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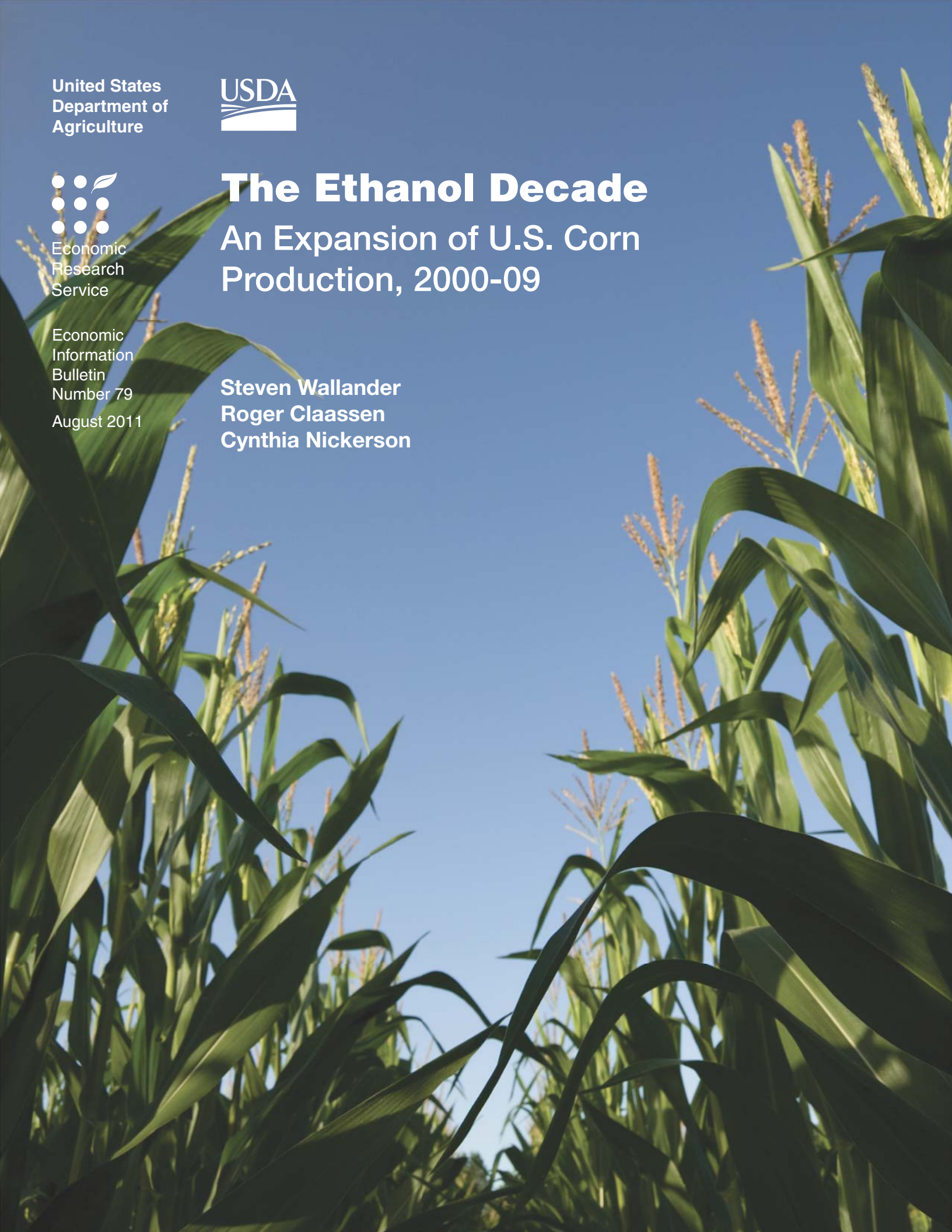
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August 2011

# **The Ethanol Decade**

## **An Expansion of U.S. Corn Production, 2000-09**

**Steven Wallander  
Roger Claassen  
Cynthia Nickerson**



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# The Ethanol Decade

## An Expansion of U.S. Corn Production, 2000-09

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### Abstract

The recent 9-billion-gallon increase in corn-based ethanol production, which resulted from a combination of rising gasoline prices and a suite of Federal bioenergy policies, provides evidence of how farmers altered their land-use decisions in response to increased demand for corn. As some forecasts had suggested, corn acreage increased mostly on farms that previously specialized in soybeans. Other farms, however, offset this shift by expanding soybean production. Farm-level data reveal that the simultaneous net expansion of corn and soybean acreage resulted from a reduction in cotton acreage, a shift from uncultivated hay to cropland, and the expansion of double cropping (consecutively producing two crops of either like or unlike commodities on the same land within the same year).

**Keywords:** Agricultural Resource Management Survey (ARMS), bioenergy, ethanol, indirect effects, land use, corn production, environmental impacts

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## Summary

### What Is the Issue?

As annual U.S. ethanol production increased 9 billion gallons between 2000 and 2009, demand for the feedstock used to produce ethanol also increased. In the United States, corn is the primary feedstock for ethanol production, and harvested corn acreage increased by roughly 10 percent (7.2 million acres) over the same period, with much of the change occurring in 2006-08. The environmental and economic implications of such a large shift in land use depend largely on where these additional corn acres are located. In this study, we analyze data from a special bioenergy survey of farm operators to determine, for the first time, how farm-level land-use decisions affected corn supplies and competing crops.

### What Did the Study Find?

As farmers react to price changes for commodities they can produce on their farms, adjustments in land-use decisions can be complex. Not only do land-use decisions by individual farmers reflect the relative productivity of farmland for specific crops, but price expectations can differ from one operator to the next and decisions can change from year-to-year as new expectations are formed. Increased demand for corn, attributed to bioenergy policies and other market conditions during 2000-09, resulted in a complex array of cropping pattern changes.

- Corn production expanded between 2000 and 2009 due partly to an increase in corn acreage relative to historic levels and partly to an increase in corn yields.
- Crop acreage shifts at the farm level indicate complex market adjustments between 2006 and 2008:
  - Farms specializing in soybeans in 2006 accounted for most of the increase in corn acreage;
  - Farms shifting from other crops into soybeans offset the shift from soybeans to corn; and
  - Some farms reduced corn acreage, while other farms expanded soybean and corn acreage simultaneously.
- Expanding total acreage in major cultivated crops on corn and soybean farms also increased corn and soybean acreage:
  - The average shift from hay, USDA Conservation Reserve Program, or grazing land into cultivated cropland accounted for about a third of the average increase in harvested crop acreage, mostly from hay; and
  - Double cropping (consecutively producing two crops of either like or unlike commodities on the same land within the same year) and a reduction in idled cropland also expanded harvested crop acreage.

## How Was the Study Conducted?

This report examines the expansion in U.S. corn production between 2000 and 2009, but focuses specifically on farm-level evidence for 2006-08—a period of dramatic corn price increases. Higher corn prices (relative to alternative crop prices) stimulated increased corn production. Analyzing farm-level survey data allows us to determine the relative scale and sources of cropland expansion. The farm-level data were drawn from a special version of the 2008 Agricultural Resources Management Survey (ARMS) that sampled corn and soybean farmers simultaneously. Corn and soybeans are often grown in rotation, so targeting producers of both crops provides a full representation of joint production for both crops. The ARMS is a detailed, annual survey of farm businesses and associated households conducted jointly by the U.S. Department of Agriculture’s Economic Research Service (ERS) and National Agricultural Statistics Service (NASS). We investigated the changes in aggregate crop acreages between 2000 and 2009 by using annual crop production summaries and the 1997, 2002, and 2007 Agricultural Censuses.

## Introduction

Between 2000 and 2009, U.S. ethanol production increased from 1.6 billion gallons to 10.8 billion gallons (U.S. Department of Energy, 2010). Over the same period, U.S. corn production increased from 9.9 billion bushels to 13.1 billion bushels, while harvested corn increased from 72.4 million acres to 79.6 million acres (USDA, National Agricultural Statistics Service, 2010).<sup>1</sup> This study examines how farms expanded corn acreage during this period, primarily between 2006 and 2008, and informs a number of questions about the unintended environmental effects of bioenergy policies.

Increasing demand for ethanol (and for corn as an ethanol feedstock) over the past decade came in response to a rise in energy prices and Federal bioenergy policies aimed at reducing greenhouse gas emissions, reducing ground-level ozone and smog, and increasing energy independence.<sup>2</sup> Previous studies suggest, however, that bioenergy policies may have unintended impacts, including those on the environment, the livestock sector, and food prices due to increased competition for corn. (See box, “Crop Prices and Ethanol Demand,” for a discussion of the changes in corn and other crop prices between 2000 and 2009.) Potential environmental impacts include the loss of wildlife habitat, greater carbon emissions, increased local air pollution from ethanol production, and reduced water quality (Searchinger et al., 2008; Hill et al., 2009; U.S. Environmental Protection Agency, 2010). The magnitude of these impacts depends on how and where corn production expansion occurs and how farmers adjust production of other crops (Malcolm et al., 2009). For example, increased conversion of hay or pasture to crop production or increased double-cropped acreage<sup>3</sup> and the use of more inputs may accelerate nutrient runoff and soil erosion. Even shifts from relatively low-input crops to high-input crops (e.g., wheat to corn) could affect environmental quality. When acreage shifts from one high-input crop to another (e.g., cotton to corn), however, ethanol-induced changes may be negligible or could even reduce environmental externalities.

<sup>1</sup>Harvested acres are used as a measure of land committed to corn rather than planted acres because the latter includes corn planted for silage.

<sup>2</sup>The Renewable Fuel Standard and ethanol production tax credits seek to replace a portion of gasoline consumption with ethanol consumption. The Clean Air Act requires the addition of oxygenates to fuel in some areas of the country to reduce ground-level ozone and smog. Ethanol is currently the preferred oxygenate in most regions of the country, particularly since MTBE (methyl tertiary butyl ether), the previously preferred oxygenate, has been identified as a drinking water pollutant.

<sup>3</sup>The practice of consecutively producing two crops of either like or unlike commodities on the same land within the same year.

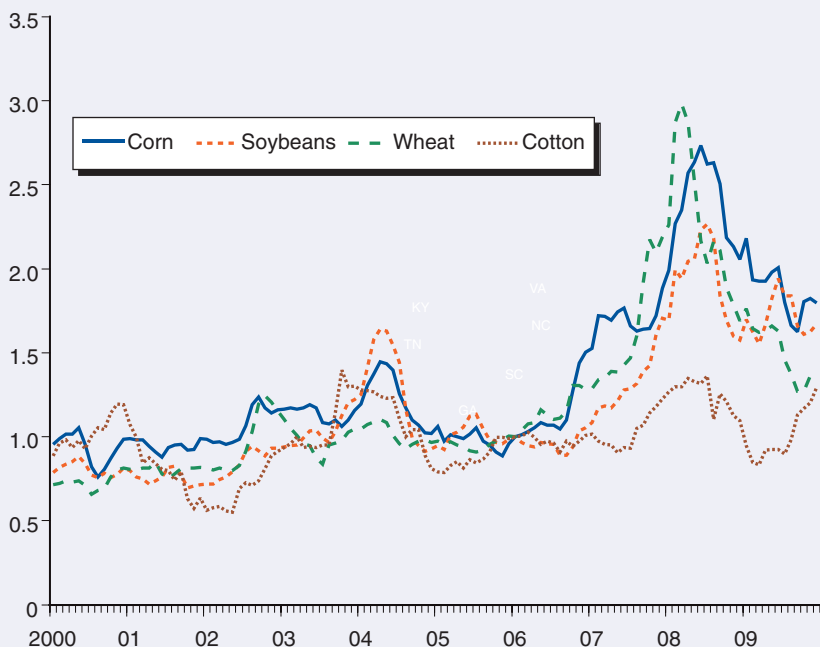


## Crop Prices and Ethanol Demand

The changes in corn production described in this report are not only a response to domestic bioenergy policies but also to other market forces and Government policies. According to the Congressional Budget Office (CBO) (2009), about 20 percent of the increase in corn prices between 2007 and 2008 was due to domestic ethanol demand. The CBO report also cites research by the International Food Policy Research Institute (IFPRI) that 40 percent of the rise in corn prices between 2000 and 2007 was due to global ethanol demand. Other factors influencing corn prices included energy prices, exchange rates, and adverse weather. Recent changes in the corn market allow us to examine how corn production has expanded. As shown in the price series below, corn price increases since 2006 were accompanied by a price increase for soybeans and wheat, but cotton prices have not increased as dramatically. Since farmers react to price trends when making land-use decisions, these price trends influence the pathways the farm sector has taken as it adjusted to increased demand for corn for ethanol production.

### Relative changes in major crop prices

Monthly crop price index (January 2006 = 1)



Source: USDA, National Agricultural Statistics Service,  
[http://www.nass.usda.gov/Charts\\_and\\_Maps/graphics/data/pitw.txt](http://www.nass.usda.gov/Charts_and_Maps/graphics/data/pitw.txt).

## Relative Importance of Corn Acreage for Corn Expansion

Agricultural markets can meet the growing demand for corn-based ethanol by:

1. Diverting corn from other uses, such as exports, food production, and livestock feed;
2. Increasing corn yields (bushels per acre); or
3. Increasing the amount of land planted to corn.

Corn acreage could be increased by reducing acreage in other crops, bringing new acreage into crop production, or expanding double-cropping practices. All of these changes occurred in response to ethanol production increases over the past decade.

Non-ethanol uses of corn have not increased over the past decade, as greater ethanol production has captured a larger share of corn production. The use of distillers' grains (a by-product of ethanol production) as livestock feed may have reduced demand for corn, but even with this substitution, some corn was diverted from other uses. Between 2000 and 2009, corn used for ethanol increased by 3.7 billion bushels, while total corn production increased by 3.2 billion bushels (fig. 1).

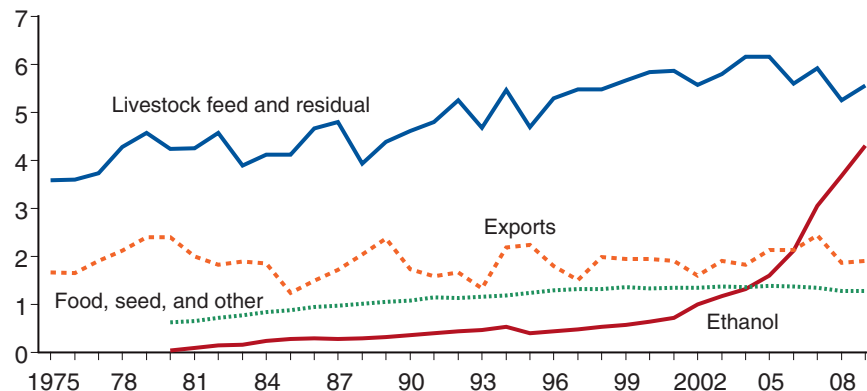
Corn yield increases have not kept up with ethanol production growth. Current agricultural projections show corn yield increasing at about 2 bushels per acre per year, which is almost the same rate that corn yield increased nationally between 2000 and 2009 (USDA, Economic Research Service, 2010). If corn acreage had been maintained at the 72.4 million acres harvested in 2000, then yield increases of 2 bushels per acre per year would have provided for only an additional 1.3 billion bushels of corn—below the amount needed to fuel expanding production of ethanol.<sup>4</sup>

<sup>4</sup>From the perspective of indirect effects, this reliance on “maintained” acreage (in conjunction with yield increases) is as relevant to the analysis of bioenergy policies as any potential reliance on “expanded” corn acreage relative to historic trends. Distinguishing between “maintained” and “expanded” corn acreage is useful, however, since each may have different environmental impacts.

Figure 1

### Primary uses of U.S. corn

Billion bushels of corn



Notes: Corn used for ethanol was not tracked separately prior to 1980. Corn used for the “food, seed, and other” category was split between several categories prior to 1980.

Source: USDA, Economic Research Service Feed Grains Database.

## Aggregate Evidence of the Expansion in Corn Acreage

Crop acreage adjustments ultimately occur at the field level as farmers decide whether to plant a particular crop on each piece of land in a given year. Often farmers make multiyear planting decisions and plant crops in rotation. One of the most common rotations sees corn and soybeans planted in alternating years on the same field, which makes shifting to more intensive corn rotations (e.g., a 3-year rotation of corn-corn-soy) a plausible adjustment to higher corn demand.<sup>5</sup>

Most crop acreage data are available only at an aggregated level (national, State, or county). In this section, we compare aggregate data (national, State, and county) with predictions from previous simulation studies. The aggregate data show that reducing soybean acreage is not the only option to expand corn acreage. Our farm-level analysis, presented in the next section, demonstrates how net acreage changes in aggregate data resulted from farm-level decisions.

Most simulation studies of bioenergy policies predicted large increases in corn acreage as ethanol production increased. The studies differ significantly, however, in the sources of those acreage increases (table 1). For two different scenarios, Searchinger et al. (2008) predicted that increases in domestic (U.S.) corn acreage would come predominately from reducing soybean and wheat acreage, as well as from increasing cropland acreage. The U.S. Environmental Protection Agency (EPA) (2010) predicted that increases in corn acreage would come from reducing soybean acreage and increasing cropland. In contrast, Malcolm et al. (2009) predicted that increases in corn and soybean acreage would come primarily from reducing idled cropland.

Observed changes are never a perfect test of simulation study predictions, which generally compare simulated outcomes with a simulated (and calibrated) baseline scenario. Observed changes may differ from those previously predicted because of the range of ethanol expansion under consideration, unexpected changes in related markets (e.g., fertilizer), or differences between shortrun and longrun adjustments. Nonetheless, the increase in ethanol demand over the past decade was precisely the type of demand-side shock that these simulation studies sought to model.

National acreage shifted out of soybeans and into corn between 2006 and 2007, but soybean acreage rebounded between 2007 and 2008 (fig. 2). Over the long run, however, both corn and soybean acreage have been expanding without an obvious historical shift out of soybeans and into corn.<sup>6</sup> In general, corn and soybean acreage expanded over both the long and short run (table 2), whereas most other crop acreage decreased over the long run, suggesting that acreage responses to greater corn demand do not mimic acreage responses predicted by simulation studies.

Regional differences in soybean acreage changes may explain why national soybean acreage did not decrease over this period. Several States in the Corn Belt and Lake State regions—most notably Iowa, Illinois, and Minnesota—show large increases in corn acreage with proportional decreases in soybean acreage (fig. 3). Other States—most notably South Dakota, Kansas, Mississippi, and Arkansas—show large increases in both corn and soybean acreage.

<sup>5</sup>Most regions of the country see substantial benefits from joint production of corn and soybeans. Corn production is nutrient intensive, whereas soybeans fix nitrogen in the soil. As a result, rotating corn and soybeans can reduce fertilizer costs. In addition, rotating corn and soybeans can reduce pesticide application costs by reducing the chance of pests and diseases becoming established.

<sup>6</sup>In the absence of bioenergy policies promoting the production of corn-based ethanol, soybean acreage might have been substantially higher. In such a case, the actual shift away from soybean acreage is simply obscured by increases in soybean demand that are unrelated to bioenergy policy. This would require a rapid increase in soybean demand that occurred simultaneously with the rapid increase in ethanol demand since 2006.

Table 1

**Comparing simulation studies of corn ethanol expansion**

Study	Searchinger et al.	Searchinger et al.	Malcolm et al.	EPA RFS2 RIA (FASOM)	EPA RFS2 RIA (FAPRI-CARD)
Year modeled	2016/17	2016/17	2015	2022	2022
<i>Billion gallons</i>					
Increase in ethanol	14.77 (from 14.75 to 29.52)	8.08 (from 14.75 to 22.84)	1.7 (from 13.30 to 15.00)	2.7 corn-based (from 12.3 to 15.00) plus 13.5 cellulosic	2.7 corn-based (from 12.3 to 15.00) plus small change in imported ethanol
<i>Predicted change in land-use/cropping selection</i>					
<i>Million acres</i>					
Predicted increase in corn acres	19.4	10.0	3.2	3.6	1.8
Predicted increase in cropland	5.5	2.9	4.9	8.1	0.7
Other major predicted increases			Soybeans (1.9)	Switchgrass (12.5)	
Major predicted decreases	Soybeans (-9.6) Wheat (-4.8)	Soybeans (-4.1) Wheat (-3.3)	Rice and sorghum (each -0.1)	Wheat (-2.9) Soybeans (-1.4) Barley (-1.2) Rice and hay (each -0.8) Oats and cotton (each -0.2)	Soybeans (-0.7)

EPA=U.S. Environmental Protection Agency.

RFS2=Renewable Fuel Standard Program.

RIA=Regulatory Impact Analysis.

FASOM=Forest and Agricultural Sector Optimization Model.

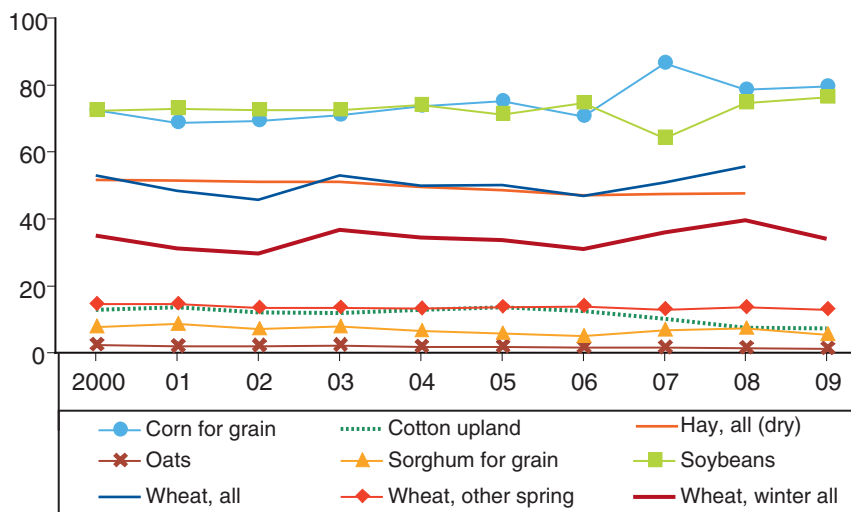
FAPRI-CARD=Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development.

Source: Searchinger et al., 2008; Malcolm et al., 2009; U.S. Environmental Protection Agency, 2010.

Figure 2

**Harvested acreage for major U.S. crops**

Millions of acres



Source: USDA, National Agricultural Statistics Service Crop Production Summaries.

Table 2

**National changes in harvested acreage, by crop**

Crop	Change in acreage	
	2006-08	2000-09
<i>Million acres</i>		
Corn (grain)	7.93	7.13
Soybeans	0.08	3.93
Cotton (upland)	(5.01)	(5.49)
Corn (silage)	(0.61)	(2.58)
Wheat (winter)	8.50	(0.97)
Wheat (durum)	0.76	(1.17)
Wheat (spring, other)	(0.36)	(1.55)
Hay (alfalfa, dry)	0.19	(2.61)
Hay (other, dry)	0.21	6.30
Oats	(0.17)	(1.09)
Sorghum (grain)	2.33	(2.25)
Total	13.86	(0.34)

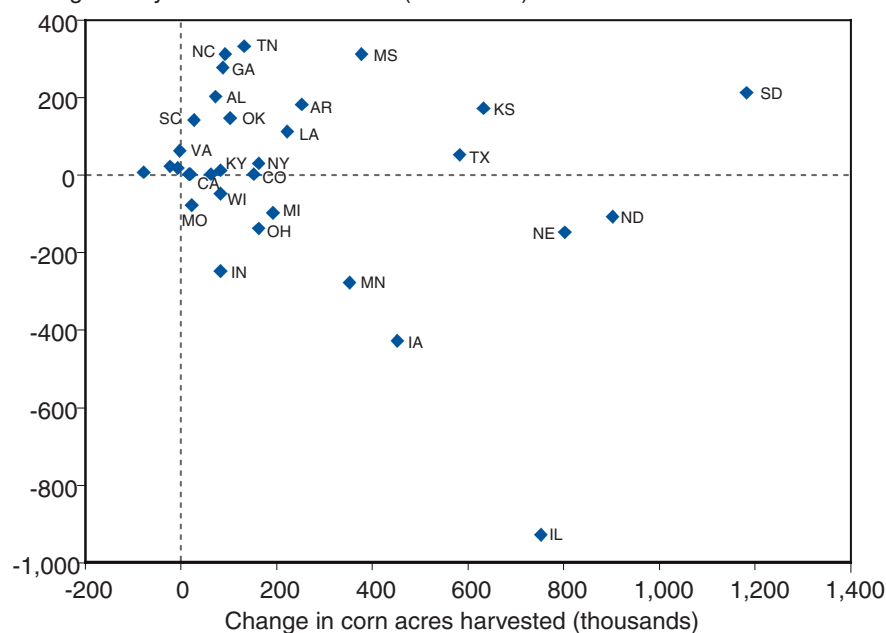
Note: Numbers in parentheses indicate decreases.

Source: USDA, National Agricultural Statistics Service Crop Production Summaries.

Figure 3

**State-level changes in corn and soybean acreage, 2006-08**

Change in soybean acres harvested (thousands)

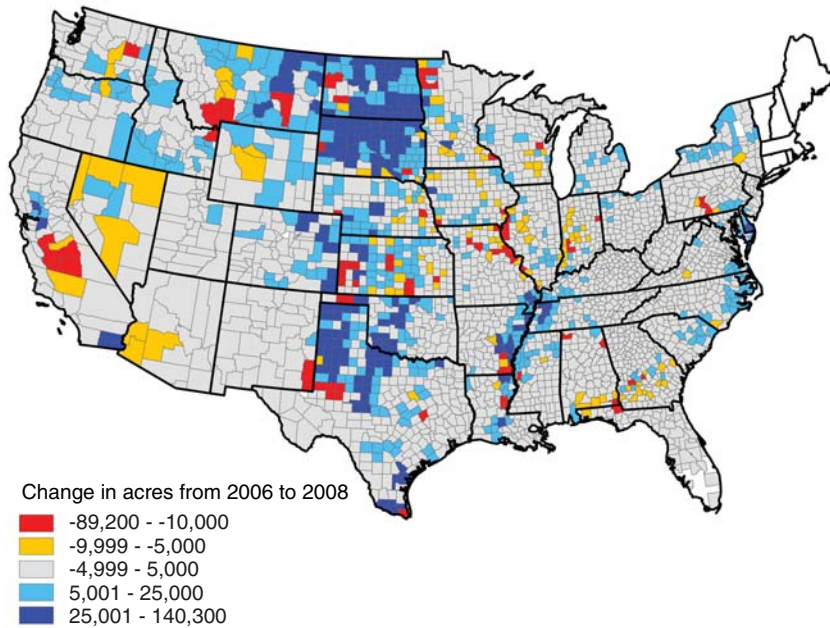


Source: USDA, National Agricultural Statistics Service Crop Production Summaries.

Regional differences are also apparent in how farms expand total harvested acreage (fig. 4). Expanding harvested acreage was an important trend in the Northern and Southern Plains, as well as in the lower Mississippi River Valley. Aggregate data sources do not provide detail on how harvested acreage might have expanded, including conversion of previously uncultivated or fallowed land to cultivated cropland or the expansion of double cropping. For that, we turn to farm-level data.

Figure 4

**County-level changes in harvested acres of corn for grain, soybeans, wheat, sorghum, cotton, barley, and alfalfa, 2006-08**



Notes: Each crop contributed to the sum of harvested acreage if nonmissing acreage was reported in the county in both 2006 and 2008. For a few counties, this means that a given crop's acreage was excluded from the sum of harvested acreage when it was reported at the county level in one year but was not reported in the other year.

Source: USDA, Economic Research Service calculations based on USDA, National Agricultural Statistics Service Crop Production Summaries.



## Farm-Level Evidence of the Expansion in Corn Acres

Farm-level data reveal important differences in how various types of farms expanded corn production. These data may explain why aggregate national data do not show a net movement out of soybeans and why county-level data show an increase in total harvested acreage in some regions. The data were derived from a special bioenergy version of the Agricultural Resources Management Survey (ARMS), in which corn and soybean farmers reported on acreage and the crops they planted over the 2006-08 period (see box, “Background on the Data: 2008 ARMS”).

Farm-level data reveal adjustments in crop acreage between 2006 and 2008. About a third of the farms growing corn and soybeans in 2008 harvested more corn acreage in 2008 than in 2006. A fourth of the farms growing corn and soybeans in 2008 harvested less corn acreage in 2008 than in 2006.<sup>7</sup> To capture the impact of movement into and out of corn (as well as into and out of other crops), we investigated changes for different categories of farms.

Due to the focus on movement into corn acreage and how ARMS selected farms for survey, our study identifies farms according to the dominant crop among noncorn acreage (table 3). (See box “Farm Classifications” for details on the farm classification scheme.) If corn acreage is coming primarily from soybean acreage, as predicted by some simulation studies, then soybean farms will account for most of the growth in corn production. Alternatively, if corn acreage is coming primarily from an expansion of cropland, then the growth in corn production may be more evenly spread across all types of farms or more concentrated among farms with land in forage production.

Both market adjustments and normal crop rotations can influence how we observe farm-level changes in acreage. To reduce the influence of normal crop rotations on observed land-use decisions, we focus on net acreage changes over the entire 2-year period (2006-08). By comparing 2006 acreage with 2008 acreage, we reduce the chance of mistaking planned rotations for market adjustments. For example, consider a farm that grows only corn and soybeans, practices corn/soybean year-on-year rotations on every field, and has 4 out of 10 equal-sized fields (40 percent of total acreage) in corn in 2006. We would expect that farm, without any market adjustments, to have 60 percent of its acreage in corn in 2007 before returning to 40 percent of its acreage in corn in 2008. Year-on-year changes in acreage would reflect rotations, whereas 2006-08 changes in acreage would reflect market adjustments. Year-on-year rotations and continuous production are the most common forms of joint production of corn and soybeans, although a full treatment of rotations introduces uncertainty into a farmers’ crop rotation selection (e.g., Livingston et al., 2008).

The contribution of each farm type to increased corn acreage is the total change in corn acreage for that type of farm (a weighted sum of the change in acreage) divided by the total change in corn acreage for all farms (a weighted sum of the change in acreage) times 100. These percentages use the ARMS sampling weights, which reflect the share of all farms growing corn and soybean represented by each farm type (table 3). Corn farms did not contribute, on average,

<sup>7</sup>The ARMS sampling for the phase 3 questionnaire targets farms that grew the desired crops in 2008. These statistics do not represent farms that grew no corn or soybeans in 2008, including those that grew one or both crops in 2006 or 2007. This approach to sampling, therefore, accurately captures the movement into corn and soybeans, but may understate movement out of corn and soybeans.

## Background on the Data: 2008 ARMS Survey

The USDA's National Agricultural Statistics Service and Economic Research Service annually conduct the Agricultural Resource Management Survey (ARMS) to obtain information on farming practices and production costs. Each year, a portion of the survey targets specific crops or livestock commodities. The 2008 ARMS incorporated several innovations that provided an unprecedented source of data on farm-level changes in corn production:

- The bioenergy version of the 2008 ARMS simultaneously sampled corn and soybean farmers. Since these two crops are often grown in rotation, targeting producers of both crops provided a full representation of how farms vary in the joint production of corn and soybeans.
- The 2008 ARMS also included questions about production practices in 2006 and 2007, particularly with respect to crop acreage. Responses provided a measure of within-farm variation in corn production over time.

## Farm Classifications

Farms were categorized according to their dominant crop in 2006. In keeping with the standard definition of a dominant crop, "corn" farms had at least 50 percent of their 2006 harvested acreage in corn. Among other farms, the goal is to identify which crop represents the most likely source for new corn acres. Among noncorn farms, a dominant crop was therefore defined as a plurality of at least 33 percent of noncorn harvested acres in 2006. Thus "soybean" farms harvested at least 33 percent of noncorn acreage in soybeans and more soybeans than any other noncorn crop. "Cotton" farms harvested at least 33 percent of 2006 noncorn acreage in cotton, and "wheat" farms harvested at least 33 percent in wheat. For "hay" farms, alfalfa and other hay were treated as a single crop category. "Other" crop farms harvested either sorghum, barley and oats (combined), or "other" as their dominant crop or were highly diversified and did not harvest a single crop that constituted at least 33 percent of their noncorn acres.

to corn acreage expansion because they reduced corn acreage between 2006 and 2008. Over half (53.2 percent) of the corn acreage expansion came from soybean farms. The remaining increase in corn acreage is split almost evenly between the other farm types. Nonetheless, cotton farms played a disproportionate role in expanding corn acreage. Cotton farms in 2006 made up less than 1 percent of the ARMS sample but were responsible for more than 12 percent of the increase in both corn and soybean acreage.

The 2006 corn farms were the largest source (42.3 percent) of expanded soybean acreage between 2006 and 2008 (table 3). Cotton farms accounted for a significant portion of soybean acreage expansion (12.2 percent) despite being a small part of the sample. "Other" farms played a larger role in soybean acreage expansion than in corn acreage expansion. In contrast, wheat farms contributed more to corn acreage than to soybean acreage.

Attributing corn and/or soybean acreage growth to a decrease in a farm's dominant crop acreage is supported by the fact that observed reductions

Table 3

**Average farm-level changes in crop acreage, 2006-08**

Item	Farm type (based on 2006 harvested acreage)					
	More than 50 percent of acres in corn	Less than 50 percent of acres in corn and more than 33 percent of noncorn acres in				
		Soybeans	Wheat	Cotton	Hay (all)	Other
Acres						
Average farm size:						
Harvested in 2008	546.4	577.5	918.9	1,683.5	208.4	566.2
Operated in 2008	637.4	660.8	1,489.5	2,267.8	508.4	794.1
Percent						
Contributions to expansion:						
Sampled population	25.7	37.0	4.9	0.6	24.2	7.6
Share of growth in corn acres	*	53.2	13.4	12.5	10.8	10.1
Share of growth in soy acres	42.3	7.6	5.5	12.2	9.2	23.1
Acres						
Average change in acres per farm:						
2006 to 2007						
Change in corn grain	-8.4 <sup>c</sup>	30.3 <sup>a</sup>	16.4 <sup>c</sup>	196.6 <sup>a</sup>	0.9 <sup>d</sup>	21.8 <sup>b</sup>
Change in soybeans	10.8 <sup>b</sup>	-22.2 <sup>a</sup>	13.2 <sup>c</sup>	55.4 <sup>b</sup>	2.3 <sup>c</sup>	5.6 <sup>c</sup>
2007 to 2008						
Change in corn grain	0.8 <sup>d</sup>	-16.6 <sup>a</sup>	9.5 <sup>d</sup>	-12.4 <sup>d</sup>	3.3 <sup>c</sup>	-9.1 <sup>d</sup>
Change in soybeans	10.0 <sup>b</sup>	24.8 <sup>a</sup>	0.8 <sup>d</sup>	182.1 <sup>a</sup>	2.5 <sup>c</sup>	32.7 <sup>b</sup>
2006 to 2008						
Change in corn grain	-7.6 <sup>d</sup>	13.8 <sup>b</sup>	25.9 <sup>b</sup>	184.3 <sup>a</sup>	4.3 <sup>c</sup>	12.7 <sup>b</sup>
Change in soybeans	20.7 <sup>a</sup>	2.6 <sup>d</sup>	14.0 <sup>c</sup>	237.5 <sup>a</sup>	4.8 <sup>b</sup>	38.2 <sup>b</sup>
Change in wheat	9.2 <sup>b</sup>	9.5 <sup>a</sup>	-19.4 <sup>d</sup>	93.7 <sup>b</sup>	2.0 <sup>c</sup>	52.8 <sup>c</sup>
Change in cotton	-0.1 <sup>d</sup>	-1.5 <sup>b</sup>	-0.4 <sup>d</sup>	-487.7 <sup>a</sup>	-0.2 <sup>d</sup>	-1.6 <sup>c</sup>
Change in hay	2.2 <sup>b</sup>	2.7 <sup>b</sup>	4.6 <sup>c</sup>	0.0 <sup>d</sup>	-6.3 <sup>c</sup>	6.3 <sup>c</sup>
Change in alfalfa	1.4 <sup>b</sup>	0.0 <sup>d</sup>	14.4 <sup>d</sup>	3.0 <sup>d</sup>	-4.2 <sup>c</sup>	1.5 <sup>d</sup>
Change in sorghum	1.5 <sup>b</sup>	0.7 <sup>d</sup>	20.1 <sup>d</sup>	36.7 <sup>b</sup>	0.2 <sup>d</sup>	-19.9 <sup>b</sup>
Change in barley/oats	0.3 <sup>d</sup>	0.2 <sup>d</sup>	11.7 <sup>d</sup>	N/A	-0.2 <sup>d</sup>	-5.0 <sup>d</sup>
Change in corn silage	1.5 <sup>b</sup>	-0.5 <sup>d</sup>	-0.6 <sup>d</sup>	6.7 <sup>d</sup>	1.7 <sup>c</sup>	-4.6 <sup>c</sup>
Change in other crop	4.5 <sup>b</sup>	5.4 <sup>a</sup>	20.7 <sup>d</sup>	39.1 <sup>c</sup>	8.9 <sup>a</sup>	-32.3 <sup>c</sup>
Change in harvested acres	33.6 <sup>a</sup>	32.0 <sup>a</sup>	73.2 <sup>b</sup>	113.1 <sup>c</sup>	10.4 <sup>b</sup>	29.5 <sup>d</sup>

<sup>a</sup> Coefficient of variation less than or equal to 25.<sup>b</sup> Coefficient of variation greater than 25 but less than or equal to 50.<sup>c</sup> Coefficient of variation great than 50 but less than or equal to 75.<sup>d</sup> Coefficient of variation great than 75.

\* The average corn farm did not contribute at all to the increase in corn acreage.

Notes: New operations (farms that had no harvested acreage in either 2006 or 2007 accounted for about 10 percent of the sample) are excluded from the calculations of these averages since they had no data for 2006 acreage to calculate changes in acreage. Values in gray are not statistically different from zero.

Source: USDA, Economic Research Service calculations based on the bioenergy version of the 2008 Agricultural Resource Management Survey conducted by National Agricultural Statistics Service and Economic Research Service.

in acreage are consistent with farm classifications (i.e., the largest average reduction in wheat acres is for wheat farms). For each farm type, the average change in total harvested acres is often larger than the average shift into both corn and soybeans (table 3). This is not the case for cotton farms. While the data show that 2008 corn and soybean farms significantly expanded harvested acreage between 2006 and 2008, the data also suggest that these farms did not exhaust opportunities for onfarm expansion of harvested acreage. The average farm operated more acres than it harvested and, in some cases, much more acreage.

Overall, farm-level averages indicate that movement from soybean acreage to corn acreage is offset by other movement into soybean acres. The new soybean acreage appear to be coming from corn, cotton, sorghum, and other crops, as well as from expansion in total harvested acreage.

## Changes in Harvested Acres

Farm-level data also provide insight into how total harvested acreage expanded:

- By cultivating land previously either idled or uncultivated (e.g., pasture);
- By expanding double cropping; or
- By consolidating (adding additional acreage by purchasing or leasing surrounding farms).

In the 2008 ARMS, farm operators were asked directly about expanding cropland into previously uncultivated acreage. About 16 percent of 2008 corn and soybean farms brought new acreage into production between 2006 and 2008. The uncultivated land brought into production by these farms accounted for approximately 30 percent of the average farm's expansion in total harvested acreage. Most acreage conversion came from uncultivated hay. Approximately 2.5 million acres of CRP land left the program in 2007, however, only a small portion of corn and soybean farms (about 2 percent) in 2008 brought CRP acreage into production between 2006 and 2008 (USDA, Farm Service Agency, 2007).<sup>8</sup>

Although the 2008 ARMS did not ask explicitly about double cropping, the extent of this practice can be inferred from the data. In 2008, about 14.6 percent of corn and soybean farms reported more harvested acreage (when summed across all crops) than total land that could be “considered cropland.”<sup>9</sup> Farms with harvested acreage larger than cropland acreage (i.e., farms inferred to be double cropping in 2008) also had a much higher rate of expansion in harvested acreage than other farms.<sup>10</sup>

Data from the 2007 Agricultural Census and annual NASS crop production summaries reveal that an estimated 12 million acres were double cropped in 2008, an increase of about 4 million acres since 2006. For this study, we estimated the total amount of double-cropped acreage in each region in census years (1997, 2002, and 2007) by taking the difference between total harvested acreage for all crops and age the reported “harvested acreage,” or any acreage on which at least one crop was harvested.<sup>11</sup> To estimate the total double-cropped acreage in 2006 and 2008, we assumed that changes in total double cropping in 2007 were proportional to changes in soybean double cropping (table 4). The amount of land double cropped has fluctuated over time, ranging from an estimated 11.2 million acres in 1997 and 6.9 million acres in 2005 to 12 million acres in 2008. Between 4 and 5 million acres of soybean are typically double cropped (and typically follow winter wheat), but patterns were atypical during 2005-08. After a low of about 2.5 million acres in 2005, double-cropped soybean acreage increased to 3.7 million acres in 2006 and to 7.2 million acres in 2008.<sup>12</sup>

Soybeans tend not to be double cropped in some major soy-producing States, such as Iowa, Minnesota, the Dakotas, and Nebraska, partly due to shorter growing seasons. Double cropping soybeans expanded over 2006-08 in almost every State where farmers used the practice. About a third of additional double cropping occurred in Appalachian States and another third

<sup>8</sup>For farmers making acreage decisions at the beginning of 2006, the potential for conversion from CRP to crop production was considerably larger than the number of actual expiring contracts indicates. Before the re-enrollment and extension of contracts during 2006, contracts on over 16 million acres of CRP land were due to expire in 2007. (See Conservation Reserve Program *Summary and Enrollment Statistics FY 2007* available online: [http://www.fsa.usda.gov/Internet/FSA\\_File/annual\\_consv\\_2007.pdf](http://www.fsa.usda.gov/Internet/FSA_File/annual_consv_2007.pdf).)

<sup>9</sup>The survey does not allow for comparable calculations in 2006 and 2007. The question about total land that can be “considered cropland” in 2006 and 2007 was not asked in the survey.

<sup>10</sup>Double-cropping farms expanded harvested acreage between 2006 and 2008 an average of 87.8 acres versus an average of 19.6 acres for other farms. Excluding those farms that reduced harvested acreage raises average expansion of harvested acreage to 128.2 acres for double-cropping farms and 47.4 acres for other farms.

<sup>11</sup>Annual estimates of double-cropped soybean acreage are available for selected States through the NASS crop production summaries.

<sup>12</sup>Based on USDA-NASS unofficial estimates of soybeans planted following another crop in 23 States. The surveyed States included those where double cropping has historically been more than trivial. See <http://usda.mannlib.cornell.edu/usda/nass/Acre//2000s/2009/Acre-06-30-2009.pdf>.

Table 4

**U.S. double cropping estimates, by region**

Region	Double cropping (all crops)			Soybeans double cropped			
	1997	2002	2007	2006	2007	2008	2009
<i>Thousand acres</i>							
Northeast	1,047	481	501	276	375	379	394
Lake States	972	334	396	*	*	*	*
Corn Belt	2,119	1,715	1,788	1,344	1,344	1,670	1,363
Northern Plains	1,831	1,976	1,980	347	398	561	185
Appalachian	1,765	1,556	1,402	1,063	1,398	2,216	1,590
Southeast	723	481	585	233	422	717	572
Delta States	1,106	821	995	375	995	1,403	510
Southern Plains	583	498	561	62	122	232	224
Mountain	456	211	779	*	*	*	*
Pacific	618	443	881	*	*	*	*
Far West	33	--	1	*	*	*	*
United States	11,253	8,516	9,868	3,699	5,053	7,177	4,837

\* States where insignificant acreages of soybeans are double cropped were not included in the survey.

-- = Data not available.

Sources: USDA, Economic Research Service calculations based on NASS Census of Agriculture, Annual Crop Production Summaries, and estimates of soybean acreage planted following another crop.

in Delta States. Tracking the expansion of double cropping in areas where soybeans are not the spring crop is more difficult due to data limitations. Regional estimates show that double cropping other crops is prevalent in some regions where soybean double cropping is limited, particularly in the Northern Plains and the Mountain States, and among a few regions where double cropping has expanded since 1997 (table 4).

Beyond increases in cropland or double cropping, harvested acreage growth at the farm level could also represent an increase in average farm size due to consolidation. This growth represents an inherent difficulty with farm-level data across multiple periods because farms that exit due to consolidation may be missed. Analysis of USDA county-level crop production summary data, for which farm consolidation is not a problem, confirms that an increase in harvested corn acreage (2006-08) is positively associated with an increase in the sum of harvested acreage for major crops. While some uncertainty remains about the relative importance of cropland expansion versus double-cropping expansion, our analysis shows that harvested acreage expansion was an important source of growth in corn production.



## Conclusions

U.S. corn production has increased dramatically over the past decade. Until 2006, corn production increases were largely due to increases in corn yields. Since 2006, corn production expansion resulted from increases in corn acreage.

Our findings partially support previous predictions about the indirect impacts of bioenergy policies; the largest source for new corn acreage was farms that grew primarily soybeans in 2006. However, there has not been a net decrease in soybean acreage. Reduced acreage of other crops and increased harvested acreage have been important sources for the simultaneous expansion of corn and soybean production. Several sources for corn (and soybean) acreage expansion—increases in double cropping, conversion of uncultivated hay, and reductions in cotton acreage—could have unintended consequences that differ from those suggested by earlier simulation studies. In addition, since observed patterns in both aggregate crop acreage data and farm-level land-use decisions reflect relative crop prices during the study period, future farm-sector and farm-level adjustments to increased ethanol production could differ from those reported here. For example, recent increases in cotton and wheat prices may mean that land-use decisions for the 2011 planting season will result in cropping patterns not observed in 2008.

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