Grassland Conversion for Crop Production in the United States: Defining Indicators for Policy Analysis

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Agricultural land use change can increase the potential for environmental damage from agricultural production. Shifting land from less intensive to more intensive uses—converting grassland to cropland, for example—may result in th`e loss of wildlife habitat, increased soil erosion and sedimentation, and higher levels of nutrient runoff and leaching to surface and ground water, respectively. In recent years, the conversion of native grassland for crop production has become an important issue in U.S. agricultural policy debates. Environmentalists, wildlife groups, and some livestock interests have become particularly concerned about the loss of native grasslands in the U.S. Northern Plains region (GAO). Native grasslands are important habitat for a number of threatened or at-risk species and, once lost, cannot be easily re-established.

Concerned groups have focused on the role of federal programs that protect crop farmers from low prices and low yields by providing commodity payments and subsidized crop insurance (Morgan). These programs reduce the risk associated with crop production and, over time, can increase average returns because farmers continue to reap the benefits of high prices or high yields while receiving benefits that offset some of the loss in the low price or low yield years. While the majority of farm program payments have been “decoupled” from current production—that is, current production does not affect payments—some payments continue to depend on current production and eligibility for those payments can be increased by converting grassland to commodity crops that are supported by the U.S. government. In more recent years there is also increasing concern about the effect of bio-fuel mandates (corn-based ethanol) on crop prices and land use.

New technology may also be encouraging conversion of grassland to crop production as genetically modified, herbicide tolerant varieties have been rapidly adopted in corn and, especially, soybeans. By saving time in the busy planting season, these varieties may be relaxing labor constraints that limited cropland acres.[1] Adoption of no-till production may further reduce spring-time labor requirements and make it easier to convert highly erodible grassland without risking the loss of farm program payments under the U.S. sodbuster provision (an environmental cross-compliance mechanism).

Focusing on land use change in the Northern Plains region of the United States, we develop indicators of movement of land between cultivated crops and forage production, including hay, pasture, and rangeland, and show how land use and land use change varies across the region. Based on a simple conceptual model of land use, we develop a series of land quality, market, policy, and technology indicators that appear to be correlated with intra-regional variations in land use and land use change. While a statistical analysis is needed to draw firm conclusions about the causes of land use change, this overall set of indicators allows us to describe *what* is happening and gain some insight on *why* it is happening.

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[1] Technology that boosts productivity could also reduce conversion by increasing commodity production on existing cropland and reducing market prices.

Land Use Change at the Cropland-Grassland Margin

We define the margin between grassland (pasture, range, and hay) and cultivated cropland as land that tends to move between these uses. While there is a high level of concern about native grassland, we consider the full range of land uses that involve perennial crops used for livestock forage[2]. In an economic sense, pasture and rangeland can be close substitutes while hay is also a key source of forage. We consider rangeland separately from pasture and hay because pasture and hay are often grown in long term rotation with cultivated crops, leading to a much more active margin with cultivated cropland when compared with the cropland-rangeland margin.

The margin between cultivated crops and perennial forage crops, particularly hay and pasture, is very active. While net movement between these uses is modest, land is regularly shifting back and forth between cultivated crops, hay, and pasture. Based on the 1997 National Resource Inventory (NRI) data[3], cultivated cropland in the United States declined by more than 49.6 million acres between 1982 and 1997, including 29.3 million acres enrolled in CRP, and a net shift of 19.4 million acres (5.2 percent) to other land uses. Over the same period combined acreage of hay, pasture, and rangeland fell by just under 16.0 million acres (2.7 percent). Net changes, however, mask a large majority of land use transitions. Between 1982 and 1997, 34.3 million acres of cultivated cropland transitioned to hay or pasture and 3.0 million acres transitioned to range (fig 1). In the

[2] As a practical matter, existing data on U.S. land use does not identify grasslands as native or non-native. Nonetheless, factors encouraging the conversion of grassland to crop production apply to native and non-native grasses alike.

[3] The NRI provides data on land use and land condition for more than 800,000 points of rural, non-Federal land in the conterminous United States. The data is collected and maintained by the USDA Natural Resources Conservation Service (NRCS). More recent NRI data (from 2007) has been collected but not yet cleared for public release.

opposite direction, 22.7 million acres of hay and pasture and 5.5 million acres of rangeland were converted to cultivated crop production. So, for a net shift of 9.1 million acres from cultivated crops to hay, pasture, and range, a total of 65.5 million acres changed use.

In more recent years, a similar trend in cultivated cropland can be observed at least when looking at land use from a national perspective. Activity along the grassland-cropland margin, however, is not evenly distributed across the U.S. While there was a nation-wide shift of cultivated cropland to hay, pasture, and range between 1997 and 2007, landowners and farmers in the Northern Plains shifted more land from hay, pasture, and rangeland to cultivated crop production than in the other direction (fig. 2). For this study, we define the Northern Plains to include the parts of Nebraska, North Dakota, and South Dakota which are located in Land Resource Regions F, G, and M (fig 3). Land Resource Regions (LRR) are areas of relatively uniform climate and soil conditions (USDA-NRCS).

Even within the Northern Plains there is considerable diversity in land use and land use change. Breaking down the Northern Plains by LRR shows that cultivated crops are the predominant land use in LRR M and F (fig. 3). LRR M, located along the Eastern border of Nebraska and South Dakota, is the western edge of the Corn Belt where corn and soybeans are the predominate crops. Wheat is traditionally the predominant crop in LRR F which covers large portions of central and Northwestern South Dakota and almost all of North Dakota. Finally, land in LRR G is largely devoted to livestock grazing as rangeland accounts for about 80 percent of agricultural land. Cropland is largely devoted to wheat and irrigated corn (where water is available).

Although the NRI data is not dense enough to make reliable estimates in small areas, USDA's Farm Service Agency (FSA) data suggest that the rate of land conversion is highest in central South Dakota and portions of Southeastern North Dakota (fig. 4). When land is converted to crop production, farmers who want to receive farm program payments must notify FSA, triggering an environmental review to determine whether the land is subject to environmental cross-compliance requirements.[4] While so-called "new land" is not necessarily rangeland or native grass, large scale land use conversions in this region would almost certainly involve grasslands. In nine counties (eight in South Dakota, one in North Dakota), the annual rate of new cropland in 2005/06 was equal to or greater than 0.8 percent of all grazing land acres (pasture and range). In two South Dakota counties, new cropland was greater the 2 percent of grazing land acreage. While these rates are high for annual conversion they are supported by Stephens *et al*., who used satellite imagery to detect localized conversion rates as high as 2 percent per year.

Land Use and Land Quality: Conceptual Issues

Land is generally allocated to the use that maximizes landowner benefits or land value. In the U.S. Northern Plains, land is valued primarily for agricultural production. Maximizing landowner benefit entails selecting which commodity to produce (e.g., corn, wheat, or hay) using land is an input.[5] The expected return to land at any given time depends on the prices of outputs and (non-land) inputs, available technology (which can

[4] Under Sodbuster and Swampbuster provisions, producers could lose all farm program payments if they convert highly erodible land (with an acceptable soil conservation plan) or wetland to crop production. See Claassen *et al*. for more detail.
[5] Land may also be valued for a wider range of goods, including recreational and ecological services. Landowners can capture some (but not all) of these values by charging fees for hunting or other recreational activities. Landowners may also value services such as recreation, aesthetic beauty, or environmental protection even if they cannot be compensated monetarily for them.

affect the per-unit cost of production), government policies, the skills and preferences of the producer (or landowner), and the quality attributes of the land itself; attributes which are often referred to collectively as *land quality*.

For agricultural land, both spatial and biophysical attributes are important. Transportation costs may reduce the value of land that is a great distance from primary markets. Productivity—the suitability of land for plant growth—is a key biophysical attribute which depends on both climate and soil properties such as depth and nutrient holding capacity. Many previous research studies have used productivity indicators in explaining land use (Lichtenberg 1989; Wu and Brorsen 1995, Plantinga 1996; Hardie and Parks 1997, Wu 1999, and and Lubowski et al. (2006) to name a few). Previous studies have also found relationships between land quality and the impact of technology or policy on land allocation (Lichtenberg (1989) and Stavins and Jaffe (1990)). Land topography, elevation, and susceptibility to soil erosion and flooding can also be important indicators of land use.

In general, soils with higher productivity are more likely to be in cultivated crop production. Figure 5 shows that the distribution of land by productivity class and use in the Northern Plains.[6] Most high productivity land is used for 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).

[6] We used the 1997 National Resources Inventory (NRI) linked to the National Commodity Crop Productivity Indicator (NCCPI; USDA-NRCS, 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.

Land use change at the cropland-grassland margin happens when there is a shift in the relative profitability of crop production and grazing or hay production. These shifts may be due to a change in market prices, technology, or policy that makes one land use more profitable relative to another. In some cases, there may be policy or other barriers that prevent landowners from switching to a higher value use. For example, past policies have limited land use change options for producers who want to maintain eligibility for Federal farm programs. Land use change may happen when these rules of rescinded or relaxed, even though data on relative returns to land cultivated crops and grazing may not show a significant shift.

For any given change in relative returns to land uses, the extent of land use change depends on the size of the change in relative returns and on the amount of land on the margin between cropland and grassland. It is reasonable to assume that medium quality land is on the grassland-cropland margin given that large quantities of medium quality land are used in crop production, hay, and grazing (fig. 5). So, the availability of medium-quality or marginal grassland is a key indicator of the potential for land use change. The amount of medium-quality grazing land varies widely across Land Resource Regions within the Northern Plains (fig. 6). More than 60 percent of rangeland located in LRR F and M has medium productivity while less than 30 percent of rangeland in LRR G has medium productivity. Potential for conversion in LRR M is modest because rangeland accounts for only a small portion of overall land. Conversion potential in LRR G may be large because it encompasses a huge area of rangeland, 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 rangeland with medium productivity representing high potential for conversion to crop production.

Market, Policy, and Technology Indictors

We start by looking at changes in cropping patterns because these changes can indicate a shift in returns to cropland, perhaps inducing landowners to convert land from other uses to cultivated crop production as well. Figure 7 shows how the mix of corn, soybeans, wheat, and other crops changed between 1997 and 2007 for Land Resource Regions F, G, and M in the Northern Plains. Cropping patterns have been stable in LRRs M and G. Cropland in LRR M is largely devoted to corn and soybeans while in LRR G a large majority of cultivated cropland is devoted to wheat production. In LRR F, 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.

This shift to corn and soybeans may have been facilitated by a change in U.S. farm policy. A crop-mix shift of the magnitude observed in LRR F would have been far less likely under U.S. farm commodity policies that existed before 1996. Annual commodity-based payments and continued eligibility for future payments were based in large part on planted acreage. To receive payments in the current year and continue receiving payments in future years producers were required continue planting traditional crops.[7] Farmers who decided to switch crops would have to relinquish payments based on the old crop to build up production history in the new crop, becoming fully eligible for

[7]Pre-1996 commodity program were somewhat more complex but the fact is that cropping patterns were much more restricted under pre-1996 programs than under post-1996 programs.

payments based on the new crop only after 5 years. After 1996 producers were free to change crops, bring additional land into crop production, or convert land from crop production to another agricultural use (except fruit or vegetables) without jeopardizing payments.

The change in U.S. agricultural policy allowed producers to respond more freely to market signals, policy incentives, and technology change. Figure 8 shows difference in average net return to crop production and pasture, normalized to zero for 1998, by Land Resource Region. Upward slopes represent an increase in return 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 three 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.

On average, return to crop production is increasing in LRR M relative to LRR F or G. For most of the period (7 of 10 years), relative return to crop production in LRR M was higher than in 1998. In LRR G, on the other hand, relative returns to crop production were higher than 1998 returns in only one 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.

Federal payments contributed significantly to the observed trends in crop returns. Marketing Loan Gains (MLG) were created in 1996 to protect producers against low prices on current production. When the market price of a covered commodity (e.g., corn, wheat, soybeans, and cotton) drop below a fixed "loan rate" the Federal government pays producers for the difference between the loan rate and the market price. Producers who were eligible for other farm program payments could receive a marketing loan gain on all eligible production, regardless of how much was grown or where it was grown. So, producers who were already eligible for farm programs payments (including the vast majority in the Northern Plains region) could receive low-price protection for crops grown on converted grassland. Figure 9 shows MLGs by Land Resource Region. The huge spike in LRR M and F was driven largely by payments to soybeans in the early part of the last decade. Before 2002, 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.

Federally subsidized crop insurance can also be purchased for crops grown on converted land. Crop insurance can protect farmers against crop production or crop revenue loss due to unfavorable weather, pests, adverse price movements, etc. Figure 10 shows average estimated net return to crop insurance purchase by Land Resource Region.[8] We assumed that the full premium rates are actuarially fair[9] and that producers

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[8] The estimated return in fig. 10 is based on the volatility of county yields as reported by NASS. The volatility of farm level yields is often larger. In ongoing research the authors have found farm-level net indemnities of more than $10 per acre per year for some South Dakota counties.

[9] There is considerable evidence to suggest that premiums are not actuarially fair to individual producers, see Just *et al*. and Makki and Somwaru. Although premiums are likely to be higher than actuarially fair for some producers and lower than actuarially fair for others, identifying which is which would be difficult.

benefit only from the premium subsidy, which is more than 50 percent for the most popular levels of crop insurance coverage. Some additional restrictions may apply on newly converted land. In general, producers must have at least one year of crop history on newly converted land to purchase crop insurance. Land that has less than 4 years of crop history may be assigned relatively low yields to "stand in" until a 4-year history of actual yields is obtained, effectively lowering the level of yield or revenue guarantee available.

Finally, changes in technology may have contributed to shifts in cropping patterns and land use. The introduction of genetically modified corn and soybean varieties may have facilitated the new cropping patterns and the conversion of grassland to cultivated cropland. Herbicide tolerant (Ht) varieties are modified to withstand contact with the herbicide Roundup. While Roundup is non-selective (it kills most plants), producers planting herbicide tolerant varieties can control weeds by spraying fields after the crop has emerged. Adoption of Ht soybeans was particularly swift, rising from roughly 20 percent in 1998 to nearly 100 percent by 2006 while adoption of Ht corn was over 50 percent by 2006 (fig. 11). 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.

Finally, adoption of no-till methods (fig. 12) may also facilitate land use conversion. Where soil and climate conditions are suitable, switching from conventional to no-till production can save labor (fewer field operations are needed) and reduce

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Moreover, premium subsidies are a large part of crop insurance benefits and capturing their effect captures a large portion of crop insurance benefits.

machinery requirements (tillage machines and large tractors needed to pull them are no longer necessary). No-till may also 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 payment on the converted land. In many instances in Northern Plains, however, no-till methods satisfy this requirement (GAO).

Conclusions

A complete set of indicators for agri-environmental policy analysis would capture both *what* happened and *why* it is happened. For land use change, understanding what happened requires characterization of *gross* land use conversions as well as *net* land use change. Reliance on indicators of net change can mask environmentally important land use transitions. Indicators of gross land use change can also signal diversity among producers. As some farmers and landowners are converting grassland to cropland others may be expanding grassland by seeding cropland for pasture or hay.

Market, policy, and technology indicators can help explain differences in land use choice across producers. Land use and land use change depend on the productivity of available land, differences in policy across crops (and, therefore, regions), and crop-specific differences in technology (e.g., genetically modified varieties or corn and soybeans have been available for more than a decade while similar wheat varieties have only recently become available). While a statistical analysis is necessary to draw firm conclusions about the relative importance of changes in market prices, policy, and technology, these indicators alone can provide significant insights on factors that could be driving land use change. Understand the role of each of these factors—that is, understanding why land use is changing—is critical to developing effective agri-environmental policy.

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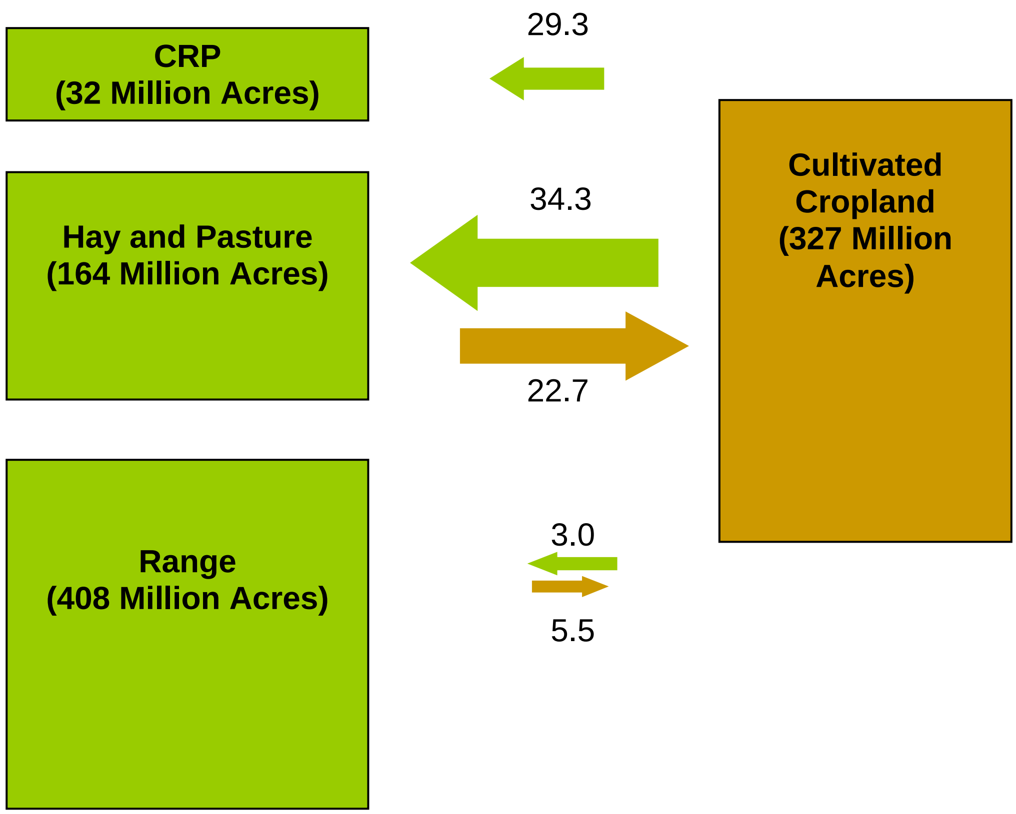
Figure 1. Acres Changing Use at the Grassland-Cropland Margin, 1982-1997, in millions of Acres



Source: ERS analysis of the 1982-1997 National Resources Inventory (USDA-NRCS).

Figure 2. Grassland to Cropland Conversion in the U.S. and the U.S. Northern Plains

Overall U.S.

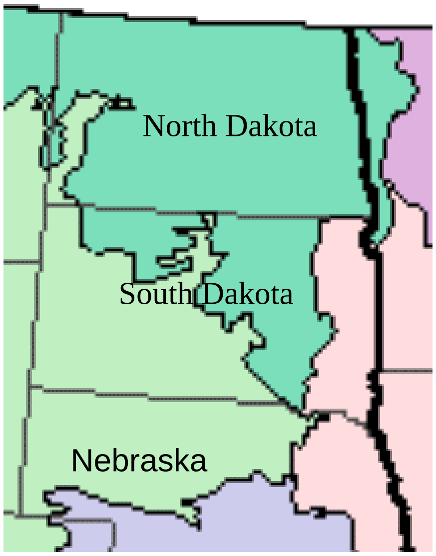
- Cultivated cropland acreage declining
- Net movement of land from cultivated crops to hay or grazing
- Net movement of cultivated cropland to CRP

Northern Plains

- Cultivated cropland acreage constant
- Net movement of land from hay or grazing to cultivated crops
- Net movement of cultivated cropland to CRP

Source: ERS

Figure 3. Land Resource Regions and Land Use in the Northern Plains, 1997

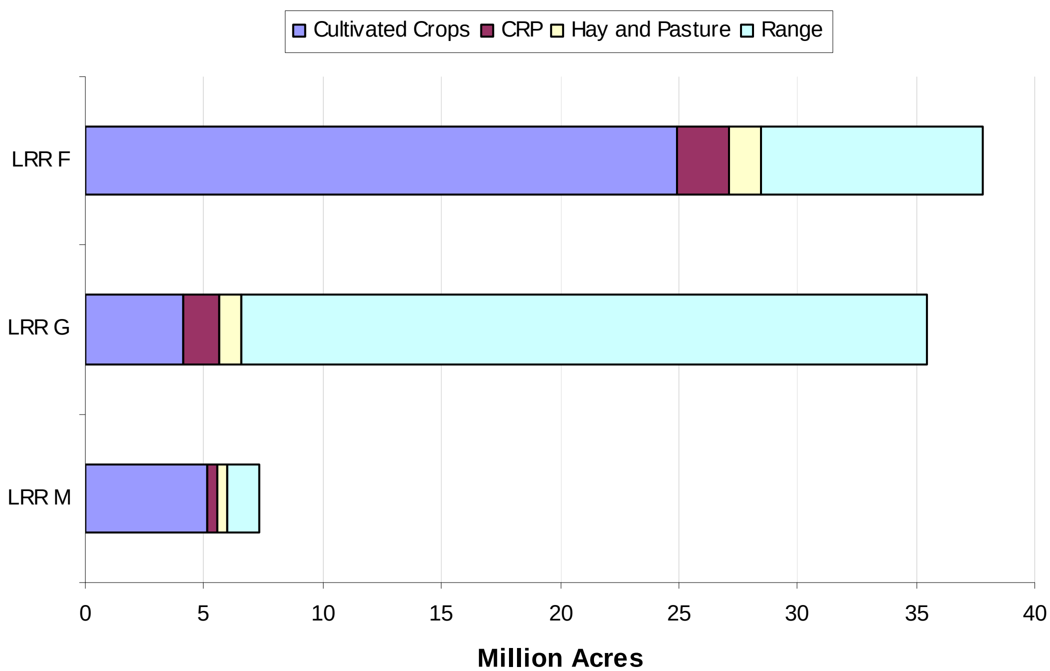


Land Resource Regions

F: Central South Dakota and North Dakota

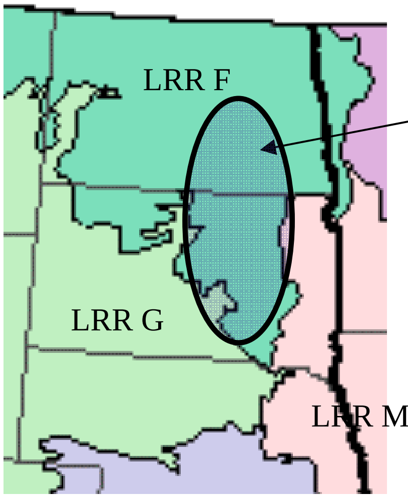
M: Eastern South Dakota and Nebraska

G: Western South Dakota and Northwestern Nebraska



Source: ERS analysis of the 1997 National Resources Inventory (USDA-NRCS).

Figure 4. Rate of "New" Cropland Highest in LRR F



Area includes 9 counties with annual rate of "new" cropland[1] in 2005/06:

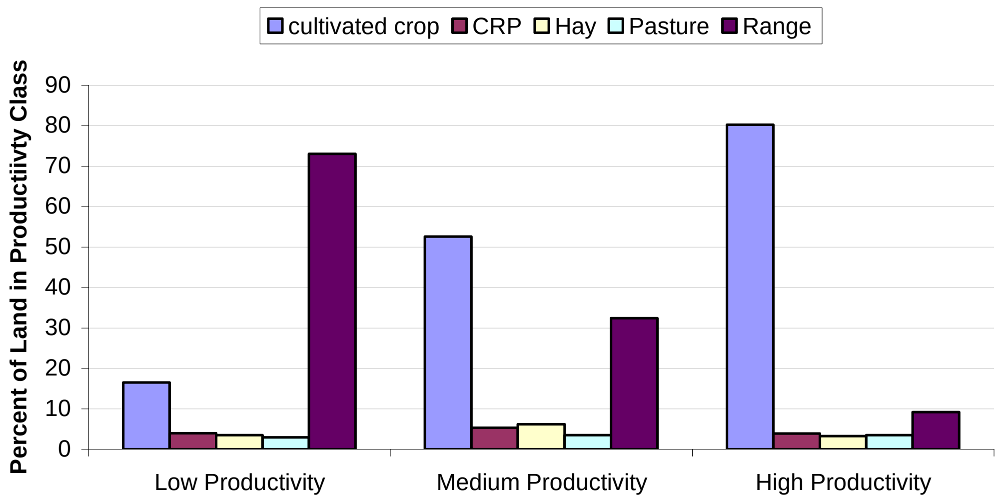
- >= 0.8% of grassland
- >= 1,500 acres

2 Counties with annual rate of "new" cropland >= 2.0 % of grassland

[1]"New" cropland is land that has no USDA history of crop production

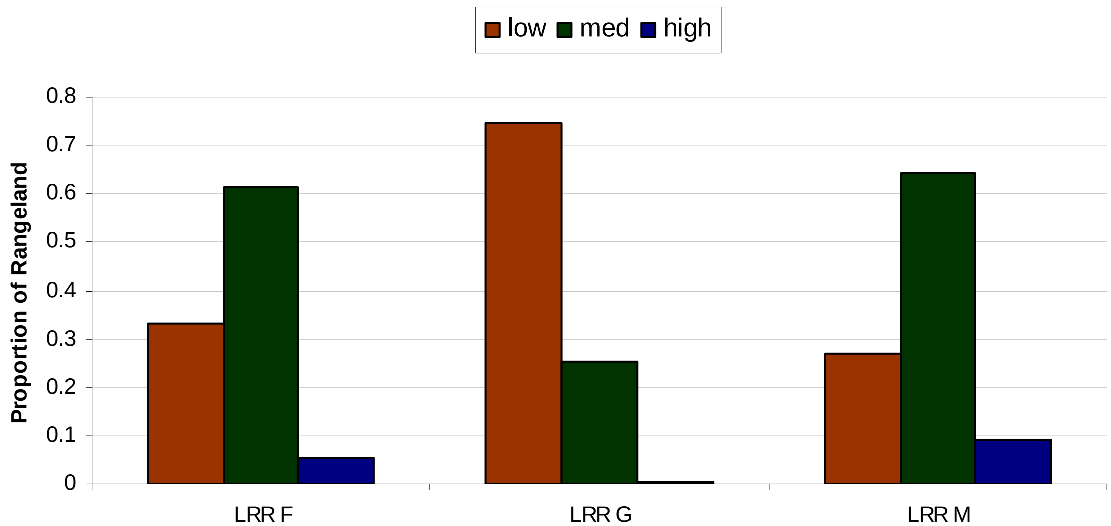
Source: ERS analysis of USDA Farm Service Agency (FSA) Data

Figure 5. Distribution of Land by Productivity Class and Use, Northern Plains Region



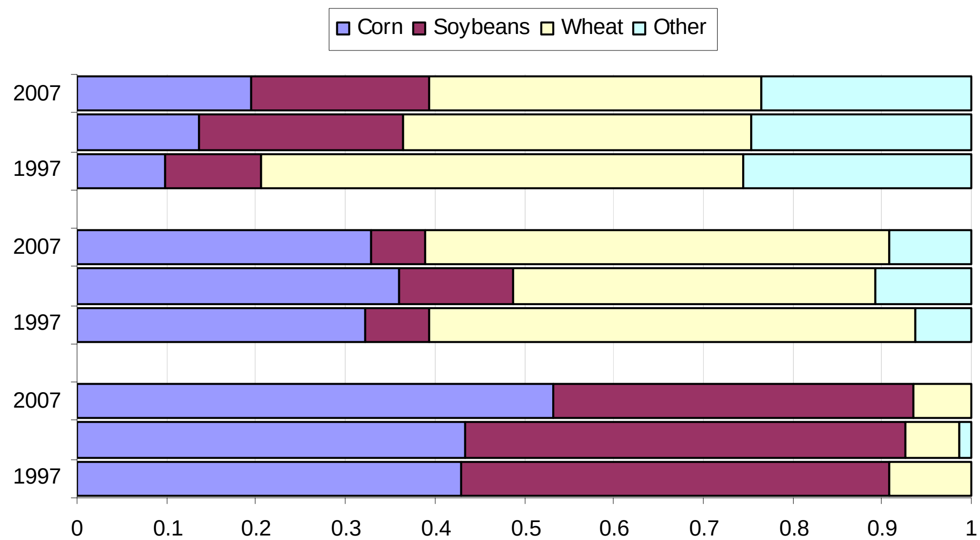
Source: ERS analysis of the 1997 National Resources Inventory (USDA-NRCS).

Figure 6. Distribution of Rangeland by Land Resource Region and Productivity Class



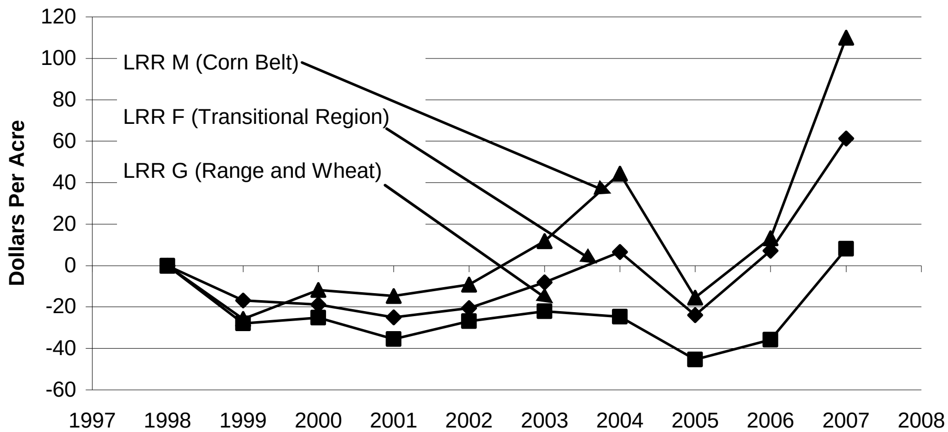
Source: ERS analysis of the 1997 National Resources Inventory (USDA-NRCS).

Figure 7. Cropping Patterns by Land Resource Region
1997, 2002, and 2007



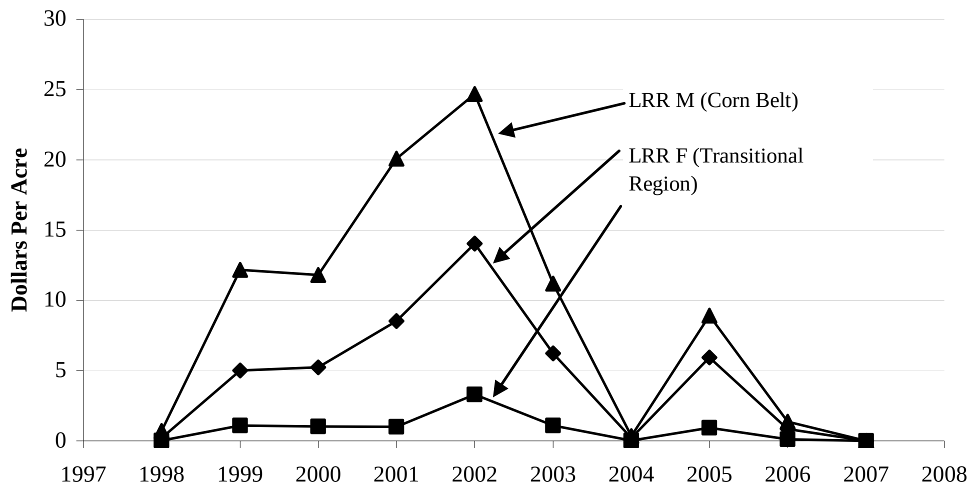
Source: ERS analysis of National Agricultural Statistics Service (NASS) data.

Figure 8. Change in the Difference Between Expected Return to Crops and Grazing, by Land Resource Region, Normalized to 1998



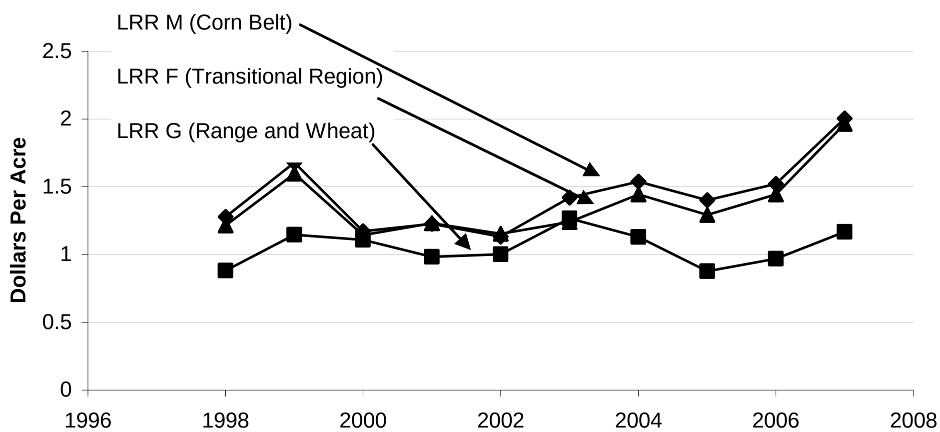
Source: ERS

Figure 9. Expected Marketing Loan Gains, by Land Resource Region



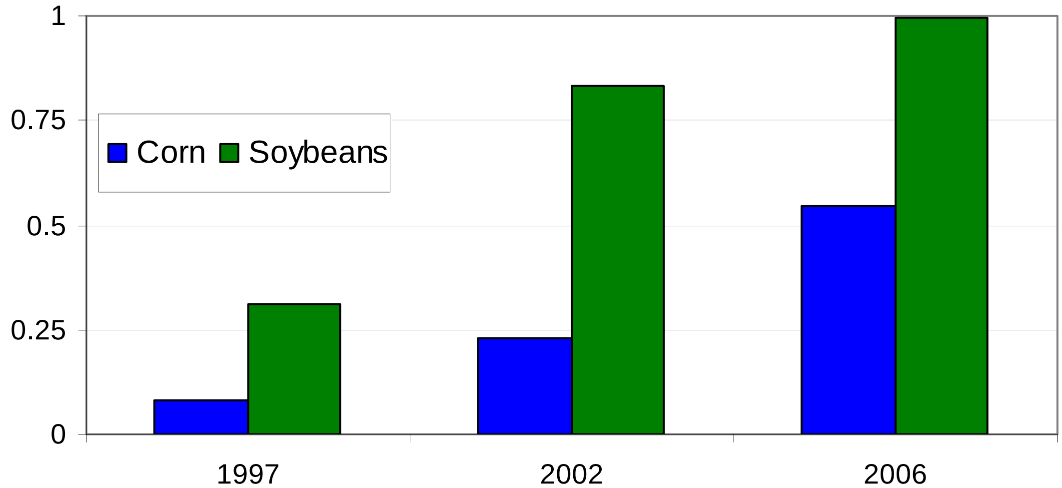
Source: ERS

Figure 10. Expected Net Crop Insurance Indemnity, by Land Resource Region



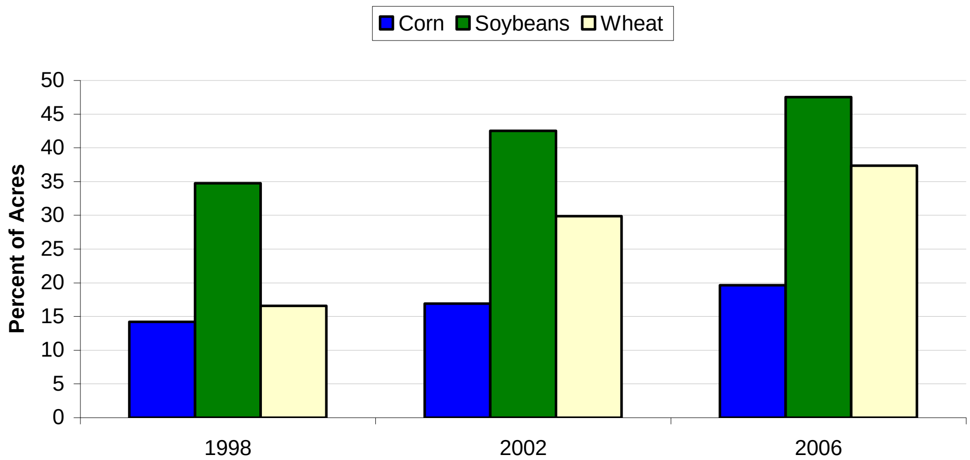
Source: ERS

Figure 11. Adoption of Herbicide Tolerant Seed in U.S. Northern Plains, Percent of Total Acreage



Source: ERS analysis of ARMS data for 1996-2006

Figure 12. No Till Adoption in the Northern Plains for Selected Years, By Crop



Source: ERS analysis of ARMS data for 1996-2006