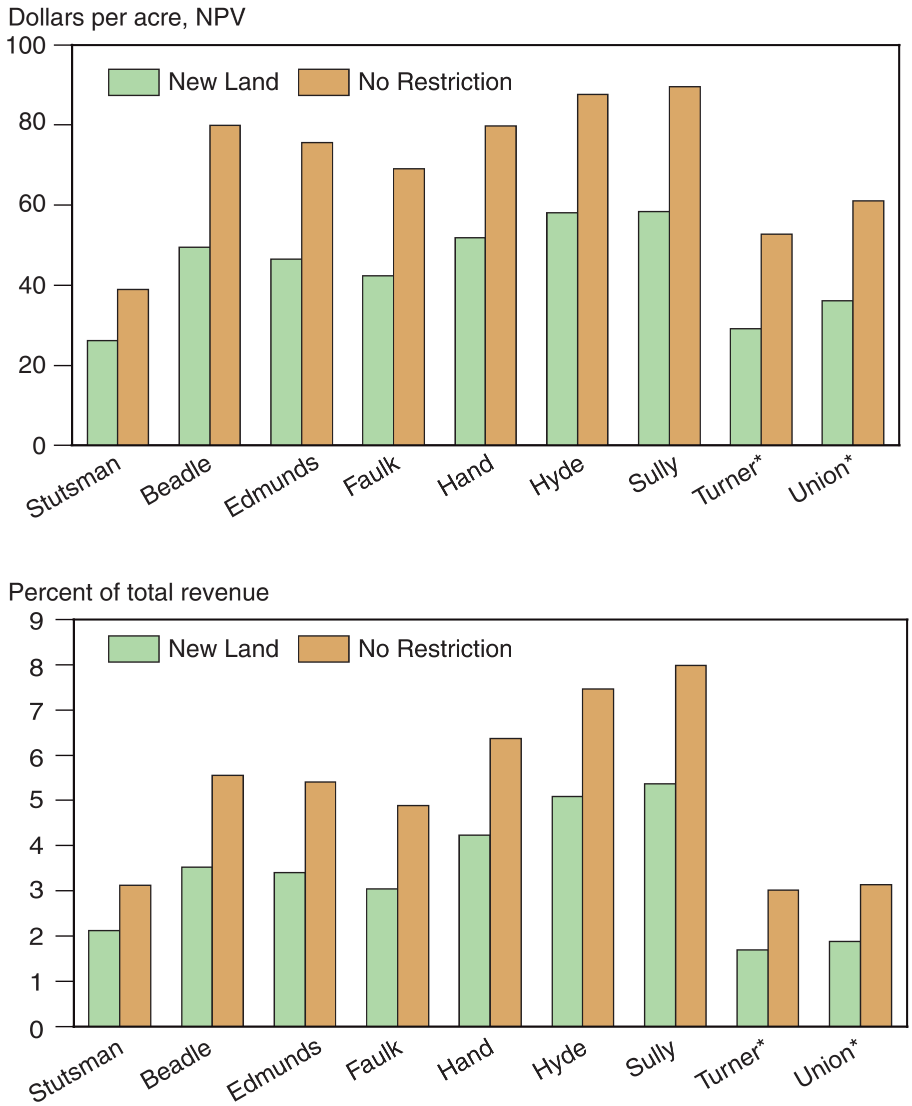




* indicates comparison county.
NPV=Net present value. SURE = Supplemental Revenue Assistance program.
Source: USDA, Economic Research Service.

If the existing RMA New Land rules were eliminated or bypassed (the rules requiring reduction in transitional yields in the first few years of crop production), the payments subject to Sodsaver sanction would be significantly larger. For the No Restriction scenario in high-conversion counties, expected payments range from $40 per acre in Stutsman County (a 50-percent increase over the New Land scenario) to $90 per acre in Sully County (55 percent higher) (fig. 19). In the comparison counties, per acre payments would be $60 in Union County (70 percent higher than under the New Land scenario) and $52 in Turner County (82 percent higher). For the No Restriction scenario, payments as a percent of revenue vary from 3 to 8 percent of total revenue in high-conversion counties and are equal to 3 percent of revenue in the

Figure 19
Expected net return to crop insurance and SURE payments under the No Restriction and New Land scenarios



* indicates comparison county.
NPV=Net present value. SURE = Supplemental Revenue Assistance program.
Source: USDA, Economic Research Service.

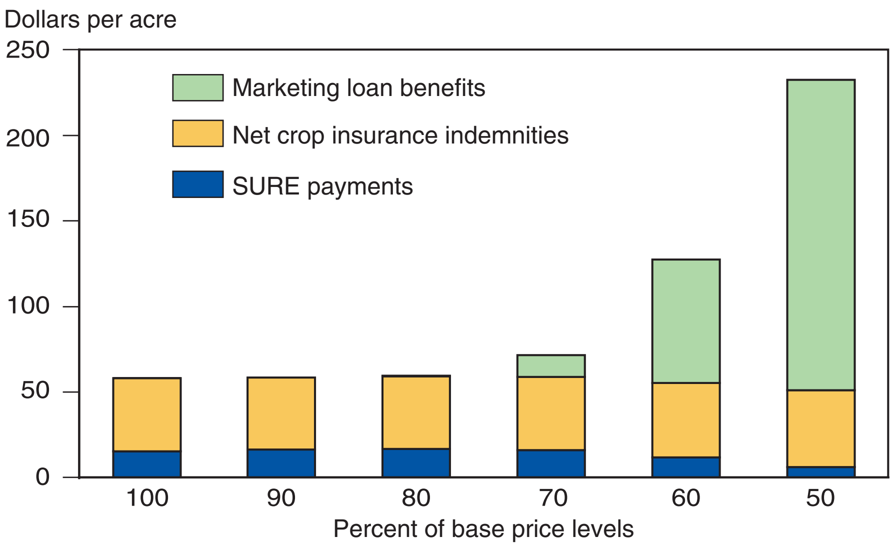
comparison counties (fig. 19). As a percentage of net return, payments range from 7 percent to 20 percent in the high-conversion counties but are under 6 percent in the comparison counties (not shown).

Results reported in figures 18 and 19 are for the 5-year period of the Sodsaver sanction. For farmers who consider the decision to convert grassland to cropland over a period of more than 5 years, the effect of Sodsaver as a percentage of expected revenue would decline. For the New Land scenario, the percentage reduction in the NPV of expected total revenue due to Sodsaver would decline from 5.1 percent over 5 years to 2.8 percent over 10 years, 2.2 percent over 15 years, and 1.8 percent over 20 years. The Sodsaver reduction in dollar terms would, of course, remain unchanged.

The crop prices underlying our analysis are based on 2008 conditions, when crop prices were high by historical standards. Changing expected prices at the beginning of the season will not necessarily change the expected value or standard deviation of net crop insurance indemnities and SURE payments. Revenue changes that could trigger these payments depend only on intra-season price movements, which are not necessarily related to the expected harvest price at the beginning of the season. Lower expected prices could, however, increase the expected likelihood and size of marketing loan benefits (MLBs). In Hyde County, for example, expected crop insurance and SURE payments would remain at or near their initial level (roughly $60 per acre for the New Land scenario), even as the expected prices of corn, soybeans, and wheat all dropped to 50 percent of initial (2008) levels (fig. 20). When expected prices decline to 70 percent of initial levels or lower, expected MLBs begin to rise and continue rising to maintain expected revenue at about 40 percent of our initial levels (see figure 20). MLBs are not subject to Sodsaver sanctions, although they may protect producers from very low prices on converted grassland.

Figure 20

Net crop insurance indemnities, SURE payments, and marketing loan benefits with lower crop prices



SURE = Supplemental Revenue Assistance program.
Source: USDA, Economic Research Service.

Farmers who convert lower productivity land may face somewhat different incentives. Based on research by Skees and Reed, RMA's rating assumes an inverse relationship between expected yields and yield variability. We re-estimated key results using yields that are 10 percent lower than yields reported in table 1, with higher standard deviations to reflect lower mean yields (see appendix A for details). In Hyde County, for example, estimated crop insurance and SURE payments under the New Land scenario would be about $65 per acre on lower yield land, compared to $58 with our base yields (a difference of $7). The NPV of market revenue over 5 years, however, drops from $1,085 with base yields, to $978 with lower yields (a difference of $107). So, the increase in net crop insurance indemnities and SURE payments offsets less than 10 percent of lower revenue.

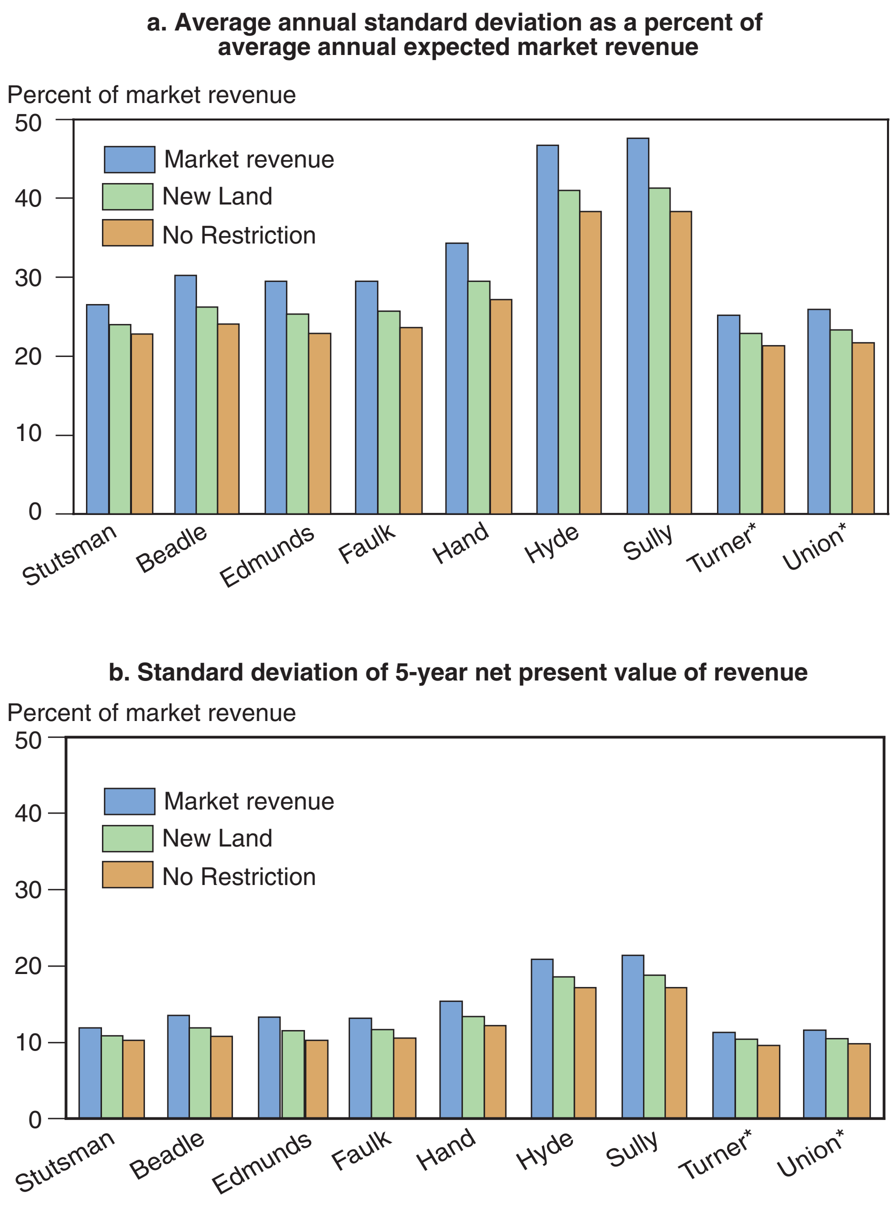
Because crop insurance and SURE protect producers against low revenue, they also can reduce the variability of revenue. In high-conversion counties, we estimate that the average annual standard deviation of market revenue (the variability farmers would face on converted grassland if Sodsaver were in force) ranges from 27 percent (Stutsman County) to 48 percent of expected market revenue (Sully County) (fig. 21a). Under the New Land scenario, in the absence of Sodsaver, average annual standard deviation would decline to 24 percent of expected revenue in Stutsman County and 41 percent in Sully County. In both of the comparison counties, the standard deviations are roughly 23 percent of expected market revenue with Sodsaver in force and would be roughly 15 percent under the New Land scenario.

While annual revenue variations can be large, they tend to average out over a period of years. For a farmer considering grassland to cropland conversion, the potential variation in the net present value of returns over a period of 5 years is much smaller than potential year-to-year variation. In Sully County, for example, where the average annual standard deviation of revenue is 41 percent of expected market revenue, the standard deviation of the 5-year NPV of expected market revenue is 27 percent (fig. 21b). Farmers may be able to adjust for annual variability by shifting large expenses such as the purchase of farm machinery or consumer durable goods to high-revenue years (Just). Remaining variability is more difficult to avoid.

A risk premium is the amount a producer would be willing to pay in exchange for reduced revenue variability. In our context, the relevant risk premium is the value a producer places on risk reduction (reduction in revenue variability) due to crop insurance and SURE during the 5-year Sodsaver moratorium. In other words, what would a producer be willing to pay for risk reduction that would be lost if the Sodsaver sanction were imposed? Based on our risk model (see appendix A), the producers represented by the conversion counties would be willing to relinquish from 0.75 percent of expected market revenue (Stutsman County) to nearly 2 percent (Sully County) to retain the risk reduction afforded by crop insurance and SURE (table 2). Using some alternative values for risk aversion, debt-to-asset ratio, and percentage of grassland converted yields risk premiums as high at 2.5 percent of expected market revenue (see table 2).

Although the effect of Sodsaver on revenue and, particularly, net return to crop production, could be substantial during the first 5 years after grassland conversion, major land use changes, like grassland to cropland conversion, tend to be relatively unresponsive to changes in revenue or net return. To be more specific, we draw land use conversion elasticities from the literature and use them to estimate the change in land use conversion that could flow from reducing net return to crop production through implementation of Sodsaver. The elasticity of rangeland to cropland conversion with respect to crop returns, for example, is the percent change in conversion given a 1-percent change in net returns to crop production. To estimate potential changes in conversion, we calculate the change in crop returns as the difference in expected net return with and without Sodsaver, plus the producer's risk premium associated with risk reduction that would be lost under Sodsaver. We

Figure 21
Standard deviation of crop revenue as a percentage of expected market revenue



* indicates comparison county.
NPV = Net present value.
Source: USDA, Economic Research Service.

Table 2

Estimated risk premium for risk reduction in selected counties due to crop insurance and SURE

Constant relative risk aversion	Grassland converted (*percent*)	Debt-to-asset ratio		Stutsman	Beadle	Edmunds	Faulk	Hand	Hyde	Sully	Turner*	Union*
2	15	0.17	*$ per acre*	10.09	10.96	10.22	10.75	12.22	21.32	20.43	15.81	20.34
			Percent of revenue	0.84	0.81	0.77	0.80	1.04	1.96	1.98	0.93	1.08
1.5	15	0.17	*$ per acre*	7.94	8.77	7.71	8.13	9.18	15.82	15.52	12.99	16.39
			Percent of revenue	0.66	0.65	0.58	0.60	0.78	1.46	1.51	0.76	0.87
2.5	15	0.17	*$ per acre*	12.22	13.67	12.74	13.47	15.40	26.93	25.45	15.81	23.08
			Percent of revenue	1.01	1.01	0.96	1.00	1.31	2.48	2.47	0.93	1.22
2	5	0.17	*$ per acre*	14.05	13.88	10.82	11.09	12.57	19.14	21.51	31.61	32.77
			Percent of revenue	1.16	1.02	0.82	0.82	1.07	1.76	2.09	1.86	1.73
2	15	0.34	*$ per acre*	12.22	13.14	12.74	13.22	15.69	27.68	25.34	15.81	21.85
			Percent of revenue	1.01	0.97	0.96	0.98	1.34	2.55	2.46	0.93	1.16

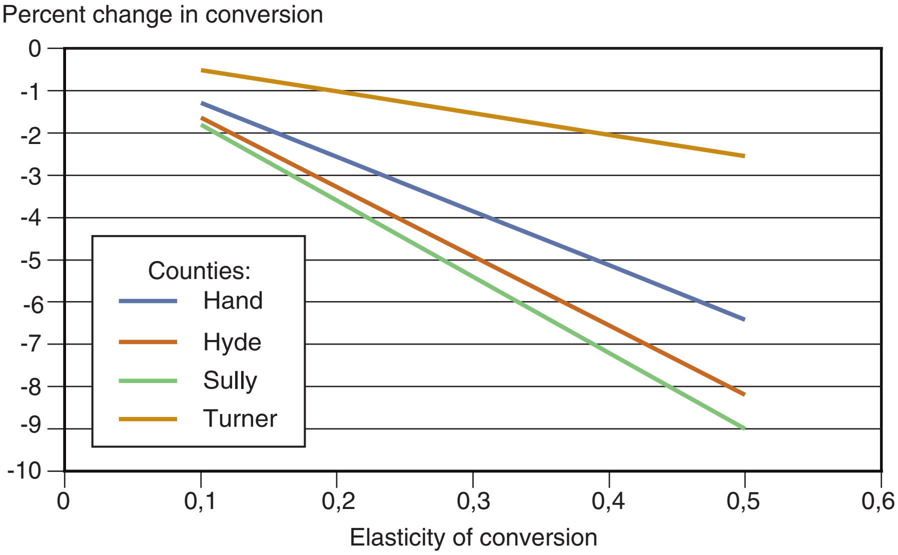
* comparison county.
SURE = Supplemental Revenue Assistance program.
Source: USDA, Economic Research Service.

note that this type of analysis is largely illustrative and is intended only to provide a general sense of the magnitude of the effect of Sodsaver sanctions on grassland to cropland conversion.

Lubowski, Plantinga, and Stavins report a comprehensive set of land conversion elasticities, generally finding that major land use change is not very responsive to changes in revenue. For rangeland conversion with respect to cropland returns, they report values of 0.35 or less, although none are significantly different from zero. For pasture conversion, estimated elasticities are as high as 0.38 and are all significantly different from zero. Barr et al. recently estimated that cropland acreage would increase by 0.029 percent for a 1-percent increase in net return to crop production. Although not directly comparable to the values reported by Lubowski, Plantinga, and Stavins, they do support the finding that major land use is not highly responsive to short-run economic conditions. Because previously reported values are likely to depend on geographic scope and overall economic conditions for the periods studied, actual response in high-conversion counties may differ. We consider conversion elasticities between 0.1 and 0.5.

Sodsaver would likely have its greatest effect in Hand, Hyde, and Sully counties. If we assume that our best estimate of the grassland to cropland conversion elasticity is 0.3, Sodsaver could reduce grassland conversion by 3.8 percent, 4.9 percent, and 5.4 percent in Hand, Hyde and Sully Counties, respectively (fig. 22). The smallest effects would be in Turner and Union Counties (the comparison counties), where conversion would be reduced by less than 2 percent. A great deal depends on the exact value of the conversion elasticity, as the slowing of grass to crop conversions in Sully County, for example, could vary from less than 2 percent to more than 9 percent.

Figure 22
Potential reduction in grassland to cropland conversion due to Sodsaver



Source: USDA, Economic Research Service.

Sodsaver May Not Be Enough To Stop Grassland Conversion

Our analysis indicates that the effect of Sodsaver would vary widely across counties. Sodsaver would reduce expected crop revenue by 4.2 to 5.4 percent and expected net return by 10 to 14 percent in Hand, Hyde, and Sully counties. In other high-conversion counties, Sodsaver would reduce expected revenue by 2.1 to 3.4 percent and net return by 4.9 to 7.7 percent. In comparison counties, the expected revenue effect would be 1.7 to 1.9 while the net return effect is roughly 3.4 percent in both. Risk effects would be even more varied. Hyde and Sully counties stand out with estimated risk premiums approaching 2 percent of expected revenue. In other high-conversion counties, however, risk premiums vary between 0.8 and 1.0 percent while comparison counties have risk premiums of 0.9 to 1.1 percent.

SURE payments, which are intended to replace ad hoc disaster assistance, account for 20 to 25 percent of payments subject to Sodsaver. In the Northern Plains, where the weather is variable and low yield years are frequent, greater certainty about the availability of disaster assistance could encourage farmers to include disaster assistance in weighing the costs and benefits of grassland conversion.

Crop insurance and SURE provide producers with protection against relatively low revenue. Regardless of whether prices are historically high or low at the beginning of the season, when crop insurance is purchased, an indemnity could be triggered due to an intraseason decline in crop prices and/or unexpectedly low yields. The same is true of SURE, although these payments would be triggered only when realized farmwide revenue is significantly lower than expected revenue at the beginning of the season. If producers choose to convert land during periods of historically high prices, crop insurance and SURE could help protect against low revenue due to unexpectedly low yields or a large, unexpected intraseason drop in market prices. Crop insurance, however, would not protect against a long-term decline in crop prices.

In contrast, MLBs are paid only when prices drop to historically low levels. In our analysis, which is based on historically high prices, the expected value of MLBs starts to rise (from zero) when expected prices are 30 to 40 percent lower than our initial prices. So, marketing loan benefits would not necessarily protect producers against intraseason losses in expected revenue, particularly when crop prices are high. In the long term, however, MLBs would protect producers against very low prices. Given our price assumptions, it is unlikely that MLBs would play a role in grassland to cropland conversion.

Reductions in the variability of crop revenue due to crop insurance and SURE are smaller than the effect of these programs on expected return, as measured by risk premiums. So, risk reduction is likely to account for a relatively modest share of producer benefit from these programs. That is particularly true if farmers can reduce the impact of risk on consumption through borrowing or shifting large purchases to high-revenue years.

The results reported here indicate that Sodsaver would do little to slow the conversion of grassland to cultivated crop production. The elasticity estimates cited above, however, are for the United States overall rather than for the Northern Plains or for portions of LRR F in the Dakotas that are represented in our analysis. In the next chapter, “Econometric Analysis of Land Use Change,” we use an econometric (statistical) model to estimate the response of land use to changes in crop revenue due to changes in market conditions or policy. In the last chapter, “Conclusions,” we use these elasticities to estimate the land use response to Sodsaver sanctions.

Econometric Analysis of Land Use Change

The simulation analysis in the previous chapter offers a way to investigate the likely effects of specific programs, particularly programs that do not currently exist (e.g., Sodsaver). Econometric (statistical) analysis based on past land use can complement simulation analysis by providing fresh insight on the overall responsiveness of producer land use decisions to variation in market revenue and cost, program payments, and land quality. While all of these factors have been considered in past studies of land use, ongoing changes in input and output markets, technology, and Government programs may be altering the relationship between farm program payments and land use.

The core of this chapter is counterfactual, or "what if," analysis. We estimate an econometric model, then use it to estimate the role of farm programs in major land use decisions. What would have happened if crop insurance, MLBs, or disaster assistance had been limited or absent altogether in the past? We focus on these programs because producers can expand eligible acreage by expanding cropland acreage through grassland to cropland conversion. Even small benefits from these programs could encourage some producers who were considering grassland conversion to go ahead and make the land use change. Other producers who would have returned cropland to grass cover could reconsider those plans based on benefits available from farm programs.

Previous research on allocation of land to major uses has generally found that farm programs affect the balance between cropland and other uses, including grassland, although conclusions about the size of this effect vary. Lubowski, Plantinga, and Stavins estimated that farm programs increased cropland acreage by about 2 percent from 1982 to 1997. Gardner, Hardie, and Parks (2010) argue that in the absence of farm programs, cropland acreage would have been 22 percent lower during 1987-1997. A number of studies have focused specifically on crop insurance. Lubowski et al. (2006) estimate that the 1994 crop insurance premium subsidy increase added between 0.5 and 1.1 percent to cropland acreage nationwide. Goodwin, Vandeveer and Deal, using data from the Corn Belt and Northern Plains, estimate that a 30-percent reduction in crop insurance subsidies would reduce cropland acreage by 0.2 to 1.1 percent. Young, Vanderveer, and Schnepf use a simulation model to argue that acreage in 10 major field crops is about 0.4 percent higher with subsidized crop insurance than without. Wu found that crop insurance encouraged producers to grow cultivated crops, particularly soybeans, rather than hay. Rashford, Walker, and Bastin (2010) include Government payments in their model but find that the effect of these payments on pasture and rangeland conversion is very small (the coefficient is not significantly different from zero), although the model does suggest that Government payments could have a modest role in keeping land in crop production.

These studies use data for periods ending in 1997 or earlier, predating changes in farm commodity policy and an increase in crop insurance subsidies. (We are not aware of any studies using more recent data on major land use change.) Farm program changes enacted in the 1996 Federal Agriculture Improvement and Reform Act (1996 Farm Act) allow farmers to expand cropland acreage without risking loss of farm program payments (except in cases of wetland or highly erodible land). The 1996 Farm Act also mandated marketing loans for grains and oilseeds. Increases in crop insurance subsidies under the Agricultural Risk Protection Act of 2000 expanded crop insurance participation and may be encouraging farmers to expand crop acreage at the expense of grassland (USGAO, 2007; Morgan, 2008). These changes in policy may have altered—and perhaps increased—the role of farm programs in major land use decisions.

Crop insurance, disaster assistance, and MLBs can increase the average revenue to crop production over time and reduce variability in crop revenue, particularly downside variability, by making payments in low-price or low-revenue years. Only a handful of previous econometric studies have considered variability in the context of major land allocation: yield variance was included as an explanatory variable by Goodwin, Vandeveer, and Deal and by Wu. While Wu and Adams also considered the effect of revenue variance and revenue-based crop insurance on the allocation of cropland among crops, their work did not address major land use change. To extend previous work, our analysis incorporates the effect of expected market revenue, the variance of market revenue, and the effect of farm programs on both. Considering variability may yield new insight into how farm program payments affect decisions about land use.

For this analysis, we broaden our geographic scope to include 77 North Dakota and South Dakota counties (fig. 23). We focus on portions of LRR F (Transitional Region) located in South Dakota and the Southern part of North Dakota and include nearby counties located in LRR G (Range Region) and LRR M (Western Corn Belt; see figure 7a). More specifically, we focus on counties in Major Land Resource Area (MLRA) 53B (Southern portion), 53C, 54, 55B (Southern portion), and 55C. The Hand-Hyde area, where Stephens et al. observed an average annual grassland conversion rate of 0.6 percent (see the chapter, "Grassland and Grassland-Cropland Conversion, 1997-2007,"), is contained in MLRA 53C and 55C. More broadly, producers in LRR F shifted large acreages of cropland from wheat to corn and soybeans during 1997-2007, suggesting major changes in overall production patterns, which also could be part of broader changes in land use. The resulting data cover a wide range of climactic and soil conditions, including Corn Belt conditions along the Eastern edge and rangeland and ranching dominated landscapes in the Far West. For this area, we have data on land use and land use drivers for each year from 1998 to 2007, a period that encompasses a wide range of economic conditions, including large variations in commodity prices and farm program payments.

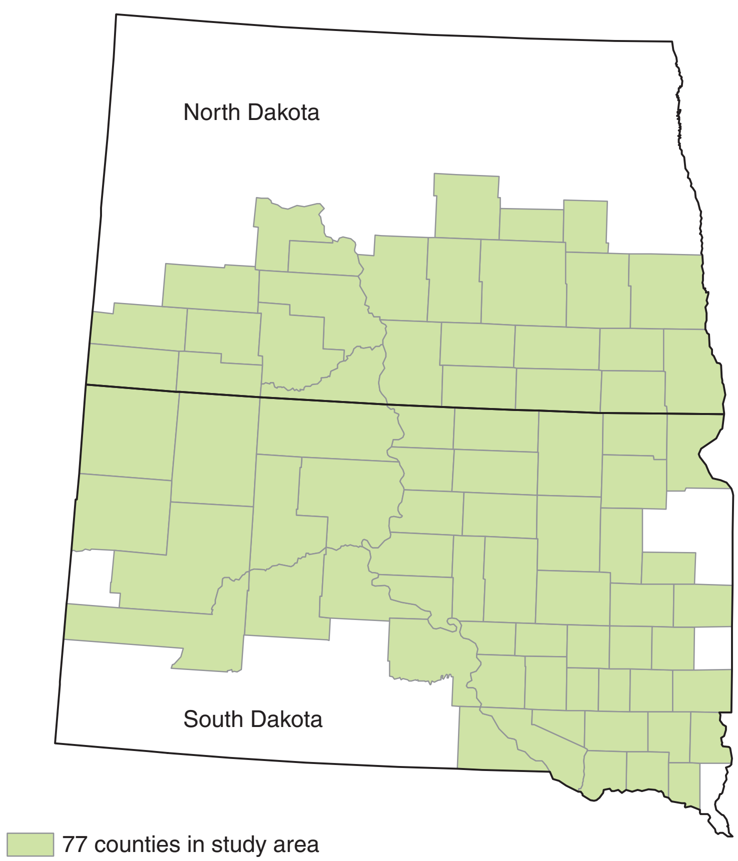
We estimate land use response to changes in expected revenue and revenue variance (including the effect of farm programs on expected revenue and revenue variance), using a probabilistic choice model. This class of statistical or econometric model is designed to estimate the probability that an individual decisionmaker will select a specific option from a set of discrete options, given the economic return to each option.

We assume that farmers/landowners choose from the four land use categories defined in the second chapter: cultivated cropland, hay and pasture, range, and the CRP. Land under an ongoing CRP contract is excluded from the dataset because continuing CRP enrollment does not represent a land use choice. (The dataset does include CRP-eligible land that has not yet been enrolled in CRP and CRP land where contracts are expiring.) Land use is represented using site-specific data from the NRI (USDA-NRCS, 2009). Land use choices are observed discretely rather than as shares. From the NRI, we define a dataset of 10,655 choice events for 1,171 NRI points over the years 1998-2007 (see appendix B for details).

To explain land use, our econometric model includes variables on expected revenue, the variance of revenue, nonland production costs, and land quality including a productivity index and binary indicators for irrigation, highly erodible soil, and hydric (potentially wet) soil. The crop revenue variable includes the effect of benefits from crop insurance, marketing loans, and disaster assistance programs because these programs were in place when land use decisions were made.[18] Land quality variables provide site-specific information on the agronomic potential, whereas revenue and cost variables can be defined only at a county level. Our dataset does not include information on technology adoption and we do not explicitly model crop choice. The effect of technology is accounted for, in part, through its effect on revenue (through yields) and costs. In estimating revenue and costs, moreover, crop mix (the proportion of cropland in corn, soybeans, and wheat) is allowed to evolve county by county as a moving average of crop acreages in the most recent 3 years. Data and methods are detailed in appendix B.

[18]Given that previous disaster payments were based on ad hoc programs that varied from year to year, the effect of these payments on revenue variability could not be systematically represented.

Figure 23
Study area for econometric estimation, North Dakota and South Dakota



Source: USDA, Economic Research Service.

Finally, for the counterfactual analysis, we estimate the change in the probability of each land use for each observation when revenue (both mean and variance) is changed to reflect the loss of farm program benefits. Changes in estimated probability are translated to estimated changes in acreage by multiplying the change in probability at each NRI point included in our sample by the acreage weight (expansion factor) for the point. Because we are using a representative subsample of the data, we adjust the weights so that they add up to the full acreage of the study area.

Together, Crop Programs Add 8.5 Percent to Average Annual Crop Revenue

Table 3 shows the effect of crop insurance, marketing loans, and disaster assistance on expected crop revenue, averaged over space and time. Marketing loans increased expected return to crop production by 3.3 percent, on average, while crop insurance subsidies and disaster assistance added roughly 1.7 and 3.6 percent, respectively, to expected crop revenue. Altogether, these programs added 8.5 percent to average annual crop revenue.

In terms of variance, crop insurance has a huge effect, reducing the crop revenue variance by 36 percent. MLBs, however, have comparatively little effect on revenue variance (and even increase it slightly). MLBs differ from crop insurance in the sense that they are triggered by low prices rather than by low yields or revenue. In the Northern Plains, crop revenue variance is dominated by yield variance so that yield-based and revenue-based crop insurance are both strongly countercyclical to market revenue. Low-price years, however, are not necessarily low-revenue years.

We did not attempt to estimate the effect of disaster assistance on crop revenue variance. Before 2008, disaster payments were ad hoc. Congress routinely enacted disaster assistance measures primarily in response to yield-reducing weather events. Actual disaster payments, however, were often received by farmers 1-2 years after losses were incurred. Disaster assistance payment data (drawn from the Consolidated Federal Funds (CFF) report from the U.S. Census Bureau) indicate only when the payments were made (not when losses were incurred), making it impossible to accurately estimate

Table 3

Change in expected value and variability of revenue as a result of farm programs

		Expected revenue		Variance of revenue	
		Dollars per acre	*Change from all revenue (percent)*	*Dollars per acre*	*Change from all revenue (percent)*
All revenue		166.14	0.00	2,282.8	0.0
Exclude:	Crop insurance	163.41	-1.65	3,110.0	36.2
	Marketing loan benefits	160.73	-3.26	2,214.3	-3.0
	Disaster assistance	160.23	-3.56	3,000.2	**
	All three programs	152.09	-8.48	3,000.2	31.4

**Variance not estimated; see appendix B for details.
Source: USDA, Economic Research Service.

the countercyclical effect of disaster assistance. Nonetheless, ad hoc disaster payments have been a major feature of U.S. agricultural policy in recent decades. Following Goodwin and Rejesus, we use a 5-year moving average of disaster assistance payments to specify the expected value of disaster assistance.

Table 4 shows average estimated elasticities[19] for each land use with respect to revenue, cost, and land productivity variables. The elasticities measure how farmers' land allocation decisions respond to a 1-percent change in one of these variables. For example, a 1-percent increase in expected crop revenue is estimated to increase the probability of using a field as cropland by 0.32 percent, on average, while reducing the probability of hay and pasture by 0.51 percent, range by 0.18 percent, and CRP by 0.15 percent. Given that there are roughly 50 million acres of agricultural land in the study area, a 0.32-percent increase in the average predicted probability of cropland (0.46) could increase cropland acreage roughly 70,000 acres. The effect of a change in variance is smaller; a 1-percent increase in crop revenue variance would decrease crop acreage by 0.03 percent, about one-tenth the size of the expected revenue effect. In reality, however, the variance response is important given the large effect of crop insurance on crop revenue variance.

Table 5 gives the average acreage for each major land use category in our study region and the average estimated change in land use probabilities and acreages from eliminating crop insurance, MLBs, and disaster assistance payments. The model estimates are changes in equilibrium acreage. Farmers may adjust to a new equilibrium by slowing grassland to cropland conversion, increasing cropland to grassland conversion, or both. Given the amount of land that moves between grassland and cropland, either adjustment is plausible (see figures 1-5). The land use effect of farm programs can vary with

[19]Elasticities are estimated for each choice event then averaged to arrive at the elasticities reported in table 4.

Table 4

Estimated average land use elasticities for revenue, cost, and land productivity variables

	Cropland	Hay and pasture	Range	CRP
Expected revenue				
Cultivated crops	0.322	-0.508	-0.175	-0.153
Hay and pasture	-0.150	0.443	-0.054	-0.015
Rangeland	-0.038	-0.052	0.184	-0.136
CRP	-0.009	-0.006	-0.040	0.060
Variance of revenue				
Cultivated crops	-0.026	0.064	0.011	0.020
Hay and pasture	0.006	-0.055	0.010	0.022
Rangeland	0.001	0.007	-0.021	0.075
Production costs				
Crop cost	-0.192	0.344	0.081	0.128
Hay cost	0.069	-0.273	0.031	0.018
Grazing cost	0.024	0.049	-0.159	0.167
Land productivity	0.225	-0.341	-0.274	-0.037

CRP = Conservation Reserve Program.
Sowurce: USDA, Economic Research Service.

Table 5

Estimated land use effect of selected farm programs

	Unit	Cropland	Hay and pasture	Range	CRP
Acreage	*Average acres (000)*	23,454	8,007	15,804	599
	Share	0.490	0.167	0.330	0.013
	Predicted probability	0.469	0.162	0.284	0.085
No crop insurance	*Probability change*	-0.0050	0.0029	0.0011	0.0010
	Acreage change (000)	-235	137	51	47
	Percent of acres	-1.0	1.7	0.3	7.9
No marketing loan benefits	*Probability change*	-0.0034	0.0018	0.0010	0.0006
	Acreage change (000)	-161	86	46	29
	Percent of acres	-0.7	1.1	0.3	4.8
No disaster payments	*Probability change*	-0.0063	0.0039	0.0018	0.0006
	Acreage change (000)	-292	180	85	27
	Percent of acres	-1.2	2.2	0.5	4.5
No program payments	*Probability change*	-0.0147	0.0087	0.0039	0.0022
	Acreage change (000)	-686	403	181	102
	Percent of acres	-2.9	5.0	1.1	17.0

Source: USDA, Economic Research Service.

economic and policy conditions. For example we estimate that marketing loan benefits prompted farmers to retain land in crop production during the early years of our time series but had very little effect in later years. The figures reported in Table 5 are the average of estimated effects for 1998-2007.

Without crop insurance, the model indicates that producers would have devoted, on average, roughly 235,000 fewer acres to crop production over 1998-2007, an average increase in cropland acreage of about 1 percent. Our estimate is comparable to previous research on the effect of crop insurance, which showed cropland effects of 0.4 to 1.1 percent.

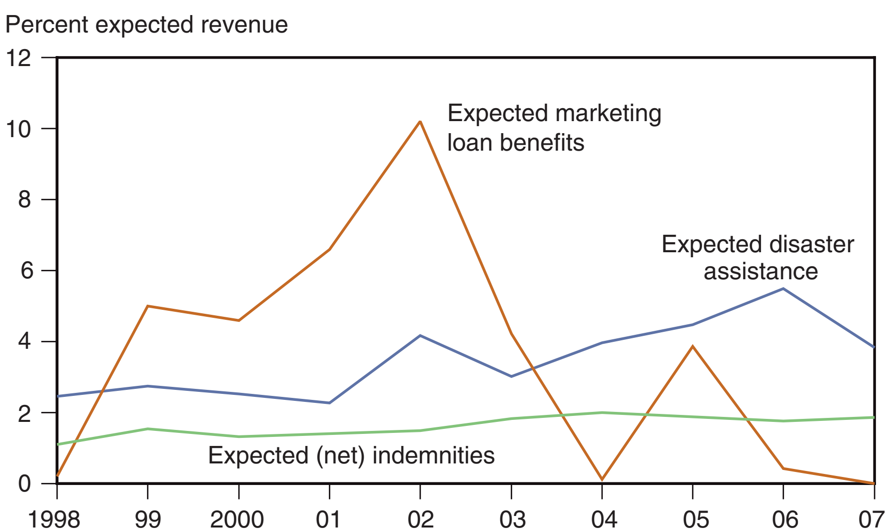
We estimate that roughly 137,000 (58 percent) of crop insurance-induced cropland acres would have been in hay and pasture in the absence of these programs, while 51,000 acres would have been in range. We note that the model underpredicts rangeland and overpredicts CRP (see the Share and Predicted Probability lines at the top of table 5) and that this could lead to underprediction of rangeland changes and overprediction of CRP change. Nonetheless, even if the rangeland acreage effect increased by 10 or 20 percent, the rangeland acreage affect would still be smaller than the hay and pasture acreage effect.

We estimate that marketing loan benefits increased cropland by 161,000 acres, while disaster assistance resulted in 292,000 additional crop acres. Again, rangeland acreage accounts for a relatively small share of the change, roughly 29 percent in both cases. The overall increase in cropland acreage is estimated to be 686,000 acres, or about 2.9 percent of average cropland acreage. The model also predicts that, in the absence of these programs, hay and pasture acreage would have been 403,000 acres larger (5 percent of 5 million acres), range acreage would have 181,000 acres larger (1.1 percent of 16 million acres), and CRP enrollment would have been 102,000 acres larger (17 percent of 600,000 acres). Our estimate is comparable to that of Lubowski, Plantinga, and Stavins, who found that farm programs accounted for about 2 percent of cropland. Our estimate is much lower than the estimate of Gardner, Hardie and Parks, who found that farm programs accounted for more than 20 percent of cropland acreage.

Acreage estimates are net changes in overall land use. As noted in the chapter "Grassland and Grassland-Cropland Conversion, 1997-2007," land moves in both directions along the margin between cropland and grassland, particularly between cropland and hay and pasture. So, an adjustment that results in increased crop acreage could be achieved by increasing the rate of grassland to cropland conversion or retaining land in crop production that might have otherwise been converted back to grass. A process that encompasses movements both into and out of grassland is likely along the margin between crops and hay and pasture. As shown in the aforementioned chapter, for the entire Northern Plains, large acreages moved between crops and hay and pasture even though the net movement of hay and pasture to cropland was small. Along the cropland-rangeland margin, however, land moved mostly from range to crops. So, it may be somewhat more likely that shifts in the allocation of land between crops and range would involve slowing rangeland to cropland conversion.

Finally, program effects vary widely across time and space. Temporal variation is largely due to changing market conditions. Between 1998 and 2007, MLBs were particularly volatile, varying from zero in high price years, to as much as 16 percent of crop revenue in years when crop prices were low, particularly soybean prices (fig. 24; see chapter, "Land Use and Land Use Change: Conceptual Issues," for more discussion). In contrast, expected crop insurance indemnities (net of farmer-paid premiums) rose steadily over time without large year-to-year swings (see figure 24). Unlike MLBs, crop insur-

Figure 24
Expected disaster assistance, marketing loan benefits, and net insurance indemnities, over time

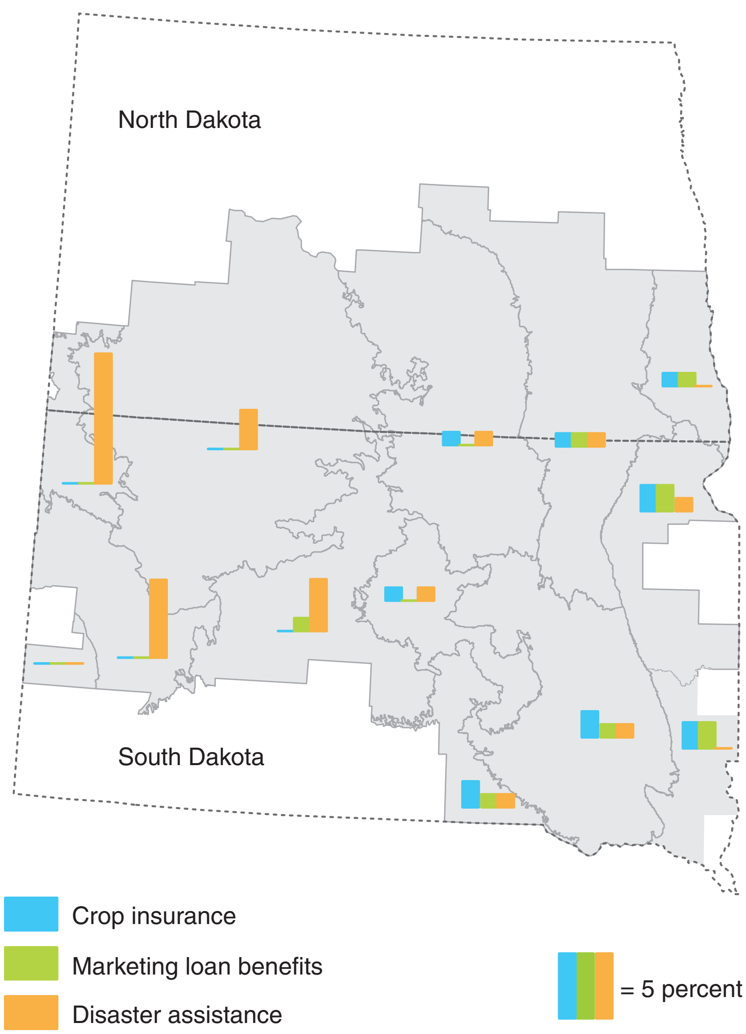


Source: USDA, Economic Research Service.

ance protects farmers against unexpectedly low yields or unexpectedly low revenue due to either low yields or an unexpectedly large intraseason decline in crop prices (see chapter "Simulation Analysis of Sodsaver: Can It Save Native Grassland?" for more discussion). Disaster payments provide a similar type of benefit.

The estimated effect of farm programs on land use varies widely across our study area (fig. 25). The crop insurance effect is spread over the eastern half of the study region. Because crop insurance is tailored to local conditions, the fact that land use effects are widespread is not surprising. For MLBs, the largest effects are in the East, where corn and soybeans are widely grown. The change is lowest in the West, where wheat is the dominant crop on (non-irrigated) cropland and yields are relatively low. As already noted, soybean producers enjoyed very large MLBs in the early years of the time series and

Figure 25
Estimated acreage effect of marketing loan benefits, crop insurance, and disaster assistance as a percentage of cultivated cropland acreage by major land resource area in 77-county study area



Source: USDA, Economic Research Service analysis of USDA, Natural Resources Conservation Service data.

a large share of the MLB effect can be attributed to those soybean payments. In percentage terms, disaster payments have a relatively large effect in western areas. Disaster payments require countywide disaster declarations, which are more common in areas where rainfall is marginal for crop production, as is the case in the western portions of our study region. While percentage changes in cropland acreage are high is the West, overall cropland acreage is small so the total number of acres affected is also comparatively modest.

Farm Programs Have Modest but Measureable Impact on Amount of Cropland

Farm programs have had a measureable impact on the amount of cropland in the portion of the Northern Plains we have studied. We estimate that, on average, for the years 1998-2007, cropland in our study region was 2.9 percent larger than it would have been without MLBs, crop insurance, and disaster payments. The largest single effect was due to disaster assistance, which increased crop production by roughly 292,000 acres (1.2 percent). MLBs are estimated to have increased cropland by 161,000 acres (0.7 percent), and crop insurance increased crop acres by 235,000 (1.0 percent). In the absence of these programs, we estimate that 181,000 acres would have remained in or been returned to rangeland, roughly 1.1 percent of rangeland acreage. Benefits from marketing loans were more likely to boost crop production in the eastern part of the study area, while disaster payments were more likely to affect land use in the western counties in the study area.

Going forward, one could expect that the effect of marketing loan benefits will likely be zero.   Given increased worldwide demand for agricultural commodities due to the boom in ethanol-related demand and other factors, crop prices are not expected to drop below commodity loan rates at any point in the foreseeable future. So long as that is true, marketing loan gains will have little impact on agricultural land use (barring an increase in commodity loan rates). Crop insurance and disaster assistance (the SURE program) will continue to protect farmers from unexpectedly low yields or low revenue relative to price and yield expectations at planting time. Even when planting-time prices are at historically high levels, producers can benefit from crop insurance and disaster payments.

Conclusions

Grassland to cropland conversion was largely focused in the Northern Plains between 1997 and 2007. Compared to other regions, producers in the Northern Plains were far more likely to convert rangeland to cropland between 1997 and 2007 and more likely to retain land in crop production rather than converting it to hay or pasture. Over the same period, however, producers in the Northern Plains were more likely than others to enroll new land in the CRP, nearly all of it converted to some type of grass cover.

Different types of grassland have different interactions with cropland. The margin between cropland and hay and pasture is characterized by constant movement of land into and out of crop production as producers rotate some of their land into and out of cultivated crops. Net adjustments in the allocation of land between these uses could be accomplished by changing the rate of conversion into or out of cultivated crops. The margin between rangeland and cropland is different in the sense that land moved mostly from range to crops between 1997 and 2007, although some land did move from crops to range. Northern Plains' producers enrolled more than 3.5 million acres of cultivated cropland in the CRP, while only half of the land exiting the CRP was returned to crop production. CRP land that remained in grass was classified, in roughly equal shares, as hay, pasture, or range.

Our econometric model predicts the net movement of land between uses, which is the sum of gross movements into and out of specific land uses. Based on our econometric model, we estimate that the combined effect of crop insurance, MLBs, and disaster assistance increased cropland acreage by an average of 2.9 percent (686,000 acres in our 77-county study area) during the study period (1998-2007). We also estimate that 26 percent of these acres were drawn from rangeland (181,000 acres; 1.1 percent of rangeland) where native grasslands are most likely to found. Most of the difference is drawn from hay or pasture (403,000 acres; 5 percent of hay and pasture) with the balance coming from land that might have otherwise been enrolled in the CRP. Because land routinely moves in both directions at the margin between cropland and grassland uses, a movement of cropland to grassland could be accomplished by reducing the rate of grassland to cropland conversion, increasing the rate of cropland to grassland conversion, or both.

Actual gross rangeland to cropland conversion between 1997 and 2007 was roughly 1.1 percent, while net conversion was roughly 0.8 percent. In comparison, the model prediction of a 1.1-percent net shift from cropland to rangeland due to the withdrawal of all three farm programs is relatively large.[20] Crop insurance accounts for about one-third of the effect, increasing cropland acreage by 1 percent and reducing rangeland acreage by 0.3 percent, while disaster payments and MLBs reduce rangeland acreage by 0.5 percent and 0.3 percent, respectively. The extent to which native grasslands would have been preserved depends on the extent to which adjustment would have been accomplished by slowing rangeland to cropland conversion and the proportion of these rangelands that are native rangeland. The size of the adjustment and mix of changes in grass-to-crop and crop-to-grass movements may vary spatially and over time.

[20]These numbers are not exactly comparable, as our estimated acreage change is an equilibrium effect, not an estimated change in the rate of grassland to cropland conversion. However, reducing grassland to cropland conversion is one way producers could adjust to a new equilibrium.

Since 2007, higher commodity prices may have reduced the role of farm programs while increasing incentives for grassland to cropland conversion. Given sharply increased corn demand (for ethanol production and other uses) and the secondary or indirect effect on the price of other commodity crops, prevailing prices for corn, wheat, and soybeans in 2008-2010 are significantly higher than pre-2007 levels. (It is unlikely that prices will be low enough to trigger MLBs at any time in the near future.) Crop insurance and SURE will continue to protect producers against intraseason drops in crop revenue, regardless of whether prices are historically high or low at the beginning of the season. So, even when crop prices are quite high, crop insurance and SURE could increase expected revenue, reduce revenue risk, and increase net movement of grassland to cropland at the margin, although the role of these programs could be diminished in the face of very strong commodity markets.

Finally, a key question is whether Sodsaver would significantly slow grassland to cropland conversion. Based on the simulation model developed in the chapter "Simulation Analysis of Sodsaver: Can It Save Native Grasslands?" and rangeland to cropland conversion elasticities drawn from the literature, we estimated that Sodsaver could slow the grassland to cropland conversion by up to 9 percent (in Sully County, SD). In the Hyde-Hand area studied by Stephens et al. (which includes part of Sully County), average annual grassland conversion was observed to be 0.6 percent per year between 1985 and 2003. A 9-percent reduction would reduce the average annual rate of conversion from 0.60 percent to roughly 0.55 percent.

Using elasticities from table 4, we re-estimated the effect of crop insurance on rangeland acreage in five counties in or near the Hyde-Hand area (Edmunds, Faulk, Hand, Hyde, and Sully). In the absence of crop insurance, rangeland acreages would have been 0.7 percent to 0.9 percent higher in these counties. As already noted, these are estimates of net change and are not directly comparable to estimates based on the conversion elasticities drawn from the literature. Nonetheless, the effects based on elasticities from our econometric model appear to be considerably larger. A critical difference is the scope of the studies from which elasticities are drawn. Our elasticity estimates are based on data from the Northern Plains and reflect the fact that the Northern Plains are a "hot spot" of grassland to cropland conversion, while the elasticities from Lubowski, Plantinga, and Stavins are average elasticities based on a national estimation.

If the average annual rate of gross rangeland to cropland conversion in the Hyde-Hand area continues to be 0.6 percent—6 percent over 10 years—our results suggest that Sodsaver, which would deny crop insurance coverage on converted native grassland for 5 years, may result in only a modest course correction. Over a period of years, ongoing conversion of grassland to cropland indicates an ongoing increase in the relative profitability of crop production when compared to grazing. The rate of conversion is unlikely to be constant over time as farmers respond to new technologies (e.g., corn seed with greater drought tolerance or improved resistance to natural pests) as they become available and changes in market conditions as they are realized. Given our estimate of the crop insurance effect on rangeland (rangeland was reduced by 0.7-0.9 percent), the loss of crop insurance may cause producers to return some cropland to grass, discourage producers from converting native grassland to crop production, or both. In the context of strong markets and technical innovation, however, the temporary loss of crop insurance could slow native grassland conversion but is unlikely to stop it.

On a broader scale, the rate of rangeland to cropland conversion is much lower, averaging less than 0.1 percent per year in the portion of the Northern Plains that intersects with LRRs F, G, and M. Our analysis suggests that much of the rangeland in LRR G (Range Region) has very low agricultural productivity and very little potential as cropland. Roughly 80 percent of agricultural land in LRR G is range while only 11 percent is cultivated for crop production. Nonetheless, our analysis indicates that disaster payments are encouraging producers to retain land in crop production that might otherwise be returned to grazing use. In the four MLRAs located with LRR G, disaster assistance is estimated to have increased cropland acreage by as much as 10 percent. Of course, a comparatively small amount of rangeland remains in LRR M, where crop production has long been the dominant land use.

Our analysis also shows that “new land” provisions governing crop insurance purchase on land that has not previously been in crop production would affect crop revenue on converted grassland. Using our model for Sully County, South Dakota, for example, we estimate that crop insurance indemnities and SURE payments would increase expected crop revenue by 5.4 percent with the new land rules in place and by 8 percent in the absence of these rules—an effect equal to 2.6 percent of expected revenue. The effect in the other counties considered in our analysis range from 1 percent to 2.5 percent of expected revenue. As already noted, relatively low T yields in Stutsman County appear to reduce the effect of crop insurance on crop revenue, at least in the first 5 years of crop production.

Ultimately, this analysis suggests that preventing native grasslands from being converted to crop production may require a broader approach than is implicit in the Sodsaver provision of the 2008 Farm Act. Other environmental compliance provisions, such as the Swampbuster provision of the 1985 Farm Act, include stronger sanctions to discourage the conversion of environmentally sensitive land to crop production. The Swampbuster provision can be used to deny all farm program payments on an entire farm for producers who drain wetlands on any part of their farm for crop production. Wetlands are similar to native grassland in the sense that they are ecologically important and, once they have been destroyed, are difficult to recreate. These stronger provisions would likely have greater effects on grassland conversion and might prove to be more effective at deterring the loss of native grasslands than we estimate for the current Sodsaver provision.

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Appendix A

Policy Models and Representative Farms for "Simulation Analysis of Sodsaver: Can It Save Native Grasslands?"

Crop Insurance Model: Net return to crop insurance participation is equal to the crop insurance indemnity less the producer-paid premium:

$$I_{it} - \rho_{it}$$

where I_{it} is the per acre indemnity for crop *i* at time *t*, and ρ_{it} is the per-acre producer-paid premium. As noted in the text, we assume that producers purchase revenue assurance (RA) at 70 percent coverage. Under the base price option, the per-acre indemnity is:

$$I_{it} = \max((\theta p_{it}^{b} \bar{y}_{it} - p_{it} y_{it}), 0)$$

where θ is the coverage level, p_{it}^{b} is the RA base (expected) price, $\bar{y}_{it}$ is the producer's actual production history (APH) yield, p_{it} is the realized price, and y_{it} is the actual yield. By law, USDA must attempt to devise actuarially fair premiums.[21] Actuarially fair premiums are equal to the expected indemnity, but farmer-paid premiums are subsidized by the Federal Government:

$$\rho_{it} = (1-\gamma) E(I_{it})$$

where γ is the premium subsidy (59 percent for 70 percent coverage).

The APH yield is a key parameter in the calculation of premiums and indemnities. Typically, the APH is based on an average of 4-10 previous crop yields. For land that has not been previously cropped, including converted grassland, special rules apply. Assuming that crop insurance is purchased in the second year of crop production, the APH yield for crop *i* would evolve as:

$$\begin{aligned}
\bar{y}_{it}^{NL} &= 0 \\
\bar{y}_{i,t+1}^{NL} &= ((1-0.20)(\tilde{y}_{i,t-1} + \tilde{y}_{i,t-2} + \tilde{y}_{i,t-3}) + y_{it}) / 4 \\
\bar{y}_{i,t+2}^{NL} &= ((1-0.20)(\tilde{y}_{i,t-1} + \tilde{y}_{i,t-2}) + y_{it} + y_{i,t+1}) / 4 \\
\bar{y}_{i,t+3}^{NL} &= ((1-0.20)\tilde{y}_{i,t-1} + y_{it} + y_{i,t+1} + y_{i,t+2}) / 4 \\
\bar{y}_{i,t+\tau}^{NL} &= \tau^{-1} \sum_{s=t}^{t+\tau-1} y_{is} \quad \tau = 4, 5.
\end{aligned}$$

where $\bar{y}_{it}^{NL}$ is the APH yield for crop *i* at time *t*, $\tilde{y}_{i,t-1}$ is the transitional yield for time *t*-1, and so on. In the No Restriction scenario, where the new land rules are relaxed, the APH would evolve as:

[21] Some researchers have argued that premiums are not actuarially fair (Just, Calvin, and Quiggen; Makki and Somwaru). Data from USDA's Risk Management Agency show that crop insurance losses are persistent in the Northern Plains (Glauber), suggesting that premiums are low and that our estimates of crop insurance premiums may be, on average, higher than actual premiums.

$$\bar{y}_{it}^{NR} = (\tilde{y}_{i,t-1} + \tilde{y}_{i,t-2} + \tilde{y}_{i,t-3} + \tilde{y}_{i,t-4}) / 4$$
$$\bar{y}_{i,t+1}^{NR} = (\tilde{y}_{i,t-1} + \tilde{y}_{i,t-2} + \tilde{y}_{i,t-3} + y_{it}) / 4$$
$$\bar{y}_{i,t+2}^{NR} = (\tilde{y}_{i,t-1} + \tilde{y}_{i,t-2} + y_{it} + y_{i,t+1}) / 4$$
$$\bar{y}_{i,t+3}^{NR} = (\tilde{y}_{i,t-1} + y_{it} + y_{i,t+1} + y_{i,t+2}) / 4$$
$$\bar{y}_{i,t+\tau}^{NR} = \tau^{-1} \sum_{s=t}^{t+\tau-1} y_{is} \quad \tau = 4, 5.$$

Supplemental Revenue Assistance (SURE) Payments Model: Payments can be made only to producers who are located in counties where a disaster has been declared (for our analysis, we assume that the U.S. Secretary of Agriculture determines that there has been a weather-related production loss of 35 percent or more in at least one crop), counties contiguous to disaster counties, or to any producer who experiences production 50 percent or more below normal levels.[22]

Once a disaster is declared, the SURE payment is made when whole-farm revenue drops below a revenue guarantee:

$$D_t = \max(0.60(G_t - R_t), 0)$$

where G_t is the SURE guarantee and R_t is total farm revenue. The SURE guarantee depends on the level of crop insurance coverage selected by the producer, expected prices, and the producer's APH yield, but is limited to no more than 90 percent of expected revenue:

$$G_t = \min\left(1.2\sum_i (a_{it}\theta p_{it}^b \bar{y}_{it}), 0.90\sum_i a_{ti} p_{it}^b \max(\bar{y}_{it}, y_i^{ccp})\right)$$

where a_{it} is planted acreage of crop i at time t (or acreage where planting was prevented) and y_i^{ccp} is the producer's counter-cyclical payment program yield. Total farm revenue (for crops) includes market revenue, commodity program payments, and crop insurance indemnities:

$$R_t = \sum_i a_{it}\left(p_{it} y_{it} + I_{it} + L_{it}\right) + 0.15DP_t + CCP_t$$

where L_{it} is the per-acre marketing loan benefit, DP_t is the producer's total (farm-level) direct payment, and CCP_t is the total countercyclical payment.[23] When the market price of a covered commodity (e.g., corn, wheat, soybeans) drops below a fixed "loan rate," the marketing loan benefit is the difference between the loan rate and the market price:

$$L_{it} = \max((\bar{p}_i - p_{it}) y_{it}, 0)$$

where $\bar{p}_{it}$ is the loan rate. The change in the SURE payment triggered by bringing new land into crop production is:

$$\Delta D_t = \max(0.60(\Delta G_t - \Delta R_t), 0) .$$

[22]Smith and Watts (2010) note that offering payments to individuals who experience low revenue may result in considerable moral hazard for individual farmers who anticipate losses large enough to trigger crop insurance indemnities but not large enough to trigger SURE payments. Once losses are large enough to trigger crop insurance indemnities, additional losses are fully offset by indemnities (assuming the market price is at or below the insurance price, which varies depending on the insurance product purchased). Producers who destroy enough of their crop (through lax practices or outright fraud) to qualify for SURE payments would see an increase in overall revenue due to the addition of the SURE payment. While we do not attempt to model this behavior, we recognize that producers may engage in this type of behavior.

[23]Farm revenue, as specified in the text, assumes the farmer will stay with traditional commodity programs. Farmers who choose the Average Crop Revenue Election program (ACRE) will lose their Counter-Cyclical Program (CCP) payment while Direct Payments (DPs) will be reduced by 20 percent and the loan rate by 30 percent.

If cropping patterns on new land reflect those of the overall farm, the per-acre change in the guarantee will be:

$$\Delta G_t = 1.2\sum_i (a_{it}/A_t)\theta p_{it}^b \bar{y}_{it} \quad \text{or} \quad \Delta G_t = 0.90\sum_i (a_{it}/A_t) p_{it}^b \max(\bar{y}_{it}, y_{it}^{ccp})$$

where $A_t = \sum_i a_{it}$ is total crop acreage at time t. Under the new land rules, the per-acre change in farm revenue will be:

$$\Delta R_t = \sum_i (a_{it}/A_t)\left(p_{it} y_{it} + I_{it}^{NL} + L_{it}\right)$$

where I_{it}^{NL} is the crop insurance indemnity under the new land rules (the change in revenue for the No Restriction scenario is obtained by replacing I_{it}^{NL} with I_{it}^{NR}). We do not include direct and countercyclical payments because they do not apply to new land. For the sake of brevity, we assume that planting decisions on existing cropland will not be affected by land use conversion.

Risk Model. When facing the new land rules, the producer's risk premium—his willingness to pay for the risk reduction due to crop insurance and SURE—is defined as:

$$\text{(A1)} \qquad E\left(u(w_t + \pi_t^{NL} - \psi_t^{NL})\right) \equiv E\left(u(w_t + \pi_t^{NL} + \varphi_t^{NL})\right),$$

where u is utility, w_t is wealth at the beginning of period t, ψ_t^{NL} is the risk premium, π_t^{NL} is the producer's (stochastic) net return during period t, and φ_t^{NL} is a term that eliminates the risk-reducing effect of crop insurance and SURE on converted grassland while holding expected wealth constant. Under the new land rules, farm profit is represented by:

$$\pi_t^{NL} = A\ (\sum_i (a_i/A\ )(p_i y_i + L_i + I_{it} - C_i - \rho_{it})) + D_t + CCP + DP +$$
$$A_{conv}(\sum_i (a_i/A\ )(p_i y_i + L_i + I_{it}^{NL} - C_i - \rho_{it})) + \Delta D_t^{NL} +$$
$$(A_g - A_{conv})(R_g - C_g),$$

where A is crop acreage before conversion; p_i is market price for crop i; Y_i is the yield; L_i is the marketing loan benefit; I_{it} is the crop insurance indemnity, C_i is per-acre cost; ρ_{it} and is the per-acre insurance premium; D_i is the SURE payment; CCP is the countercyclical payment; DP is the direct payment; A_{conv} is acreage converted from grass to crops; I_{it}^{NL} is the indemnity on converted land; ΔD_t^{NL} is the change in SURE payment due to conversion; A_g is grazing acreage before conversion; R_g is annual per-acre grazing land revenue; and C_g is annual per-acre grazing land (beef cow-calf) cost. Finally, φ_t^{NL} is a term that eliminates the countercyclical effect of crop insurance and SURE payments on acres converted from grassland to cropland:

$$\varphi_t^{NL} = A_{conv}\left(\sum_i (a_i/A\ )(E(I_{it}^{NL}) - I_{it}^{NL})\right) + E(\Delta D_t^{NL}) - \Delta D_t^{NL}.$$

This term effectively replaces the crop insurance and SURE terms in π_t^{NL} with their expected values, so that $\pi_t^{NL} + \phi_t^{NL}$ is a mean preserving spread of π_t^{NL}.

The left hand side (LHS) of (A1) is expected utility with variance reduction due to crop insurance and SURE, less the risk premium. The right hand side (RHS) of (A1) is expected utility without this variance reduction. To simulate risk premiums, we specify utility as a power function: $u(v_t) = (v_t)^{1-\eta} / (1-\eta)$, where η is the coefficient of relative risk aversion and v_t is end of period wealth. This function has been used previously in similar work (see Vedenov and Powers; Gray et al.).

Representative Farms: Price-Yield Distributions and Simulation Methods

We develop a series of representative farms based on county data. Underlying each representative farm is a joint distribution of prices and yields for the three predominant crops (corn, soybeans, and wheat) and grazing land. Our work builds on, but is distinct from, previous efforts to develop joint price-yield distributions such as Vedenov and Powers, Featherstone and Kastens, and Grey et al. In this section, we (1) develop the price and yield distributions, (2) show how the mean and variance effects of program benefits are calculated using these distributions, and (3) specify the utility function, farm-level profit, and risk parameters needed (along with the joint distributions) to estimate risk premiums.

The joint distribution of yields and prices for corn, soybeans, and wheat is modeled by generating correlated within-season price and yield deviates (Cooper 2009a, 2009b, 2010). First, national average yields (obtained from USDA's National Agricultural Statistics Service) are re-expressed as within-season yield deviations for crop i in year s as $\Delta Y_{is} = \left(Y_{is} - E\left(Y_{is}\right)\right) / E\left(Y_{is}\right)$,

where expected yields, $E(Y_{is})$ are estimated by regressing national average yields on a linear trend using data for 1975-2008. We use capital letters to denote past yields and prices, distinguishing them from the prospective yields and prices, and s to denote past years. County yields, obtained from NASS, are also transformed to deviation form (denoted as ΔY_{is}^k) where k indexes the county.

Realized harvest prices are also transformed into deviation form:

$$\Delta P_{is} = \left(P_{is} - E\left(P_{is}\right)\right) / E\left(P_{is}\right),$$

where $E(P_{is})$ is the planting time expected price. We follow RMA definitions for expected (RA base) and realized prices. The expected price of corn is the average of daily closing prices in February for the December Chicago Board of Trade (CBOT) corn contract. The realized price is the average of daily closing prices during October for the CBOT December corn contract. Expected and realized soybean prices are based on the February and October prices, respectively, for the December CBOT soybean contract. For hard red spring wheat, expected and realized prices are based on March and August prices, respectively, for the Minneapolis Grain Exchange (MGE) September contract.

The relationship between price and yield vectors is estimated by regressing onand other explanatory variables (z_i):

(A2) $\Delta P_{is} = g(\Delta Y_i, z_i) + \varepsilon_i$

where ε_i is the error term. We expect that $d\Delta P_i / d\Delta Y_i < 0$, i.e., the greater the realization of national average yield over the expected level, the more likely harvest time price will be lower than the expected price. See Cooper (2009a, 2009b, 2010) for details.

We jointly estimate the distributions of price and yield deviations by repeated estimation of equation (A2) using a pairs-bootstrap approach in a joint resampling methodology that involves drawing *i.i.d.* observations with replacement from the original data set (e.g., Yatchew). For each draw of a yield deviation, we estimate a price-yield coefficient vector using (5). The procedure creates M (=1,000) coefficient vectors representing uncertainty in the yield-price relationship.

Next, deviation vectors for national and county yields, $\Delta\hat{Y}_i$ and $\Delta\hat{Y}_i^k$, respectively, i = 1,..,3, (i.e., corn, soybeans, and wheat) are generated using a block-bootstrap approach (e.g., Lahiri) in which the pair-wise relationship between yield values is maintained across each crop and yield aggregation. We draw N (=1,000) times with replacement from ΔY_i and ΔY_i^k, i = 1,..,3, k = 1,…,9, always drawing from the same row (same s) from all vectors. The simulated yield data maintains the underlying historical Pearson and rank correlation—as well as any other relationship between the variables—between county and national yield data, both within crops and across crops. For each element of the simulated national yield deviation vector (e.g., $\Delta\hat{Y}_{in}$ where n indexes the elements of $\Delta\hat{Y}_i$) we generate M simulated price deviations for each crop based on the M price-yield coefficient vectors, resulting in an MxN (1000x1000) price deviation matrix, $\Delta\hat{P}_i$, with typical element $\Delta\hat{P}_{mni}$.

We do not extrapolate yields into the future using estimated trends. If yields are trending upward, APH yields will lag behind actual yields, decreasing the probability of a crop insurance indemnity. Modeling the trend, however, would require modeling the effect of higher yields on crop prices without other variables used in estimating price deviations. Forecasting those variables would add considerably to the uncertainty of our results.

We make two adjustments to the crop yield distributions. First, grassland is less productive, on average, than cropland. In the seven "high conversion" counties we consider, average rangeland productivity is 18 percent lower than average cropland productivity. Because relatively high productivity rangeland is most likely to be converted to crop production, we assume that crop yields on converted grassland will be about 10 percent lower than on average cropland.

Second, farm-level crop yields are typically more variable than county average yields. To represent farm-level yields, county-level yield standard deviations are inflated using a method similar to that of Coble, Dismukes, and Thomas. We select the inflation factor, α_{ki} , such that the APH indemnity calculated from our yield distribution is equal to the APH premium:

$$\underset{\alpha_{ki}}{MIN}\left[\omega_i^k - N^{-1}\sum_n \max\left\{ p_i^{APH}\left(\theta E(Y_{i,2008}^k) - y_{ni}^k\right), 0 \right\}\right]^2 ,$$

where $y_{ni}^k = \hat{Y}_{in}^k + h_{in}\left(\left(\alpha_{ki}\cdot\sigma(\hat{Y}_i^k)\right)^2 - \left(\sigma(\hat{Y}_i^k)\right)^2\right)^{0.5}$, $\hat{Y}_{in}^k = E(Y_{i,2008})(1+\Delta\hat{Y}_{in}^k)$, h_{in} is a $N(0,1)$ random variable, $\sigma(\hat{Y}_i^k)$ is the standard deviation for $\hat{Y}_i^k$, ω_i^k is the RMA premium rate (excluding the fixed rate load), p_i^{APH} is the APH price, and the coverage rate, θ , is .65. The expected value and standard deviation of resulting yields are reported in table 1 in the text, "Expected yields, standard deviations, and county transitional yields." In the balance of the discussion, we drop the county superscript (k) to reduce clutter.

As no better estimate of prices and yields (excluding the yield trend) exists for periods $t = 1,\ldots, T$ than the estimates for period 0, we assume that the density of price and yield is the same for each period, the allocation of acreage across crops is fixed, and total crop acres are fixed except for the conversion of grassland from within the farm. We drop time subscripts for acreages, expected (RA base) prices, realized prices, and actual yields but retain the time subscript for the APH yields because they evolve through time during the first few years of crop production.

Using the joint distribution, the expected value of crop insurance indemnities that would be denied by Sodsaver, assuming the new land rules are in force, would be:

$$E(I^{NL}) = (MN)^{-1}\sum_m\sum_n\sum_i T^{-1}\sum_t \delta_t (a_i/A_c) I_{it}^{NL}(p_{mni}, y_{ni} \mid \theta, \overline{y}_{it}^{NL}) ,$$

where T is the time horizon (=5) and δ_t is a discount factor based on a 7 percent discount rate. Similar expressions are used to calculate the expected value of market revenue, SURE payments, marketing loan benefits, and total revenue under USDA-RMA new land rules and the No Restriction scenario. The variance of crop revenue on converted acreage, given the new land rules, would be:

$$V(\Delta R_c^{NL}) = (MN)^{-1}\sum_m\sum_n T^{-1}\sum_t \delta_t \left(\Delta R_{ct}(p_{mni}, y_{ni} \mid \theta, \overline{y}_{it}^{NL}) - E(\Delta R_{ct}(p_{mni}, y_{ni} \mid \theta, \overline{y}_{it}^{NL}))\right)^2$$

Other variance expressions are obtained by changing the APH calculation or excluding crop insurance and SURE from the revenue calculation.

Yield and price deviation vectors are also created for grazing land. We assume that grasslands are used for cow-calf operations. Cow-calf revenue per animal unit (AU) is based on ERS farm cost and returns estimates for the Northern Plains for 1975-2008. Expected revenue is the trend revenue obtained by regressing revenue on lagged revenue, futures prices (average of July closing for fed cattle for the following year August contract (i.e., July 2002 closing prices for August 2003 contract)), and a time trend. Revenue variability is based on the error term. Forage yield variability is based on Soil

Survey estimates from USDA's Natural Resources Conservation Service for normal years, favorable years, and unfavorable years. Following the U.S. Government Accountability Office's 2007 report (GAO), we assume that favorable conditions are realized with 20 percent higher than average rainfall and unfavorable conditions occur when rainfall is 20 percent lower than average. Forage yields are converted to stocking rates (animal units (AU) per acre) using rules derived from NRCS technical documents (see Metz). Deviation vectors for cow-calf revenue (the "price" in dollars per AU) and stocking rate (the "yield" in AU per acre) are generated as part of the block-bootstrap procedure already described. We draw *N* (=1,000) times with replacement from the cow-calf revenue and forage yield vectors always drawing from the same row (same year) as crop yield vectors to maintain historical correlations between the grazing "price" and "yield" as well as with crop prices and yields.

Cropland and grazing acreages are county averages from the 2007 Census of Agriculture (appendix table A-1). The proportion of cropland in corn, soybeans, and wheat is based on three year averages (2005-07) of NASS county estimates. Crop-specific non-land production costs are based on ERS estimates for the Northern Great Plains (NGP) for 2007 (we assume that net return is the residual return to land). Crop revenues and production costs are aggregated using these proportions as weights. Non-land cost per animal unit in the NGP is obtained from the ERS and converted to cost per acre using the estimated stocking rate.

Initial wealth (at *t*=0) is based on the county average value of land and buildings, adjusted for the average proportion of land rented (ranges from 43 to 61 percent, based on the 2007 Agriculture Census) and debt-to-asset ratio (0.17, based on the 2007 ERS farm balance sheet for the Northern Plains)

Appendix table A-1

Acreages, initial wealth, and production costs in representative farms

County	Initial cropland†	Initial grassland†	Converted grassland**	Proportion of land rented†	Initial wealth	Corn††	Soybeans††	Wheat††	Crop cost†††	Grazing cost†††
	Acres				*Dollars*	*Proportion of cropland*			*Dollars per acre*	
Stutsman	932	155	23	0.48	403,326	0.16	0.55	0.28	207.63	128.08
Beadle	756	231	35	0.47	579,196	0.39	0.41	0.20	234.07	155.41
Edmunds	972	560	84	0.39	798,872	0.33	0.39	0.28	225.71	118.38
Faulk	1,334	684	103	0.42	982,699	0.23	0.43	0.34	214.13	124.69
Hand	1,026	777	116	0.40	856,701	0.29	0.22	0.49	217.35	143.67
Hyde	1,016	1,594	239	0.46	764,702	0.20	0.05	0.76	200.56	123.20
Sully	2,556	471	71	0.44	1,308,987	0.18	0.05	0.77	198.24	127.69
Turner*	451	43	6	0.54	317,515	0.53	0.47	0.00	254.14	198.19
Union*	471	41	6	0.57	256,874	0.52	0.48	0.00	253.25	126.55

* comparison county.

**15 percent of initial grassland.

Source: † USDA, National Agricultural Statistics Service, Census of Agriculture 2007; †† USDA, NASS county crop data 2005-07; ††† USDA, Economic Research Service, Farm Costs and Returns Estimates, available at: http://www.ers.usda.gov/Data/CostsAndReturns/.

(see appendix table A-1). Wealth may accumulate (decline) during the 5-year Sodsaver moratorium, possibly reducing (increasing) the risk premium in years 2-5. Producers may also see greater uncertainty as the possibility of a series of particularly bad years creates uncertainty about initial wealth in these years, possibly increasing the risk premium in years 2-5. Given these uncertainties, we elect to calculate a risk premium for each year assuming $w_t = w_0$, t=1,…,4 and report the 5-year NPV of annual risk premiums.

Finally, we assume that the coefficient of constant relative risk aversion (CRRA) is constant and equal to 2 (see Harwood et al.) but test the sensitivity of the model using values of 1.5 and 2.5. A range of values has been estimated for U.S. agriculture. Many studies report values in the range of 1-3, as reported in table 2 of Saha, Shumway, and Talpaz, although some studies report higher values, at least on the upper end of a range (e.g., Chavas and Holt report a range 1.42-6.76 for CRRA). More recently, Lence reports an estimated CRRA of 1.136. Just and Peterson suggest that many risk aversion coefficient values reported in the literature are implausibly high. So, we consider only a relatively narrow range of values. We also consider changes in acreage and debt-to-asset ratio (see table 2 in the text "Estimated risk premium for risk reduction due to crop insurance and SURE").

Appendix B

Econometric Model of Agricultural Land Use

Our main behavioral assumption is that producers and landowners face a choice among four alternative land uses (cultivated crops, hay or pasture, range, and CRP; see chapter, "Grassland and Grassland-Cropland Conversion, 1997-2007," for details) and in each choice event *t*, choose the alternative with the highest utility. The underlying theoretical model is the random utility model (RUM), which assumes that each alternative has a utility function and an additive random error (see Hensher, Rose and Greene for details).

Econometric Model Selection and Specification

Many previous econometric models of major land use implement multinomial (MNL) or nested logit (NL) models because they are analytically tractable, have closed-form probability expressions, and tend to perform well in terms of model fit (Gardner, Hardie, and Parks, 2010; Lubowski, Plantinga, and Stavins; and others). In an MNL model, errors are assumed to be independently and identically distributed following a type I extreme value distribution, which implies a property known as the independence of irrelevant alternatives (IIA). Under IIA, choice patterns must be proportional to estimated probabilities. Suppose, for example, that an increase in crop revenue increases the probability of cropland. Under IIA the estimated probabilities that the land would come from hay and pasture, range, or CRP must be proportional to the overall probability of each land use. As shown in the chapter "Grassland and Grassland-Cropland Conversion, 1997-2007," however, the margin between cultivated cropland and hay/pasture is much more active than the margin between cultivated cropland and range, even though the study region includes a lot more rangeland than hay and pasture. Nested logit models have been used to avoid IIA but are also quite restrictive; correlation among alternatives within each nest must be constant and IIA must hold across nests. If the pattern of correlations across land uses is complex, for example, patterns of correlation that could lead to overlapping nests which cannot be accommodated in a nested logit model.

To avoid IIA, we estimate a mixed logit model with random parameters and error components to account for correlation among the utilities for different alternatives (Train; Hensher, Rose, and Greene). We specify an error component for each pair-wise combination of land use alternatives, a total of six. Each error component is assumed to follow a normal distribution with zero mean and finite variance. These components capture unobservable similarities and differences across alternatives that a standard multinomial logit model cannot capture and that a nested logit model may not be able to capture, depending on the complexity of the pattern of these similarities and differences.

Random parameters are specified for the three economic variables: expected revenue, revenue variance, and production costs. Random parameters capture differences in producer response to changes in revenue or cost that may flow factors that cannot otherwise be modeled. For example, full-time farmers may be more responsive to market and policy incentives than are part-time farmers who work primarily off the farm. Producers' response to the variability of returns may reflect differences in risk aversion or the ability (or inability) to diversify risk. Differences in the difficulty of converting land from one use to another and differences in location relative to markets may also lead to differences in response.

The random parameters are assumed to follow a lognormal distribution. Because the lognormal distribution admits only non-negative values but we expect negative coefficients on the revenue variance and cost variables, we multiplied the revenue variance and production cost variables by -1 so that the associated parameter values would be positive. We estimated the model without random parameters to confirm that the expected signs of the economic variables would be realized without the restrictions imposed by the lognormal distribution. Because the economic variables vary across alternatives, a single parameter is estimated for each. Implicitly, we assume that the effect of a dollar of expected revenue, revenue variance, or production cost effects each alternative-specific utility function in the same way.

We assume that error components and random parameters vary across National Resource Inventory (NRI) points (in cross-section) but are fixed across observations on a single NRI point (in time series). By incorporating the panel structure of the data into our simulation-based model, we assume that idiosyncratic factors are constant across time, owing to the likelihood that location and land-specific factors will not change over time and that the landowner and/or land manager will also be constant in many cases.

Land quality parameters are assumed to be fixed. Land quality factors include an indicator of the availability of irrigation, an index of soil productivity, and indicators of highly erodible land and hydric soil (a proxy for soil wetness). Because these variables do not vary across the alternatives, separate parameters are estimated for each land use-specific utility function except for the normalized alternative—Conservation Reserve Program (CRP) land. In other utility functions, these parameter estimates represent the difference between the parameters for utility of land use *j* and CRP utility. A positive and significant parameter on the land productivity variable in the cropland equation, for example, implies that higher productivity land is more likely to be devoted to crop production than to be enrolled in the CRP.

For cropland, hay and pasture, and rangeland, the general form of the random utility function is:

(A3) $U_{jnt}=\alpha_j + \beta_n' X_{jnt}+\gamma_j'X_n+\theta_{jn}+\varepsilon_{jnt}$,

where

- U is utility, j indexes land use alternatives, n indexes individual points of land, and t indexes time;
- α_j is the alternative-specific constant term;
- $\beta_n' X_{jnt} = \sum_{m=1}^{3} \exp(\omega_m + \sigma_m Z_{nm}) X_{jntm}$ is the (random) effect of economic attributes that vary across alternatives, points of land and choice events (expected revenue, variance of revenue, and production cost),

where m indexes the attribute, ω_m and σ_m are parameters to be estimated, and Z_m~N(0,1);

- $\gamma_j{}'X_n = \sum_{m=4}^{8} \gamma_{jm} X_{nm}$ is the (deterministic) effect of land quality attributes that vary across points of land but not across alternatives or choice events (irrigation indicator (crop equation only), productivity index, highly erodible land (HEL) indicator, and hydric soil indicator), where X_{nm} is the attribute and γ_{jm} is the corresponding parameter;

- $\theta_{jn} = \sum_{k\neq j} \theta_{jkn} = \sum_{k\neq j} \mu_{jk} Z_{jkn}$, where θ_{jkn} represents the error component for alternatives j and μ_{jk}, represents the correlation between error terms for alternatives j and k and Z_{jkn}~N(0,1);

- and ε_{jnt} is the usual vector of individual specific random errors, with type I extreme value as in the multinomial logit model.

Because the model is normalized on the CRP alternative, land quality variables are excluded but some CRP-specific variables are included:

$$U_4 = \alpha_4 + \beta_n{}' X_{4nt} + \xi B_n + \theta_{4n} + \varepsilon_{4nt},$$

where j=4 indexes the CRP alternative, X_{jnt} are the economic attributes (revenue variance and cost are equal to zero and expected revenue is equal to zero for points that are not eligible for CRP), B_n is the exogenous environmental benefits index (EBI), ξ is the associated parameter, and $\theta_{4n} = \sum_{k\neq 4} \theta_{4kn} = \sum_{k\neq 4} \mu_{4k} Z_{4kn}$ and Z_{n4k} ~N(0,1).

Probabilities, Elasticities, and Counterfactual Analysis

Once model parameters were estimated, we used them to estimate the probability of each land use at each NRI point in the sample. The probability of land use j for the error components version of the mixed logit model is given by (subscripts for the NRI point and choice event have been dropped to reduce clutter):

$$P_j = \int L_j(\phi) f(\phi) d\phi$$

where ϕ is the overall parameter vector, $L_j(\phi) = \frac{\exp(U_j(\phi_j))}{\sum_k \exp(U_k(\phi_k))}$, and $f(\phi)$ is a density function. In practice, the integrals are approximated numerically at each NRI point using 1,000 draws on the random variables in the specified model (Z_m, m=1,2,3 and Z_{jk}, $j\neq k$, j,k=1,2,3,4)—a total of 9 random variables.

Elasticities can be derived by taking derivatives of the probability functions. For any variable, x, that varies across alternatives (expected revenue and production cost) "own" elasticies are:

$$\frac{\partial P_j}{\partial x_j}\frac{x_j}{P_j} = \frac{x_j}{P_j}\int L_j(\phi)(1-L_j(\phi))\frac{\partial U_j}{\partial x_j} f(\phi) d\phi$$

And the "cross" elasticities are:

$$\frac{\partial P_j}{\partial x_j}\frac{x_j}{P_j} = \frac{x_j}{P_j}\int L_j(\phi) L_j(\phi)\frac{\partial U_j}{\partial x_j} f(\phi) d\phi$$

For variables that do not vary across alternatives, we consider "relative" elasticities derived from the ratio of the probability of land use *j* to the probability of CRP (*r*). Conceptually, the elasticity is equal to the difference in expressions that are analogous to the "own" elasticity expression:

$$\frac{\partial(P_j/P_r)}{\partial x}\frac{x}{P_j/P_r}=\frac{x}{P_j}\frac{\partial P_j}{\partial x}-\frac{x}{P_r}\frac{\partial P_r}{\partial x}.$$

Because the CRP equation does not actually contain land quality variables, however, relative elasticities can be calculated as:

$$\frac{\partial(P_j\ /\ P_r\ )}{\partial x}\frac{x}{P_j\ /\ P_r}=\frac{x_j}{P_j}\frac{\partial P_j}{\partial x}=\frac{x_j}{P_j}\int L_j(\phi)(1-L_j(\phi))\frac{\partial U_j}{\partial x_j}f(\phi)d\phi$$

Finally, we use the probability model to develop counterfactual analysis on acreage change that would result from the elimination of crop insurance, marketing loan benefits, and disaster payments. First, we calculate the change in land use probabilities due to a change in expected crop revenue and crop revenue variance that reflects the withdrawal of payments from individual programs and all three combined. The change in probability at each point, multiplied by the NRI expansion factor, gives the estimated acreage change for the NRI point. Because only a subset of NRI points are used in our econometric estimation, we increase the expansion factors, proportionally, so that the total amount of farmland represented by NRI points used in our study is equal to the number of farmland acres estimated using all NRI points in the study region (farmland points are NRI points that remain in cultivated crops, hay and pasture, range, or CRP throughout the study period.) Finally, we sum over point-specific changes to obtain an overall estimate of land use change for the study region.

Model Results

Appendix table B-1 reports parameter estimates. Based on a likelihood ratio test, we reject the null hypothesis that all model parameters (other than the constant terms) are zero, at a level of significance of well under 1 percent (the LR statistic is 24,668, well above the critical value of 45.6 for the χ^2 distribution for $\alpha = 0.01$ with 26 degrees of freedom). The McFadden pseudo-R_2 equals 0.83 and represents a good fit of the data.

The mean and standard deviation coefficients for expected revenue, revenue variance, and cost variables are significantly different from zero at the 1-percent level. Because the underlying parameters are assumed to follow a lognormal distribution, their sign is fixed as already noted. The productivity parameter in the cropland equation is positive, not significant in hay and pasture, and negative in rangeland, indicating that high-productivity land is more likely to be cropland and less likely to be rangeland when compared to CRP. Highly erodible and hydric soils are less likely to be cropland and more likely to be rangeland relative to CRP. Irrigated land is more likely than other land to be in cultivated crops.

The parameters imply inelastic response to changes in market conditions and policy. Elasticities reported in table 4 in the main text are a weighted average of elasticities calculated for each observation in our data set (as shown above). On average, a 1-percent increase in expected revenue for cultivated crops increased the probability of crop production by only 0.32 percent.

Appendix table B-1

Estimated parameters for mixed logit model of land use

Cultivated cropland equation		Estimate		Standard error	t-statistic	p-value
Constant		16.9822	***	2.13684	7.947	<.0001
Economic variables	Expected revenue–mean[a]	-3.71026	***	0.10853	-34.187	<.0001
	Expected revenue–SD[a]	0.87806	***	0.05588	15.713	<.0001
	Variance revenue–mean[b]	-14.2645	***	1.18924	-11.995	<.0001
	Variance revenue–SD[b]	5.27541	***	0.70082	7.527	<.0001
	Production cost–mean[b]	-4.55713	***	0.24411	-18.668	<.0001
	Production cost–SD[b]	0.80778	***	0.10897	7.413	<.0001
Land quality variables	Productivity index	15.0706	***	5.66399	2.661	0.0078
	Highly erodible soil	-9.02793	***	1.62314	-5.562	<.0001
	Hydric soil	-5.04334	***	1.69155	-2.981	0.0029
	Irrigation	4.94041	***	1.51155	3.268	0.0011
Error components	Cultivated and hay/pasture	20.7692	***	1.26807	16.379	<.0001
	Cultivated and range	1.44906	***	0.33947	4.269	<.0001
	Cultivated and CRP	7.66778	***	0.41269	18.58	<.0001
Hay and pasture equation (see crop equation for revenue and cost parameters)						
Constant		10.3645	***	2.07533	4.994	<.0001
Land quality variables	Productivity index	1.83095		5.6167	0.326	0.7444
	Highly erodible soil	0.90594		1.64906	0.549	0.5828
	Hydric soil	3.82606	**	1.63373	2.342	0.0192
Error components	Cultivated and hay/pasture	20.7692	***	1.26807	16.379	<.0001
	Hay/pasture and range	4.36186	***	0.45152	9.66	<.0001
	Hay/pasture and CRP	4.51635	***	0.35791	12.619	<.0001
Rangeland equation (see crop equation for revenue and cost parameters)						
Constant		8.40158	***	2.0947	4.011	0.0001
Land quality variables	Productivity index	-5.76774		5.92495	-0.973	0.3303
	Highly erodible soil	10.9581	***	1.88448	5.815	<.0001
	Hydric soil	3.18464	*	1.66202	1.916	0.0553
Error components	Cultivated and range	1.44906	***	0.33947	4.269	<.0001
	Hay/pasture and range	4.36186	***	0.45152	9.66	<.0001
	Range and CRP	5.31803	***	0.63999	8.309	<.0001
Conservation Reserve Program (CRP) equation (see crop equation for revenue parameter)						
Economic variable	Exogenous EBI	0.20499	***	0.03229	6.348	<.0001
Error components	Cultivated and CRP	7.66778	***	0.41269	18.58	<.0001
	Hay/pasture and CRP	4.51635	***	0.35791	12.619	<.0001
	Range and CRP	5.31803	***	0.63999	8.309	<.0001

EBI = Environmental Benefits Index
CRP = Conservation Reserve Program.
Mean = mean of normal distribution underlying the lognormal parameter.
SD = standard deviation of normal distribution underlying the lognormal parameter.
[a] Parameter is common to all equations.
[b] Parameter is common to cultivated crop, hay and pasture, and range equations.
***, **, and * = significance at 1-, 5-, and 10-percent levels, respectively.
Source: USDA, Economic Research Service.

The 1-percent increase in crop revenue would reduce the probability of hay and pasture by 0.50 percent, the probability of range by 0.18 percent, and the probability of CRP by 0.09 percent. Using a standard multinomial logit model (assuming IIA) these “cross” elasticities would have been constant across all three alternative land uses. Similar sets of elasticities are reported for changes in expected revenue to hay and pasture, rangeland, and CRP.

The average effect of a 1-percent change in crop revenue variance on cropland acreage is less than one-tenth the size of the change that would flow from a 1-percent change in expected crop revenue. A 1-percent increase in crop revenue variance would decrease cultivated crop acreage by 0.026 percent while hay and pasture, rangeland, and CRP acreage would rise by 0.064 percent, 0.011 percent, and 0.010 percent, respectively. The average effect of production costs are also smaller than that of expected revenue, but much larger than the effect of revenue variance. A 1-percent increase in crop cost would decrease cropland acreage by 0.192 percent while increasing hay and pasture, range, and CRP acreage by 0.34, 0.081, and 0.063 percent, respectively. Again, similar sets of elasticities are reported for changes in expected revenue to hay and pasture, rangeland, and CRP.

Data—Land Use

In estimating land use response, we assume that farmers/landowners choose from the four land use categories defined in the chapter “Grassland and Grassland-Cropland Conversion, 1997-2007”: cultivated cropland, hay and pasture, range, and the Conservation Reserve Program. Land use is represented using site-specific data from the National Resources Inventory collected and maintained by the USDA Natural Resources Conservation Service (USDA-NRCS, 2009). For each year from 1998 to 2007, NRI includes annual land use observations for a nationally representative set of 110,771 “core” points. We use 1,171 core points that (1) were located in our study region (defined in the text; see fig. 23), (2) remained in cultivated crops, range, hay, pasture, or CRP throughout 1998-2007, and (3) were designated as Point No. 1 within each primary sampling unit. Primary sampling units are plots of 40-160 acres that typically include three NRI points. Selecting only the first point reduces spatial correlation within the data and reduces the size of the data set to make advanced, simulation-based econometric techniques possible.

A land use choice event is defined as a decision to use a specific plot of land as cultivated cropland, pasture or hay, range, or to enroll land in the CRP in a specific year. We observe up to 10 land use choice events for each NRI point included in our data set, although fewer are observed for points where land is under CRP contract. Land under an ongoing CRP contract is excluded from the data set because continuing CRP enrollment does not represent a land use choice. The data include CRP-eligible points that are not yet enrolled in CRP, and points under an existing CRP contract that will expire before the end of the year. Expiring CRP land is automatically eligible for re-enrollment—producers can offer bids during the last year of an existing contract. The resulting data set contains a total of 10,655 land use choice events.

Data—Economic Variables

In this section, we describe the development of per acre expected revenue, revenue variance, and production costs for cropland, hay and pasture, and grazing land. For cropland, the revenue variables include the effect of crop insurance, marketing loan benefits, and disaster payments. For crop revenue, we begin by describing the development of joint distributions for crop prices and yields. We then develop models of marketing loan benefits and crop insurance indemnities and describe disaster assistance data. Finally, we show how the joint distribution and policy models are combined to estimate expected revenue and revenue variance. The discussion of crop revenue is followed by discussions of hay and pasture revenue, rangeland revenue, and production costs for all three land uses.

Crop Revenue—Joint Distribution of Prices and Yields. We use three major crops (corn, wheat, and soybeans) to represent cropland revenue. Crop yields are represented by empirical distributions derived from NASS county data using a methodology developed by Cooper (2009a, 2009b, 2010). Expected yields are calculated as an Olympic average of the most recent five yields (the average with the high and low values removed). To estimate yield deviations, we start with deviations from a linear trend, fitted using the most recent S (=23) yields. Because these deviations are based on county-average yields, however, they reflect the effects of averaging and most likely underestimate farm-level deviations. To approximate farm-level conditions, we inflate the county yield deviations until expected losses, based on a yield guarantee of 65 percent, equal yield-based (MCPI) crop insurance premium rates for 65 percent coverage—a procedure similar to that of Coble, Dismukes, and Thomas. The yield distribution vector for crop i at time t, denoted, contains S elements defined as:

$$\hat{y}_{its} = E(y_{it})\Delta y_{its} = E(y_{it})\left(\frac{\alpha_i(y_{i,t-s} - y^T_{i,t-s})}{y^T_{i,t-s}} + 1\right),$$

where $E(y_{it})$ is an Olympic average of the most recent five yields, Δy_{its} is the yield deviation factor, $y_{i,t-s}$ is the realized yield, $y^T_{i,t-s}$ is the trend yield at time (year) t-s, and $\alpha_i$is the inflation factor. County- and crop-specific inflation factors are chosen, using 2007 data, so that the expected loss per dollar of liability, based on a 65-percent yield guarantee, is equal to the MCPI premium based on 65 percent coverage:

$$\text{(A4)}\quad \min_{\alpha_i}\left\{\left(\omega(\bar{y}_{i,2007}) - S^{-1}\sum_s \max\left(\frac{(0.65\bar{y}_{i,2007} - E(y_i)\Delta y_{i,2007,s}(\alpha_i))}{0.65\bar{y}_{i,2007}}, 0\right)\right)^2\right\}$$

where $\omega(\bar{y}_{i,2007})$ is the APH (yield insurance) premium rate (dollars per dollar of liability) for 65 percent coverage (excluding the fixed rate load) calculated from RMA county actuarial data, and $\bar{y}_{i,2007}$ is a simple average of 1997-2007 yields for the county, which approximates the APH yield. The right hand side of (A4) is the expected loss per dollar of liability given 65 percent coverage. The inflation factors are used for all years, even though they are calculated using 2007 data.

Crop prices are also represented by empirical distributions based on futures price data. Expected prices are represented by planting time prices for the harvest month future contract. For example, the expected price of corn is the average of daily closing prices in February for the December Chicago Board of Trade (CBOT) corn contract. The realized price is the average of daily closing prices during October for the CBOT December corn contract. Expected and realized soybean prices are based on the February and October prices, respectively, for the December CBOT soybean contract. For hard red spring wheat, expected and realized prices are based on March and August prices, respectively, for the Minneapolis Grain Exchange (MGE) September contract. The price distribution vector for crop *i* at time *t*, denoted $\hat{p}_{it}$, contains *S* elements defined as:

$$\hat{p}_{its} = E(p_{it})\left(\frac{p_{i,t-s} - E(p_{i,t-s})}{E(p_{i,t-s})} + 1\right),$$

where

$E(p_{it})$ is the planting time (expected) price, harvest month futures contract, time *t*,

$P_{i,t-s}$ is the harvest time (realized) price, harvest month futures contract, time *t-s*,

$E(P_{i,t-s})$ is the planting time (expected) price, harvest month futures contract, time *t-s*.

Crop Revenue—Marketing Loan Benefits. Marketing loans protect crop producers from very low prices. When the market price of a covered commodity (e.g., corn, wheat, soybeans) drops below a fixed "loan rate" (see appendix table B-2), the Federal Government pays producers for the difference. On a per-acre basis, the marketing loan benefit is:

$$L_{it} = \max((\overline{p}_i - p_{it})y_{it}, 0),$$

where L_{it} is the marketing loan benefit for crop *i* at time *t*; $\overline{p}_{it}$ is the loan rate; P_{it} is the realized price; and y_{it} is the producer's actual yield. An S-element distribution vector is denoted $\hat{L}_{it}$ with typical element $\hat{L}_{its} = \max((\overline{p}_i - \hat{p}_{its})\hat{y}_{its}, 0)$.

Crop Revenue—Net Crop Insurance Indemnity. Revenue- and yield-based crop insurance are widely purchased in the Northern Plains. Revenue insurance products were introduced only in late 1990s. RMA data show that producers switched to revenue insurance gradually between 1997 and 2007. For 2007, the RMA Summary of Business data show that revenue assurance (RA) accounted for 74 percent of insured corn acreage (most insured for 70 and 75 percent coverage), 82 percent of insured soybean acreage (mostly 70 and 75 percent coverage), and 44 percent of insured wheat acreage, almost all of it at 65, 70, or 75 percent coverage.

Coverage levels also increased over that period because of changes in the premium subsidy schedule. Before 1999, most insurance was sold at 65 percent coverage and carried a subsidy rate of 42 percent. Producers could also buy 70 percent coverage, which carried a premium subsidy of 32 percent. In 1999 and 2000, Congress enacted temporary premium subsidy increases that

Appendix table B-2
National average commodity loan rates

	Soybeans	Corn	Wheat
	-------*Dollars per bushel*-------		
1998	5.26	1.89	2.58
1999	5.26	1.89	2.58
2000	5.26	1.89	2.58
2001	5.26	1.89	2.58
2002	5.00	1.89	2.80
2003	5.00	1.89	2.80
2004	5.00	1.95	2.75
2005	5.00	1.95	2.75
2006	5.00	1.95	2.75
2007	5.00	1.95	2.75

Source: USDA, Farm Service Agency.

were made permanent under the Agricultural Risk Protection Act of 2000 (see appendix table B-3). The new subsidy schedule encouraged producers toward 70 percent coverage by applying a subsidy rate of 59 percent to both 65 and 70 percent coverage.

Based on RMA Summary of Business data, we devised acreage shares and coverage levels for yield and revenue insurance by crop, county, and year. Revenue assurance with the base price option is used to represent revenue insurance. Because grassland to cropland conversion is most likely to happen on nonirrigated land, we considered insurance for nonirrigated production only.

The per-acre indemnity for the RA base price option is paid when crop revenue drops below a guarantee level:

$$I_{it}^{ra} = \max((\theta p_{it}^{b} \overline{y}_{it} - p_{it} y_{it}), 0),$$

where I_{it}^{ra} is the RA indemnity for crop i at time t, θ is the coverage level, p_{it}^{b} is the RA base (expected) price, $\overline{y}_{it}$ is the producer's APH yield, p_{it} is the realized price, and y_{it} is the actual yield. As S-element distribution vector, $\hat{I}_{it}^{ra}$, has typical element

$$\hat{I}_{its}^{ra} = \max((\theta p_{it}^{b} \overline{y}_{it} - \hat{p}_{its} \hat{y}_{its}), 0).$$

Appendix table B-3
Crop insurance subsidy rates

Crop insurance coverage level	Pre-1999 subsidy rates	Subsidy rates 1999-present
	Percent	
55	46	64
60	38	64
65	42	59
70	32	59
75	24	55

Source: USDA, Farm Service Agency.

The per-acre indemnity for APH (yield) insurance is paid when realized yield falls below the yield guarantee:

$$I_{it}^{aph} = \max((p_{it}^{aph}(\theta\overline{y}_{it} - y_{it})),0)\,,$$

where I_{it}^{aph} is the APH indemnity and p_{it}^{aph} is the (predetermined) APH price for crop *i* at time *t*. As S-element distribution vector, $\hat{I}_{it}^{aph}$, has typical element

$$\hat{I}_{its}^{aph} = \max((p_{it}^{aph}(\theta\overline{y}_{it} - \hat{y}_{its})),0)\cdot$$

By law, USDA must attempt to devise actuarially fair premiums. Actuarially fair premiums would be equal to the expected indemnity, but farmer-paid premiums are subsidized by the Federal Government:

$$\rho_{it}^{ra} = \left(1-\phi(\theta)\right)E(I_{it}^{ra}) = (1-\phi(\theta))S^{-1}\sum_{s}\hat{I}_{its}^{ra}$$
$$\rho_{it}^{aph} = \left(1-\phi(\theta)\right)E(I_{it}^{aph}) = (1-\phi(\theta))S^{-1}\sum_{s}\hat{I}_{its}^{aph}\,,$$

where ρ_{it}^{ra} and ρ_{it}^{aph} are the farmer-paid premiums for RA and APH insurance, respectively, and ϕ is the premium subsidy rate for coverage level θ.

Crop Revenue—Crop Disaster Assistance. Northern Plains producers received disaster assistance a number of times during the study period based on ad hoc legislation passed by Congress in response to drought or other adverse conditions. Producer expectations about ad hoc programs are difficult to model because program rules about eligibility, payments, and other provisions can change from year to year and are not known by producers before the beginning of the season when land use and cropping decisions are finalized. Moreover, ad hoc disaster payments are typically received 1-2 years after the disaster. Nonetheless, the frequency and size of disaster assistance payments implies that producers are likely to have some expectation of disaster assistance. As a proxy for expected disaster assistance payments, Goodwin and Rejesus use a 4-year rolling average of county-level disaster assistance payments reported in the Consolidated Federal Fund Report (CFFR), divided by the number of cropland acres in the county. We adopt a very similar method, using a 5-year moving average of county-level disaster assistance, based CFFR data, divided by cropland acreage. We do not attempt to assess the effect of disaster payments on the variability of crop returns. Because the CFFR data reflect payments based on disasters in previous years, the countercyclical effect of ad hoc disaster assistance cannot be determined.

Crop Revenue—Expected Revenue and Revenue Variance. Finally the expected value and variance of crop revenue, including the effect of farm programs, can be represented as:

$$E(R_t) = (A_t S)^{-1}\sum_{s}\sum_{i} a_{it}(\hat{p}_{its}\hat{y}_{its} + \hat{L}_{its} + \hat{I}_{its} - \rho_{it}) + E_t(D)$$
$$V(R_t) = (A_t S)^{-1}\sum_{s}\left(\sum_{i} a_{it}(\hat{p}_{its}\hat{y}_{its} + \hat{L}_{its} + \hat{I}_{its} - \rho_{it}) - E(R_t)\right)^2$$

where:

R_t is crop revenue in year t;

a_{it} is acreage of crop i in year t;

$A_t = \sum_i a_{it}$ is overall crop acreage in year t;

$$\hat{I}_{its} = (a_{it}^{ra}/a_{it})\hat{I}_{its}^{ra}(\theta_t^{ra}) + (a_{it}^{aph}/a_{it})\hat{I}_{it}^{aph}(\theta_t^{aph})$$

a_{it}^{aph} is acreage of crop i in year t with APH (yield) coverage;

a_{it}^{ra} is acreage of crop i in year t with RA (revenue) coverage;

θ_t^{aph} is coverage level for crop i in year t with APH (yield) coverage;

θ_t^{ra} is coverage level for crop i in year t with RA (revenue) coverage;

$$\rho_{it} = (a_{it}^{ra}/a_{it})\rho_{it}^{ra}(\theta_t^{ra})) + (a_{it}^{aph}/a_{it})\rho_{it}^{aph}(\theta_t^{aph}))$$

$E_t\,(D)$ is the expected disaster payment in year t.

(All variables are county-specific but are not indexed by county to reduce clutter.)

Hay and Pasture Revenue—Expected Revenue and Revenue Variance. We use hay prices and yields to represent hay and pasture revenue. Yields are based on county data obtained from NASS. The yield distribution vector is developed using the same method applied to cultivated crops. Prices are based on State-level season-average prices, also obtained from NASS. The price distribution vector is developed using the same methods applied to crops, except that the expected hay price is a moving average of the previous 3 years' prices. Using these data, expected revenue and revenue variance are derived using the same applied to cultivated crop revenue:

$$E(R_{ht}) = S^{-1}\sum_s \hat{p}_{hts}\hat{y}_{hts}$$

$$V(R_{ht}) = S^{-1}\sum_s \left(\hat{p}_{hts}\hat{y}_{hts} - E(R_{ht})\right)^2$$

where:

R_{ht} is hay and pasture revenue in year t;

$\hat{p}_{hts}$ is element s from the hay price distribution vector for year t;

$\hat{y}_{hts}$ is element s from the hay yield distribution vector for year t;

Rangeland Revenue—Expected Revenue and Revenue Variance. Revenue per animal unit (the "price" in this case) is based on ERS cost and returns estimates for cow-calf operations in the Northern Plains. Expected revenue at time t is the predicted revenue obtained from a regression of revenue on lagged revenue, futures price (average of July closing for following year's August fed cattle contract, i.e., July 2002 closing prices for August 2003 contract), and a time trend using the most recent S (=23) years. Deviations are the difference between realized revenue (as reported in the cost and returns data) and expected revenue. Using this data, the price distribution vector is developed using the methods applied to cultivated crop revenue.

Rangeland forage yields (pounds of dry matter per acre) for normal years, favorable years, and unfavorable years are obtained from NRCS soil survey data and converted to carrying capacity in animal units per acre (the "yield" in this case) using rules derived from cooperative extension literature and NRCS technical documents (Metz). Each animal unit requires roughly 915 pounds (lbs) of forage per month. In a 6-month grazing season, total forage needs for one animal unit would be 5,490 lbs. Suppose the available forage is estimated at 2,000 lbs per acre per year. Good grazing practice involves leaving some forage in the range/pasture—a widely used rule is to "take" only half of the available forage—up to 1,000 lbs per acre in this example. Grazing efficiency is only about 50 percent, as some of the available forage is trampled, located far from water, or otherwise goes unutilized. Using the "take half" rule and 50-percent grazing efficiency, about 25 percent of available forage is actually consumed by cattle. In the example, cattle consume 500 lbs per acre over the course of the season (0.25*2,000 lbs per acre). The number of animal units (AU) supported by 1 acre is the forage available per acre divided by the forage need for one AU: (500 lbs per acre)/(5490 lbs per AU)=0.091 AU/acre (or roughly 11 acres per AU). A coefficient that converts forage yield (lbs per acre) into a stocking rate (AU per acre) can be defined as: $\varphi = 0.25/5490 = 0.00004554$.

Yield variability is estimated using annual rainfall data to adjust forage yields to year-specific conditions following a method used by the U.S. Government Accountability Office (GAO). We assume that producers are able to adjust to variation in forage production on grazing land by varying stocking rates and/or buying or selling hay. The GAO cites local expert opinion in assuming that favorable conditions are realized with a 20-percent increase in rainfall over average levels and unfavorable conditions occur when rainfall is 20 percent below average. We use a similar rule, approximating the effect of variations in rainfall on forage yields as:

$$y_{gt} = \phi\left(y_g^{normal} + \frac{y_g^{low} - y_g^{high}}{1.2\bar{z} - 0.8\bar{z}}(z_t - \bar{z}) \right),$$

where

y_{gt} is estimated forage yield for grazing in year *t*;

y_g^{normal} is expected forage yield in a normal year;

y_g^{low} is expected forage yield in an unfavorable year;

y_g^{high} is expected forage yield in a favorable year;

z_t is rainfall in year *t*;

$\bar{z}$ is average annual rainfall.

The yield distribution vector for rangeland, $\hat{y}_{gt}$, would have typical element:

$$\hat{y}_{gts} = y_g^{normal}\left(\frac{y_{g,t-k} - y_g^{normal}}{y_g^{normal}} + 1 \right).$$

Using the price and yield distribution vectors described above, expected revenue and revenue variance are calculated as:

$$E(R_{gt}) = S^{-1}\sum_{s}\hat{p}_{gts}\hat{y}_{gts}$$

$$V(R_{gt}) = S^{-1}\sum_{s}\left(\hat{p}_{gts}\hat{y}_{gts} - E(R_{gt})\right)^2,$$

where:

R_{gt} is rangeland revenue in year t;

$\hat{p}_{gts}$ is element s from the rangeland price distribution vector for year t;

$\hat{y}_{gts}$ is element s from the rangeland yield distribution vector for year t;

Per-Acre Production Cost—Crop Costs. Cost data are derived from annual production cost estimates published by ERS (USDA-ERS, 2010). Cost estimates for corn, wheat, and soybeans are based on estimates for the Northern Great Plains. Because grassland-cropland conversion involves a major change in non-land capital input needs, we include both allocated overhead and operating costs in our estimate of crop costs, except that land costs are excluded because net return is assumed to be the residual return to land. To derive a single measure of crop production cost, we use an acre-weighted average of corn, wheat, and soybean costs. Weights are the average acreage over the 3 most recent years based on NASS county crop data:

$$C_t = A_t^{-1}\sum_{i} a_{it}C_{it},$$

where:

C_t is overall cropland production cost at time t; and

C_{it} is production cost for crop i at time t.

Per-Acre Production Cost—Hay and Pasture Cost. We use hay production costs to represent hay and pasture costs. We assume that producers plant a mix of alfalfa and smooth brome grass. Costs include tillage, planting, and fertilizer for establishment, annual fertilizer for maintenance, and harvest (bailing costs).

Establishment is assumed to involve tandem disking (twice), fertilizer application, harrowing, and drilling (Barnhart, Duffy, and Smith). The cost of machine operations is taken from custom farming rates obtained from State-specific rates (Aakre; Anderson and Noyes; Jose and Bek). For each State, custom rates for the most recent available year are used with adjustments to account for inflation. For establishment, we assume that producers will apply 60 lbs per acres of nitrogen, 15 lbs of phosphate, and 45 lbs of potash. We assume that establishment costs are amortized over a period of 5 years.

Annual costs. Annual fertilizer includes 15 lbs of phosphate and 45 lbs of potash. Nitrogen is not applied annually because the pasture is seeded to a legume-grass mixture. Fertilizer prices are obtained from NASS (USDA-NASS, 2010). To calculate annual costs of mowing-conditioning, we assume that farmers harvest three cuttings each year. Bailing and hauling costs are estimated from per-ton custom bailing and hauling rates (Aakre; Anderson and Noyes, Jose and Bek). These figures are converted to a per-acre basis using expected hay yields.

Putting all of the pieces together, the annual cost of hay production is:

$$C_{ht} = \delta C_e + C_{at} + 3 * C_m + E(y_{ht}) C_B \ ,$$

where:

C_{ht} is annual production cost for hay;

δC_e is the annual share of establishment cost, amortized over 4 year;

C_{at} is annual maintenance (fertilizer) cost;

C_m is the cost (per acre) of hay mowing and conditioning;

$E(y_{ht})$ is the expected yield at time t; and

C_B is bailing and hauling cost.

Per-Acre Production Cost—Rangeland Cost. We use cow-calf production cost estimates for the Northern Great Plains, published by ERS (USDA-ERS, 2010). ERS cost estimates are expressed on an animal-unit basis. To convert cost to a per-acre basis, we multiply by the number of animal units that can be supported by a single acre, given the expected (normal) forage yield:

$$C_{gt} = C_{gt,AU} \phi y_g^{normal} \ .$$

We include both fixed and variable costs in our estimate of rangeland costs.

Data—Land Quality Variables

Productivity is represented by the National Commodity Crop Productivity Indicator (NCCPI) developed by USDA's Natural Resources Conservation Service for use in implementing USDA programs, including CRP (Dobos, Sinclair, and Hipple). Productivity is measured on 0-1 scale where 0 is least productive and 1 is most productive. In our study region, NCCPI ranges from 0 to .62 with a mean of 0.27. The NCCPI assumes nonirrigated production. Soils can have low ratings due to dry climate, even though irrigation (if available) could make them very productive. To capture the effect of irrigation, we use a site-specific (NRI-based) indicator of irrigation.

The suitability of land to crop production is described by two variables. Potential for high erosion rates make highly erodible land (HEL) unsuited to crop production without the use of practices that help slow erosion. Conservation tillage (particularly no-till), terraces, contour farming, and other practices can help reduce soil erosion. Producers who crop HEL are required to implement a soil conservation system to retain eligibility for farm program payments (all payments, not just on land where conservation requirements have not been satisfied, with the exception that crop insurance indemnities are not subject to the HEL conservation requirement). Farmers who convert highly erodible grassland to crop production must apply stricter and more costly plans or risk loss of farm program payments. A site-specific, binary indicator of HEL, drawn from NRI, is used to capture the effect of HEL status on grassland-to-cropland conversion.

Wet soils may also impede crop production, as producers may be forced to delay planting or farm around wet spots. The Prairie Pothole Region is named for small, isolated wetlands that dot the region. Under the Wetland

Conservation (Swampbuster) provision currently in force, farmers who drain these wetlands become ineligible for farm program payments. Nonetheless, many are dry enough in some years to farm and are often referred to as farmable wetlands. Soils that develop under wet conditions are classified as "hydric soils." To capture the effect of soil wetness on land use, we use a binary indicator of hydric soil.

Data—Conservation Reserve Program Variables

CRP enrollment decisions are made jointly by the producer (or landowner), who decides to offer a CRP contract, and by USDA, which decides whether or not to accept the offer. Because CRP is a longstanding program and producers are given a great deal of information about their environmental benefits index or EBI score before they finalize bids, most applicants have prior beliefs about the EBI cutoff that determines which contract offers will be accepted. CRP applicants are informed of their EBI environmental score before bids are finalized. While the weight given to the contract cost component of EBI and the overall cutoff score (above which contracts are accepted) are not known by the producer when bids must be finalized, the cost weight and the cutoff score have changed only modestly over time, providing producers with reasonably good prior information (see Barbarika, et al., page A-29). Given this level of prior information, the producer's decision to offer a contract will depend on roughly the same factors as the Government's decision to accept or reject the offer: (1) whether the land is eligible for CRP, (2) the potential revenue and costs, and (3) the EBI environmental score.

CRP eligibility is based on program criteria for 1997-2007. In general signups, that includes land (1) with an erodibility index greater than or equal to 8 or (2) located in any one of seven national and State priority areas, including the Prairie Pothole Region, which includes a majority of our study area, is eligible for CRP. Land can also be eligible for continuous signup for high-priority practices or the Conservation Reserve Enhancement Program (CREP)—a Federal-State partnership program designed to encourage concentrated effort to clean up a specific resource such as a river or lake. Because a large majority of CRP acres were enrolled in general signup during 1997-2007, we use general signup criteria in determining eligibility.

CRP revenue is based on county soil rental rates (SRRs) obtained from USDA's Farm Service Agency (USDA-FSA). The SRR is then adjusted to field-specific conditions using productivity indicators and other information. USDA generally adds $4 to $10 per acre to cover the costs of annual maintenance, depending on the type of cover or practice installed. We represent CRP revenue using the county-average SRR but also include an indicator of soil productivity in the model (NCCPI). The SRR is set to zero for NRI points that are ineligible for CRP.

The "exogenous" portion of the EBI is an indicator of the likelihood of CRP enrollment, if the producer or landowner decides to make an offer. The exogenous EBI is made up of factors that cannot be controlled or changed by the producer. That includes the water quality, soil erosion, air quality, and conservation priority area criteria. Wildlife benefits are not included because they depend largely on the type of cover applied. Producers and landowners who score high on the exogenous EBI may be more likely to submit CRP bids when compared to producers with land of similar value, but lower exogenous EBI scores. Those with high EBI scores are also less likely to need to “sweeten” bids by bidding down financial assistance or offering cover that is better for wildlife but more expensive to install and maintain. The EBI for CRP general signups 26-33 are used to develop our estimates of the exogenous EBI. The exogenous EBI is set to zero for land that is not eligible for CRP.