Weather Effects on Expected Corn and Soybean Yields

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Drought and high temperatures during the 2012 growing season affected many agricultural production regions in the United States. For the third consecutive year, national average corn yields were reduced below trend expectations due to weather. Similarly, weather pushed national average soybean yields below trend for the second year in a row. As a result, there is a renewed interest in the relationship between weather and yields for these crops. This paper addresses this issue by developing U.S. corn and soybean yield models that account for weather and other factors.

To better understand weather effects on crop yields, a review of the weather and yields for 2012 is presented. National yield models for corn and soybeans are then developed, with selected model properties examined. Next is a discussion of how the weather-related yield models performed through the 2012 growing season. Lastly, implications for expected yields in 2013 are presented.

Background—2012 Growing Season

The 2012 growing season got off to a good start. USDA's *Prospective Plantings* report in March indicated a 4-percent increase in corn plantings and only a small reduction in soybean area. Weather was mild, facilitating early plantings of crops. Planting progress data for corn indicated an advanced pace through much of the spring. Figure 1 shows that corn plantings as of the middle and the end of April were ahead of a typical pace, a factor usually favorable for boosting yields. Additionally, the mild weather and advanced planting pace facilitated an increase in plantings of both corn and soybeans beyond the initial intentions (figure 2), with corn acreage rising to 97.2 million acres and soybeans to 77.2 million acres.

Following this favorable start, however, growing season weather was very poor. June 2012 was very dry. Precipitation totals in four of the top 10 corn producing States that month ranked in the top 10 driest Junes since 1895 (table 1).[1] The 4 States with less than 2 inches of precipitation in June 2012 have had fewer than 10 such Junes since 1895. Looking at an aggregation of eight primary corn-producing States (Iowa, Illinois, Indiana, Ohio, Missouri, Minnesota, South Dakota, and Nebraska), figure 3 shows how extreme the dry weather of June 2012 was, similar to June 1988.

July 2012 was the hottest July on record for the United States. Average temperatures in nine of the top ten corn producing States that month ranked in the top four hottest Julys since 1895 (table 2). July 2012 was also dry in several key corn producing States (table 3). The top three corn producing States had precipitation totals that month that ranked in the top four driest Julys since 1895. Figures 4 and 5 illustrate the hot and dry July 2012 across the eight selected corn-producing States.

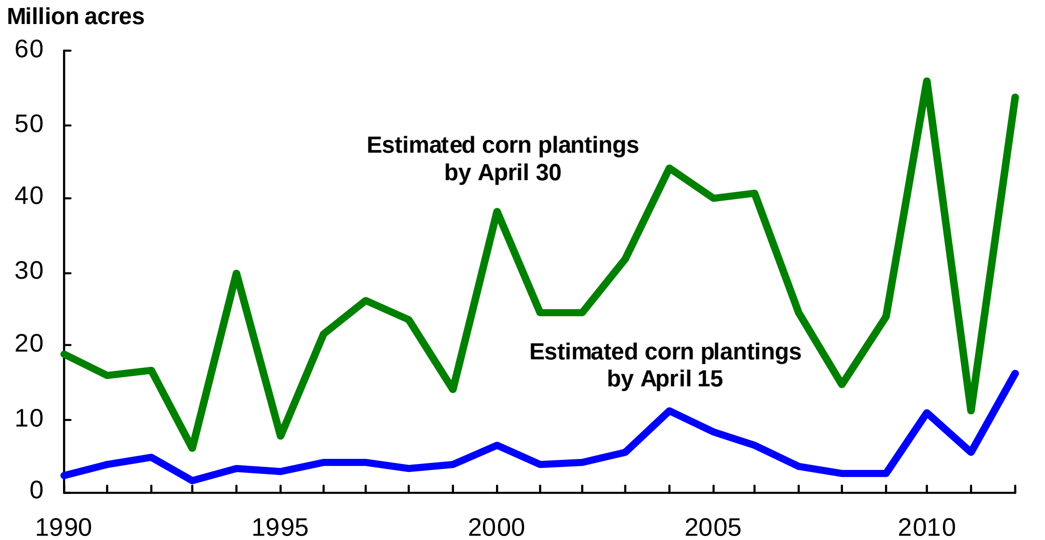
Results of this unfavorable weather were a sharp reduction of corn yields for the 2012 crop to 123.4 bushels per acres and a decrease of soybean yields to 39.6 bushels per acre (figs. 6-7).

[1] While the discussion in this section is presented mostly in the context of corn-producing States, these same States are also leading producers of soybeans.

Figure 1

2012 corn production prospects started out very promising:

Early corn plantings typically beneficial for yield prospects

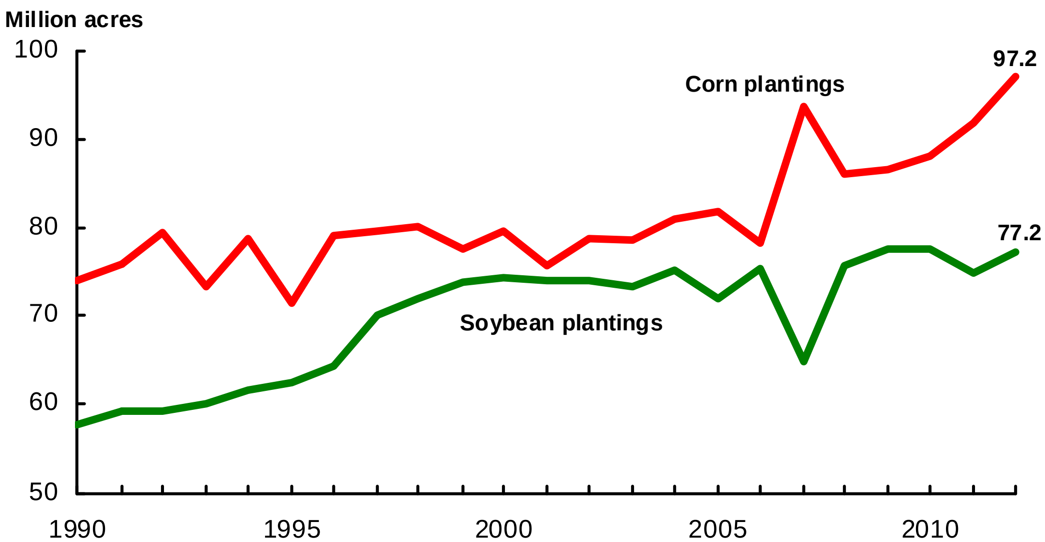


Source: ERS calculations, derived from the March *Prospective Plantings* report for U.S. total intended corn plantings times the 18-State (17-State in 1990s) aggregate corn planting progress as of April 15 and April 30 (USDA-NASS *Quick Stats*).

Figure 2

2012 production prospects started out very promising:

Corn plantings largest since the 1930s;
Soybean plantings third highest on record



Source: USDA-NASS *Quick Stats*.

Table 1

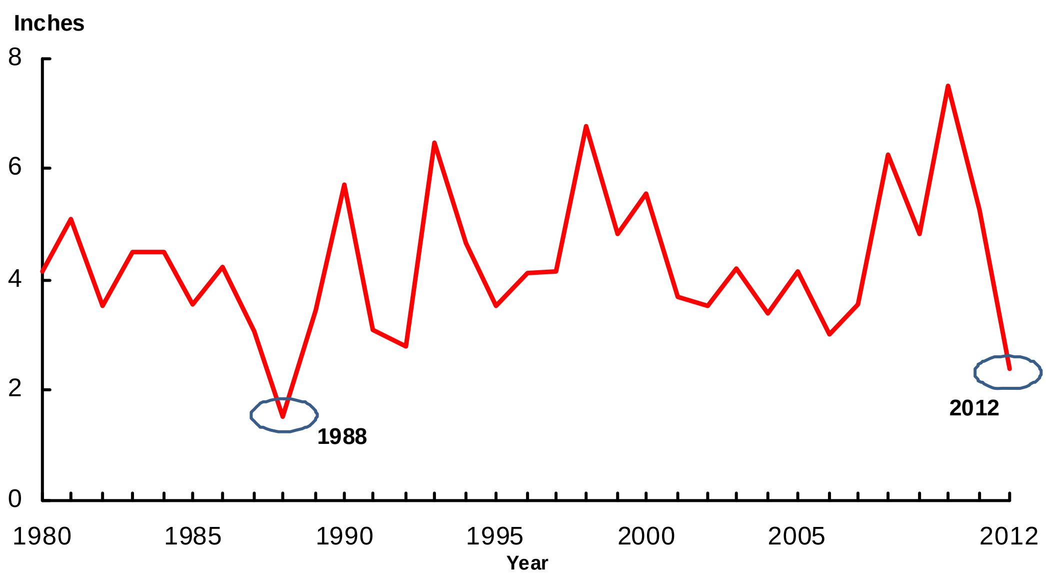
June 2012 was dry

State	2011 corn production rank	June 2012 precipitation (inches)	Low ranking since 1895
Iowa	1	2.88	15
Illinois	2	1.80	8
Nebraska	3	1.62	4
Minnesota	4	4.41	73
Indiana	5	1.30	3
South Dakota	6	2.15	23
Wisconsin	7	3.23	38
Ohio	8	2.13	12
Kansas	9	2.17	11
Missouri	10	1.93	6

Figure 3

June precipitation, 8-State weighted average

June 2012 was dry, much like June 1988



Eight States included are Iowa, Illinois, Nebraska, Minnesota, Indiana, South Dakota, Ohio, and Missouri. Weighted by corn harvested acreage.

Table 2

Hottest July on record for the United States

State	2011 corn production rank	July 2012 temperature ranking since1895
Iowa	1	3
Illinois	2	2
Nebraska	3	4^{t}
Minnesota	4	2^{t}
Indiana	5	3^{t}
South Dakota	6	2^{t}
Wisconsin	7	4^{t}
Ohio	8	2
Kansas	9	7
Missouri	10	4

t = tie ranking.

Table 3

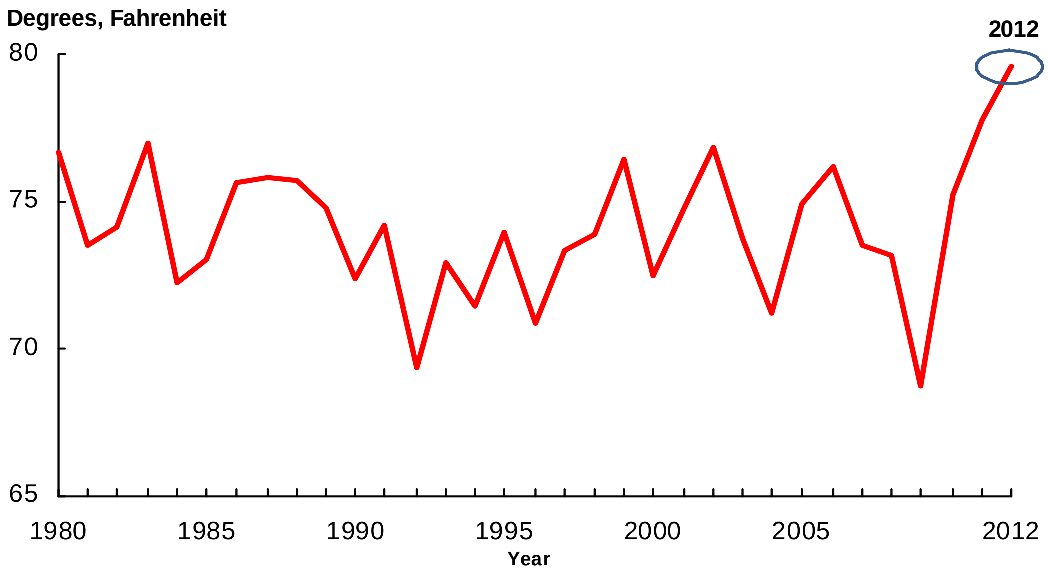
…also dry in July in several key corn producing States

State	2011 corn production rank	July 2012 precipitation (inches)	Low ranking since 1895
Iowa	1	1.18	3
Illinois	2	1.48	4
Nebraska	3	1.06	3
Minnesota	4	3.34	57
Indiana	5	2.62	21
South Dakota	6	1.60	23
Wisconsin	7	3.28	42
Ohio	8	3.36	32
Kansas	9	1.36	13
Missouri	10	1.58	7

Figure 4

July average daily temperature, 8-State weighted average

July 2012 was very hot

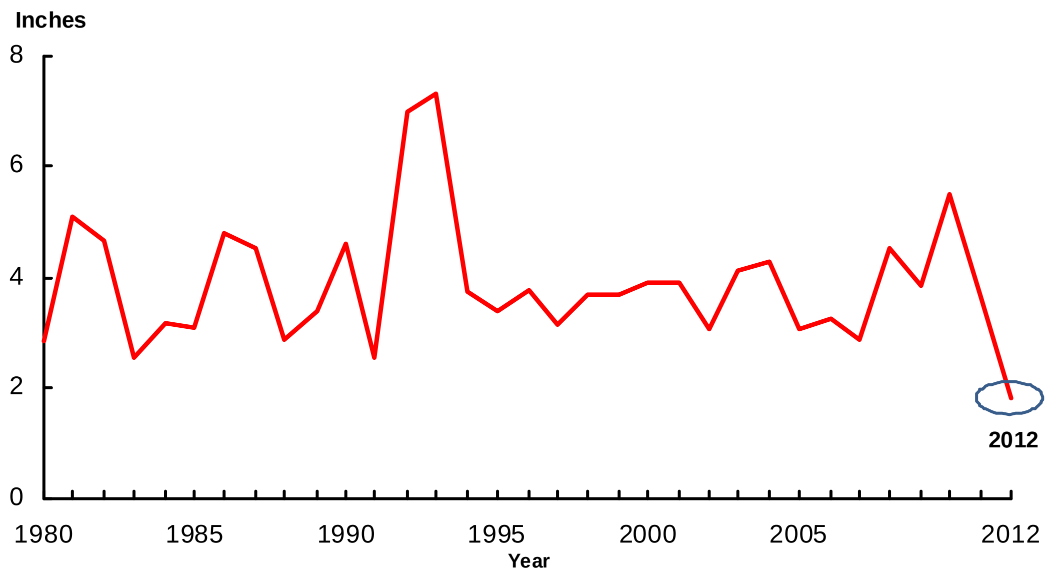


Eight States included are Iowa, Illinois, Nebraska, Minnesota, Indiana, South Dakota, Ohio, and Missouri. Weighted by corn harvested acreage.

Figure 5

July precipitation, 8-State weighted average

July 2012 was dry



Eight States included are Iowa, Illinois, Nebraska, Minnesota, Indiana, South Dakota, Ohio, and Missouri. Weighted by corn harvested acreage.

Figure 6

U.S. corn yields

2012 yields sharply reduced;
2010 and 2011 below expectations

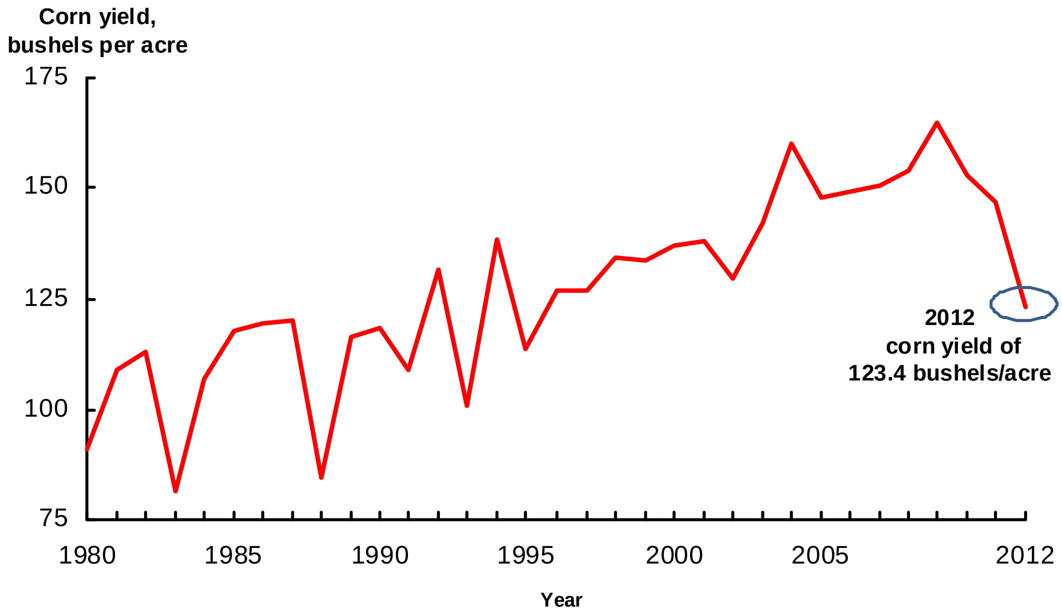
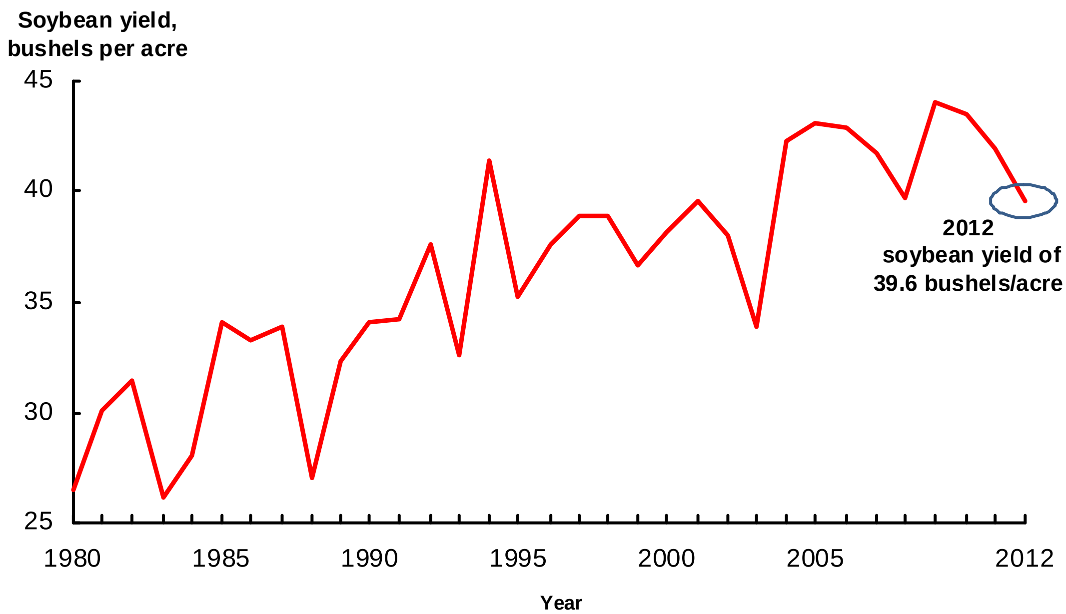


Figure 7

U.S. soybean yields

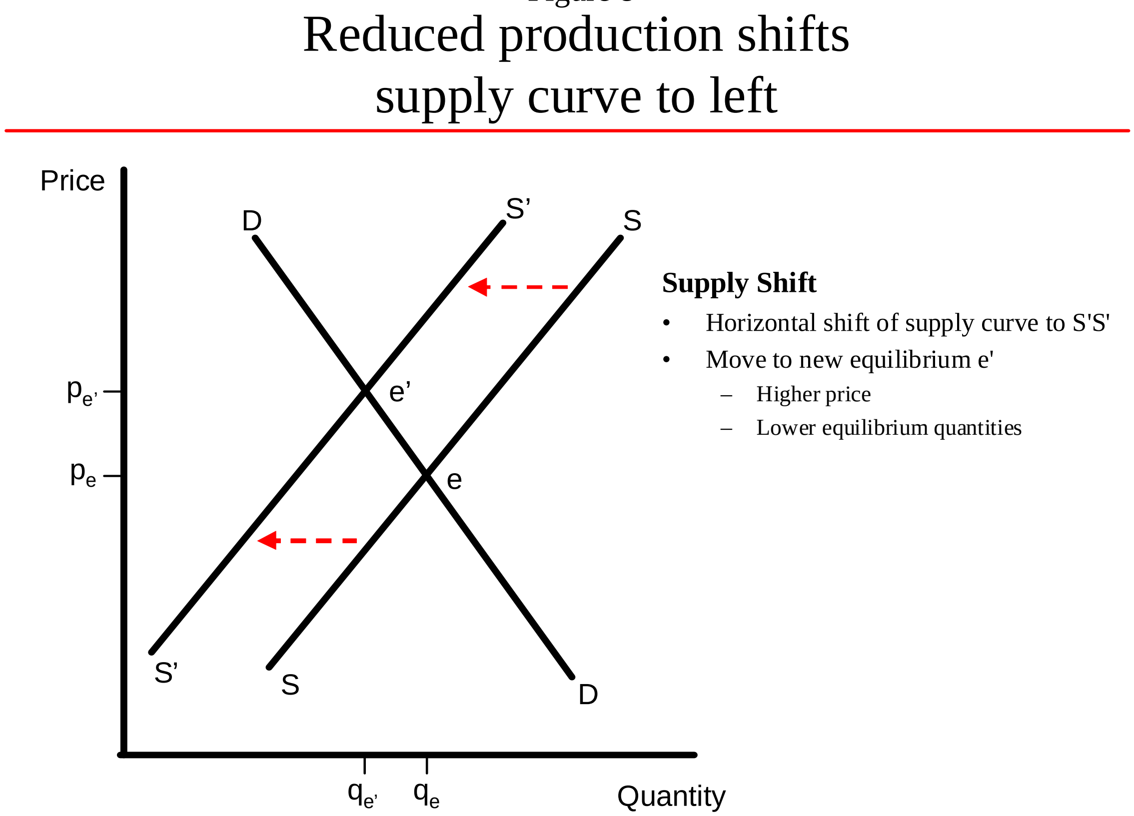
2012 yields also sharply reduced



2012 Market Impacts

A general economic framework for assessing market impacts of the reduced corn and soybean yields is shown in figure 8. Reduced yields shift the supply curve to the left, raising prices and reducing quantities demanded as the market equilibrium moves up the demand curve. The new equilibrium occurs with higher prices allocating reduced quantities among demands.

Figure 8



Although not a perfect measure of the impacts of the reduced yields of 2012 (since other factors changed, as well), a comparison of the corn and soybean supply and demand balances for 2012/13 as projected by USDA in the May 2012 *World Agricultural Supply and Demand Estimates* (WASDE) report compared with similar USDA projections from the January 2013 WASDE report provides general indications of the impacts since the reduction in yields was the major changing factor. Shown in tables 4 and 5 are the projections in May 2012 and January 2013 as well as the change between the two projections. The last column of each table indicates how the reduction in supply was allocated across various demands.

For corn, a $2.80 per bushel higher price resulted from the lower yields. Ending stocks fell the most, with feed and residual use and exports also declining sharply. Much of the reduction in feed and residual use reflects the residual component of this category, which tends to be partly related to corn production. Soybean prices are $1.25 per bushel higher in the current projections from the May 2012 projections. A much larger percentage of the adjustments in the soybean sector occurs for exports. Higher soybean meal prices, up $95 per ton, and the higher corn prices raise livestock sector feed costs.

Table 4

Corn sector impacts

Higher prices and lower use

U.S. corn projections, 2012/13 marketing year, May 2012 and January 2013 forecast comparison

Item	May 2012 forecast	Jan. 2013 forecast	Change	Percent of supply change
Planted acres (million acres)	95.9	97.2	1.3	
Harvested acres (million acres)	89.1	87.4	-1.7	
Yields: Bushels per harvested acre	166.0	123.4	-42.6	
Supply and use (million bushels):				
Beginning stocks	851	989	138	
Production	14,790	10,780	-4,010	
Imports	15	100	85	
Supply	15,656	11,869	-3,787	100
Feed & residual	5,450	4,450	-1,000	26
Ethanol and by-products	5,000	4,500	-500	13
Other food, seed, & industrial	1,425	1,367	-58	2
Domestic use	11,875	10,317	-1,558	
Exports	1,900	950	-950	25
Total use	13,775	11,267	-2,508	
Ending stocks	1,881	602	-1,279	34
Farm price (dollars per bushel)	4.60	7.40	2.80	

Note: Marketing year beginning September 1 for corn.

Table 5

Soybean sector impacts

Exports adjust relatively more

U.S. soybean projections, 2012/13 marketing year, May 2012 and January 2013 forecast comparison

Item	May 2012 forecast	Jan. 2013 forecast	Change	Percent of supply change
Planted acres (million acres)	73.9	77.2	3.3	
Harvested acres (million acres)	73.0	76.1	3.1	
Yields: Bushels per harvested acre	43.9	39.6	-4.3	
Supply and use (million bushels):				
Beginning stocks, September 1	210	169	-41	
Production	3,205	3,015	-190	
Imports	15	20	5	
Total supply	3,430	3,204	-226	100
Crush	1,655	1,605	-50	22
Seed and residual	125	119	-6	3
Exports	1,505	1,345	-160	71
Total disposition	3,285	3,070	-215	
Ending stocks	145	135	-10	4
Prices:				
Soybeans, farm ($ per bushel)	13.00	14.25	1.25	
Soybean oil (dollars per lb)	0.545	0.510	-0.035	
Soybean meal (dollars per ton)	350	445	95	

Note: Marketing year beginning September 1 for soybeans.

Incorporating Weather into Yield Models

Trend analysis is a useful initial framework for examining crop yields. Long-term trends in crop yields reflect improvements in yield-enhancing technology (such as new hybrids) as well as improvement in production practices (such as better pest and nutrient management and precision planting) that in turn support greater per-acre plant populations. Despite these long-term improvements, weather-related yield reductions for corn and soybeans have resulted in below-trend outcomes in the United States for the last 2-3 years. Thus, assessing the effects of weather on recent yields is important for determining underlying trend yields for these crops as well as developing yield expectations for 2013.[2]

Corn Yield Model

A model for national corn yields was estimated over the past 25 years (1988-2012), thereby including both the 1988 and 2012 droughts. In addition to a trend variable, the model uses as explanatory variables mid-May planting progress, July weather (precipitation and average temperature), and a June precipitation shortfall measure in selected years. Including those variables helps explain previous yield variations and deviations from trend.

Corn plantings by mid-May are important for yield potential because that allows more of the critical stages of crop development, particularly pollination, to occur earlier, before the most severe heat of the summer. Earlier pollination is also generally associated with less plant stress from moisture shortages. Most of the corn crop develops in July, so weather in that month is included in the model, including variables for both precipitation and temperature. Finally, while weather in June is important for development of the corn crop (and June typically has lower temperatures and more rain than July), effects of June weather are typically small relative to July weather effects. However, extreme weather deviations from normal in June can have larger impacts, as seen in 2012 and in 1988. To represent that effect, the model uses a measure of the precipitation shortfall from average in years when June precipitation is in the lowest 10 percent tail of its statistical distribution. The mid-May planting progress variable is based on weekly data from USDA's National Agricultural Statistics Service and is prorated to May 15 from adjacent weeks' results for years that the statistic was not reported for that specific date. The weather data is from the National Oceanic and Atmospheric Administration.

The planting progress and weather data used is for eight key corn-producing States (Iowa, Illinois, Indiana, Ohio, Missouri, Minnesota, South Dakota, and Nebraska). Those eight States typically rank in the top 10 corn-producing States and accounted for an average of 76 percent of U.S. corn production over the estimation period. An aggregate measure for the eight States for each of those variables is constructed using harvested corn acres to weight State-specific observations.

The effects of mid-May planting progress and July temperatures on corn yield are each linear in the model—for those variables, each unit of change has a constant effect on yield. Similarly, the June precipitation shortfall variable is linear for the years it is nonzero. However, the effect of July precipitation is nonlinear in the model to reflect the asymmetric response of corn yields to different amounts of precipitation above and below its average. That is, reductions in corn yields when rainfall is below average are larger than gains in corn yields when rainfall is above average. The

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[2] The analysis does not cover how numerous non-weather factors contribute to long-term yield trends, focusing on how weather factors influence actual yield outcomes relative to those trends.

Table 6

U.S. corn yield equation, using trend and 8-State weighted averages for mid-May planting progress and June and July weather*

	Intercept	Trend	Mid-May planting progress	July temperature	July precipitation	July precipitation squared	June precipitation shortfall **
Coefficient	228.5	1.952	0.289	-2.283	13.793	-1.522	-9.537
Standard error of coefficient		0.129	0.056	0.443	4.730	0.473	1.667
t-statistic		15.1	5.2	-5.2	2.9	-3.2	-5.7
R-squared		0.964					
Standard error		4.2					
Estimation period		1988-2012					

* All 8-State aggregates are weighted by harvested corn acres. Eight States are Iowa, Illinois, Nebraska, Minnesota, Indiana, South Dakota, Ohio, and Missouri. Those States were ranked 1-6, 8, and 10 in the United States in terms of 2011 corn production, accounting for 76 percent of the national total.

** June precipitation shortfall equals average precipitation minus actual precipitation when the actual is in the lowest 10 percent tail of its statistical distribution.

model uses a squared term for July precipitation to represent that asymmetric effect. The estimated regression equation (table 6) explains over 96 percent of the variation in national corn yields during the estimation period (more than 91 percent of the variation around the equation's trend).

Figures 9 and 10 show various model results. Figure 9 shows the model predicted values with the actual yields, depicting good model performance over the estimation period. Figure 10 provides an illustration of the underlying weather-adjusted trend corn yield. This trend estimate is calculated using sample averages for July weather, 80-percent Mid-May planting progress (the most recent 10-year average), and no June weather adjustment (implicitly assuming June weather is not extremely dry). Additionally, an adjustment is made to derive this trend to reflect part of the asymmetric response of corn yields to July precipitation variations around its average (see further discussion, pages 14-15).

Figure 9

U.S. corn yield model results

Predicted and actual

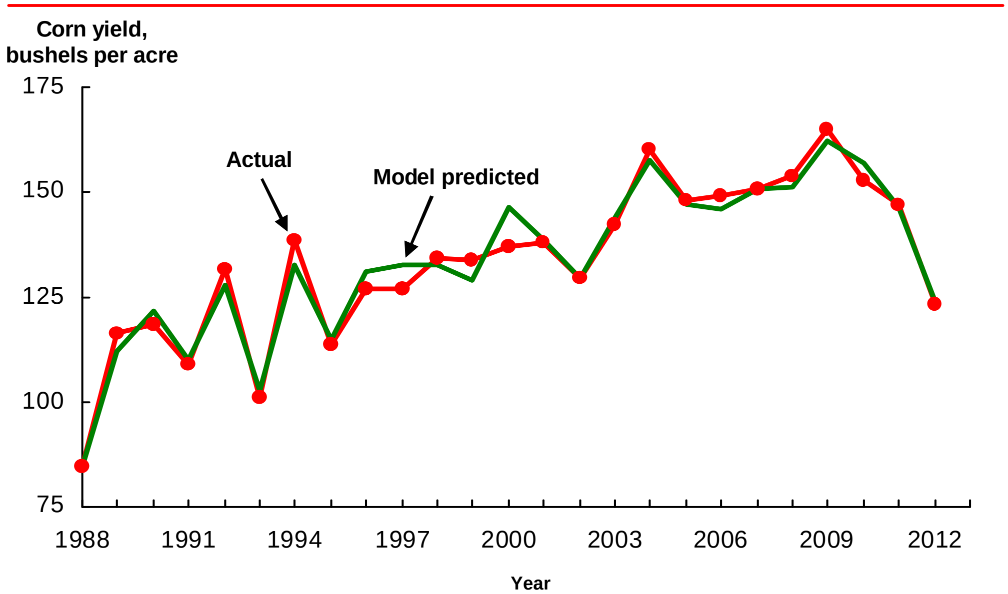
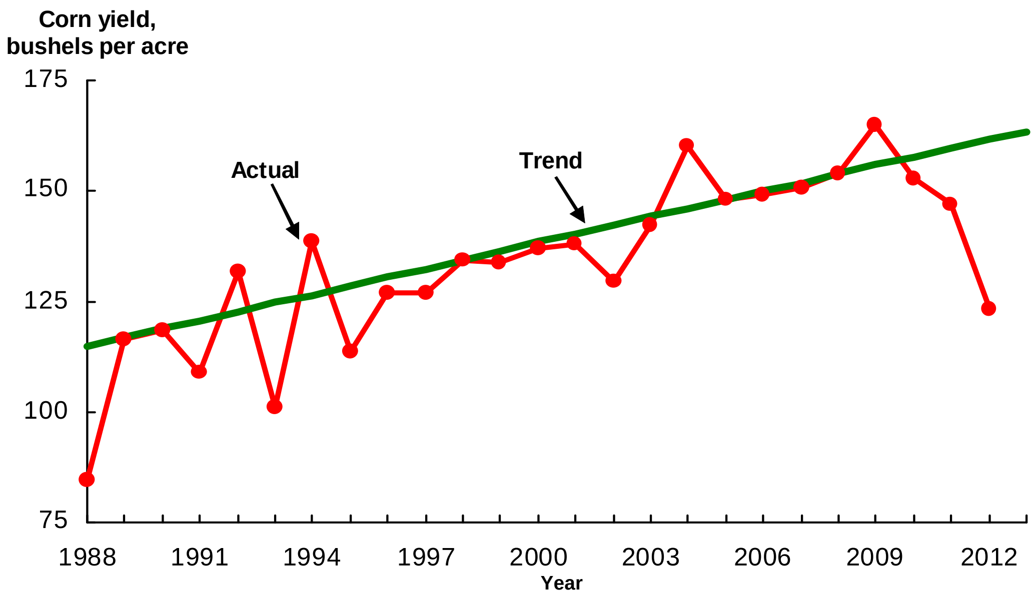


Figure 10
U.S. corn yield model results
Implied weather-adjusted trend



Trend evaluated at 10-year average for mid-May planting progress, sample means for July weather variables, adjusted for asymmetric yield response to July precipitation. Assumes June weather is not extremely dry.

Soybean Yield Model

A similar approach was used to develop a weather-adjusted trend yield model for soybeans. The model was estimated over the same 25-year period (1988-2012) as for corn. The soybean equation differs, however, by not including a planting progress variable and by using an average of July and August weather variables rather than just July weather. Those differences reflect a wider window for reproduction for soybeans than for corn. Nonetheless, a similar variable for June precipitation shortfall is included to reflect the potential importance of extreme weather situations in that month, such as in 2012 and 1988. Also, the weather variables included are weighted averages for seven States (Iowa, Illinois, Indiana, Ohio, Missouri, Minnesota, and Nebraska), using harvested soybean acres to weight State-specific observations. Those are currently the top seven soybean producing States, accounting for about 70 percent of U.S. soybean production over the estimation period.

Similar to the model for corn, the effects of July-August temperatures and the June precipitation shortfall variable are linear in the soybean yield model, and the July-August precipitation effect in nonlinear. The estimated regression equation (table 7) explains 80 percent of the variation in national soybean yields over the estimation period (50 percent of the variation around the equation's trend). Overall, the model's weather variables have lower statistical significance in explaining soybean yields than in the corn yield model, likely reflecting the longer reproductive period for soybeans which makes the timing of favorable weather less critical than for corn.

Table 7

U.S. soybean yield equation using trend and 7-State weighted averages for June, July, and August weather*

	Intercept	Trend	July-August temperature	July-August average monthly precipitation	July-August average monthly precipitation squared	June precipitation shortfall **
Coefficient	60.1	0.447	-0.514	5.083	-0.619	-1.279
Standard error of coefficient		0.061	0.237	4.447	0.512	0.723
t-statistic		7.3	-2.2	1.1	-1.2	-1.8
R-squared		0.800				
Standard error		2.1				
Estimation period		1988-2012				

* All 7-State aggregates are weighted by harvested soybean acres. Seven States are Iowa, Illinois, Minnesota, Nebraska, Indiana, Ohio, and Missouri. Those States were ranked 1-7 in the United States in terms of 2011 soybean production, accounting for 67 percent of the national total.

** June precipitation shortfall equals average precipitation minus actual precipitation when the actual is in the lowest 10 percent tail of its statistical distribution.

Figures 11 and 12 show various results for the soybean yield model. Figure 11 shows the model predicted values with the actual yields. As suggested by its lower explanatory power, the soybean yield model's performance, while good, is not as good as the corn yield model. Figure 12 shows the implied underlying weather-adjusted trend soybean yield. This trend estimate is calculated using sample averages for July-August weather and assumes no June weather adjustment. Similar to the corn weather-adjusted yield, an adjustment is made in calculating this soybean trend to account for part of the asymmetric yield response to July-August precipitation variations around its average (see further discussion, page 19).

Figure 11

U.S. soybean yield model results

Predicted and actual

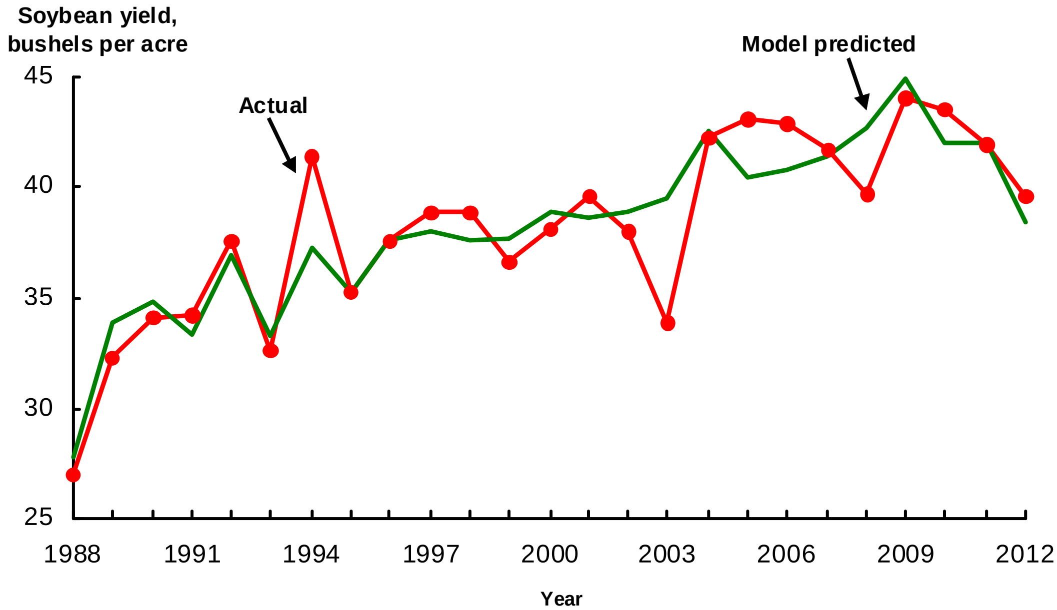
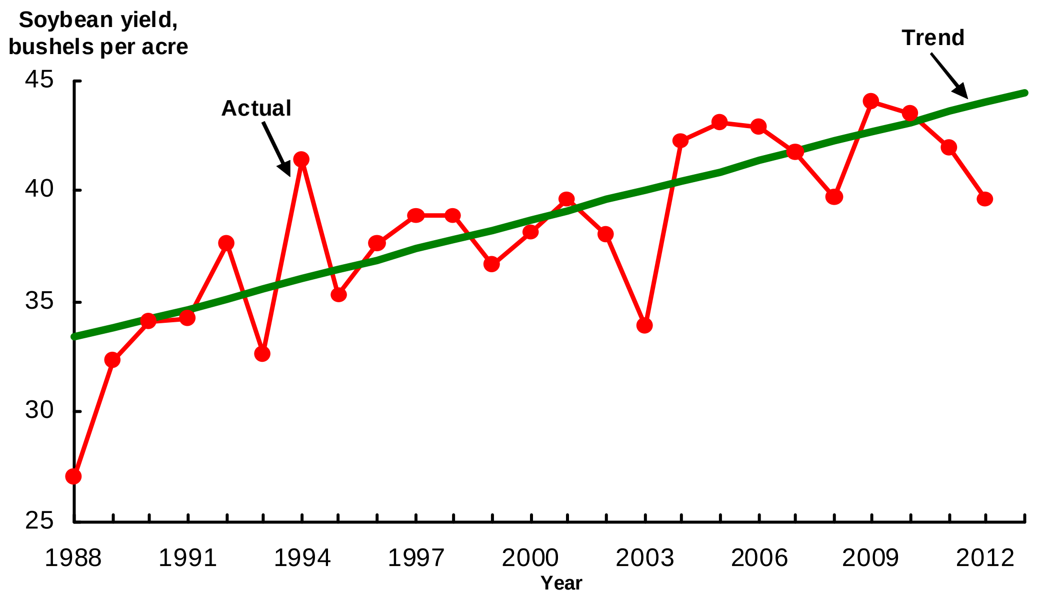


Figure 12

U.S. soybean yield model results

Implied weather-adjusted trend



Trend evaluated at sample means for average July-July weather variables, adjusted for asymmetric yield response to average July-August precipitation. Assumes June weather is not extremely dry.

General Model Properties

The estimated models can be used to illustrate yield responses to various growing season conditions. Discussed first are effects of planting progress and weather variables on corn yields, followed by weather variable effects on soybean yields.

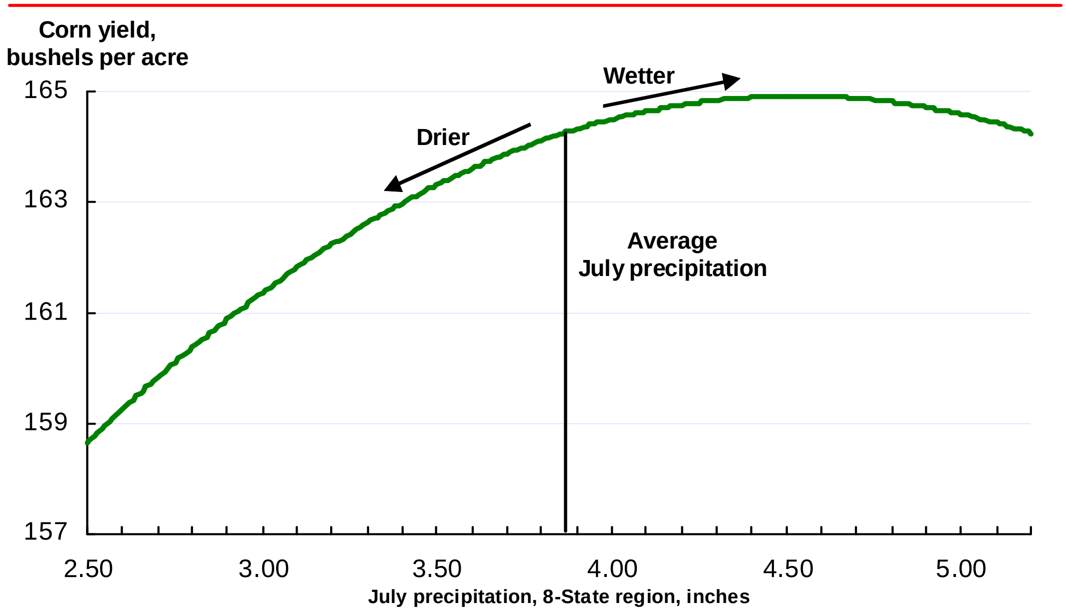
Corn Yield Asymmetric Response to July Precipitation Variation

Figure 13 shows the yield response to July precipitation when other explanatory variables in the model are held constant. The weighted average of July precipitation in the eight selected corn-producing States is 3.87 inches. The quadratic form of this precipitation variable in the model results in an asymmetric yield response to variations in July precipitation above and below its mean. As can be seen in figure 13, reductions in July precipitation below its average result in larger declines in corn yields than the gains in corn yields resulting from equal-sized increases in July precipitation above its average.

Figure 13

Corn yield model properties

Asymmetric yield response to July precipitation



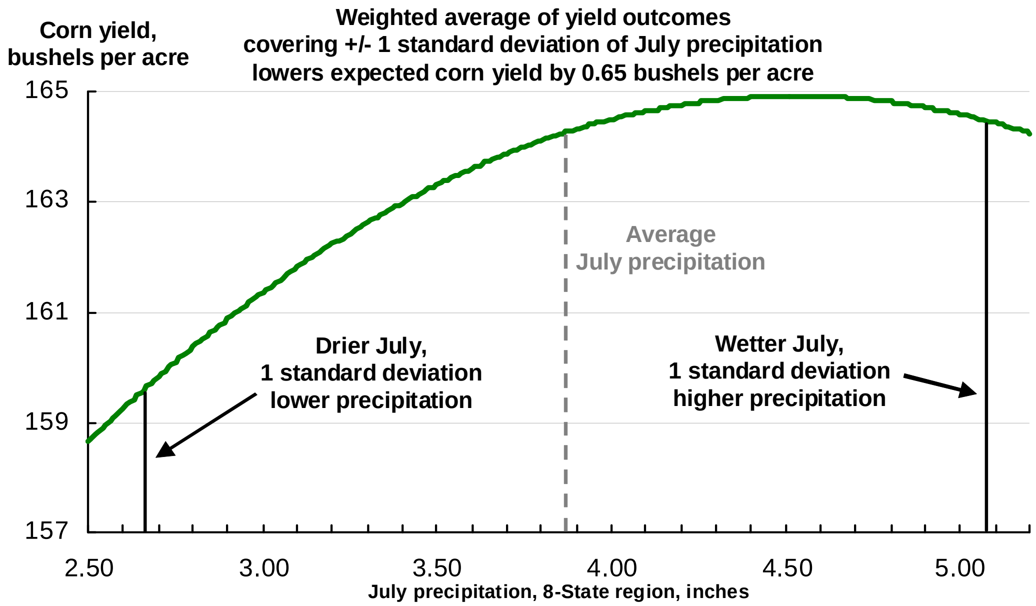
Note: Based on sample period average for July temperatures and 80 percent mid-May planting progress in the 8-State region.

Implications of Asymmetric Yield Response for Expected Corn Yields

Expected yields can be derived using the corn yield model based on assuming that all explanatory variables are at their sample averages. However, an alternative is to adjust the expected yield to reflect some of the asymmetric yield response to July precipitation.

That type of asymmetric yield response adjustment is illustrated conceptually in figure 14. Compared to an expected yield evaluated at the average for July precipitation, a weighted average of corn yield estimates for alternative levels of July precipitation within one standard deviation above and below its average results in a 0.65-bushels-per-acre lower mean expected corn yield. For that adjustment, July precipitation is assumed to have a statistically normal distribution in the weighting of the alternative corn yield estimates. Thus, the lower expectation accounts for yield effects of 68 percent of the statistical distribution of July precipitation.

Figure 14
Corn yield model properties
Asymmetric yield response to July precipitation



Note: Based on sample period average for July temperatures and 80 percent mid-May planting progress in the 8-State region.

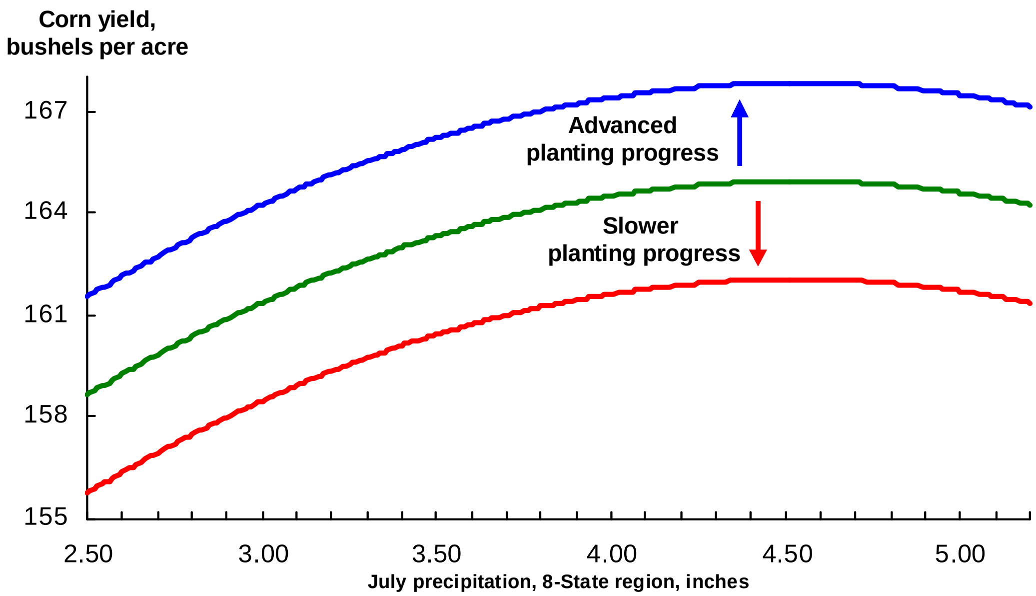
Corn Yield Response to Planting Progress

As depicted in the corn yield model, earlier plantings of the corn crop tend to be beneficial to yields because they typically help the crop avoid stress from moisture shortages and heat during pollination. Figure 15 illustrates this effect on corn yields for 10-percent higher and 10-percent lower mid-May planting progress relative to a base case. The middle curve in figure 15 is the same expected corn yield result for different levels of July precipitation that was shown in figures 13 and 14. Advanced planting progress, as measured in the corn yield model by the percent of the corn crop planted by mid-May, shifts the expected corn yield curve upward. With a coefficient of 0.289 for that term in the corn yield model, 10-percent more of the corn crop planted by mid-May raises the expected corn yield by 2.89 bushels per acre, as shown in figure 15. Similarly, 10-percent less of the crop planted by the middle of May reduces the model's per-acre yield expectations by 2.89 bushels.

Figure 15

Corn yield model properties

Yield response to mid-May planting progress

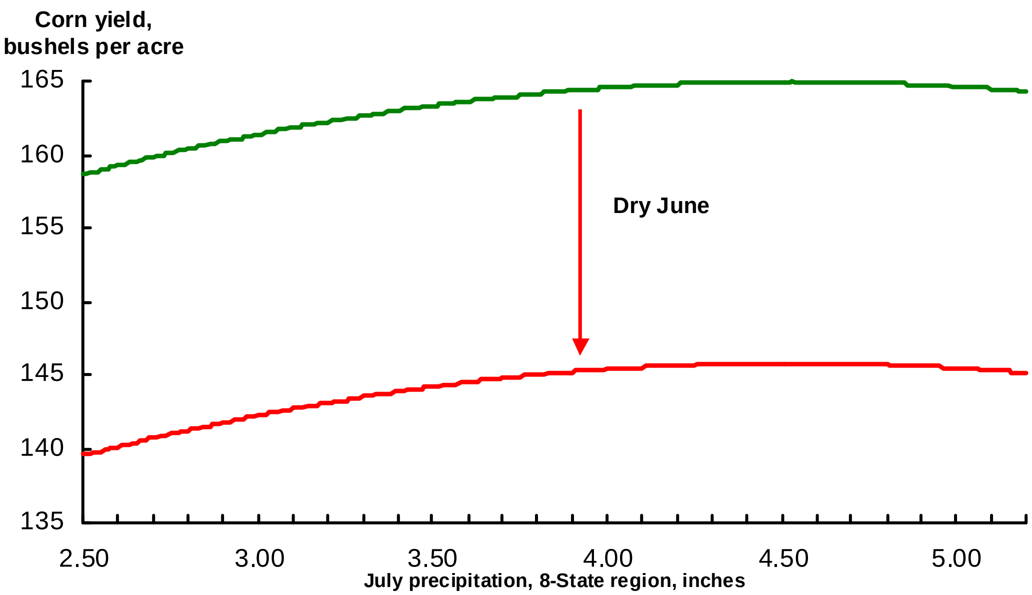


Note: Based on sample period average for July temperatures in the 8-State region. Middle curve assumes 80 percent mid-May planting progress in the 8-State region.

Corn Yield Response to Dry Weather in June

The corn yield model includes an adjustment to account for effects of June precipitation when exceptionally dry in that month. This adjustment represents the effects of the extremely dry Junes of 1988 and 2012, when monthly precipitation amounts were in the lower 10 percent tail of the statistical distribution. Figure 16 shows the effects on corn yield expectations should there be another such year. The higher curve again is the same expected corn yield result for different levels of July precipitation that was shown in figures 13 and 14. The lower curve in figure 16 shows the reduction in corn yield for June precipitation of 2.33 inches, 2 inches below the 4.33 inch average for the 8 selected corn producing States. A minimum of a 1.82 inch shortfall in June precipitation from its average is needed to trigger this variable in the model. The precipitation shortfall was 1.96 inches in June 2012 and 2.82 inches in June 1988. With the coefficient in the model for this term of -9.537, the 2 inch June precipitation shortfall shown in figure 16 reduces corn yields by 19.1 bushels per acre.

Figure 16
Corn yield model properties
Yield response to very dry June



Note: Based on sample period average for July temperatures and 80 percent mid-May planting progress in the 8-State region.

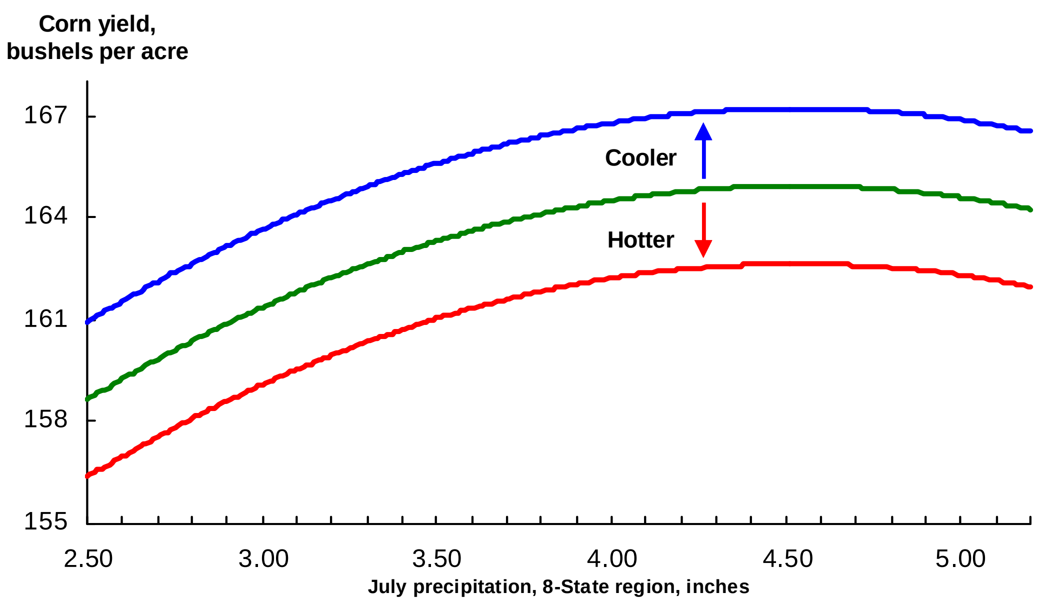
Corn Yield Response to July Temperatures

Finally, the corn yield model includes temperatures in July, typically the most critical month for the development of the U.S. corn crop. Shown in figure 17 are the effects of hotter and cooler temperatures. The middle curve again represents corn yield expectations for different amounts of July precipitation and the sample mean for the average temperature in July. If the average July temperature for the 8 selected corn producing States is cooler, corn yield expectations are raised, while hotter temperatures lower expected corn yields. With the coefficient in the model for the July temperature variable of -2.28, the scenarios of 1 degree cooler and 1 degree hotter shown in the figure raise and lower expected corn yields by 2.28 bushels per acre.

Figure 17

Corn yield model properties

Yield response to July temperature



Note: Based on 80 percent mid-May planting progress in the 8-State region. Middle curve assumes sample period average for July temperatures in the 8-State region.

Soybean Yield Asymmetric Response to July-August Precipitation Variation

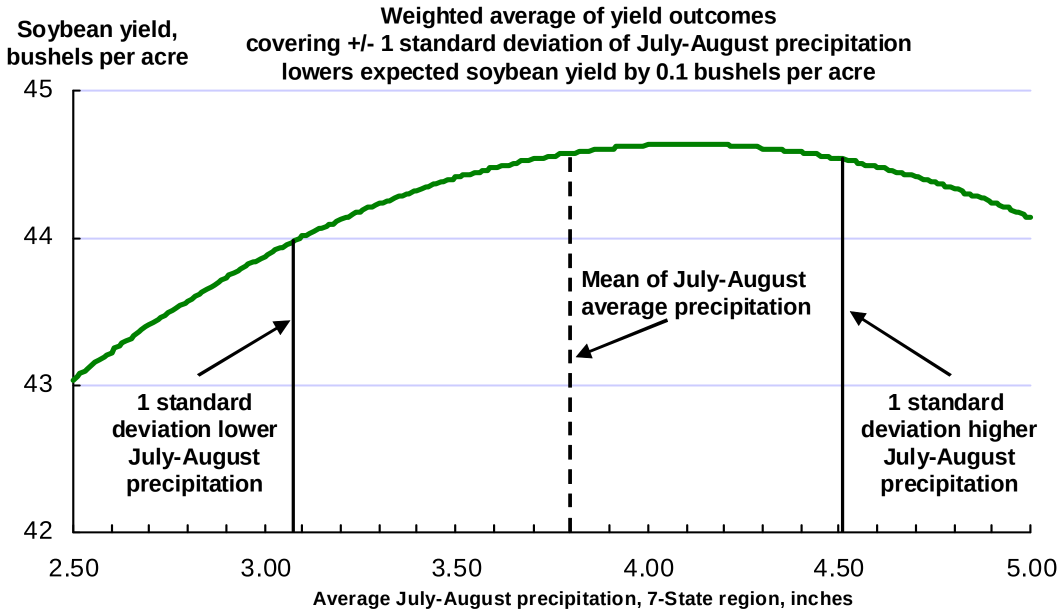
Similar relationships to those shown for corn can be illustrated for soybean yield responses to weather variables. Figure 18 shows the asymmetric response of soybean yields to variations in precipitation in July and August. Yield reductions due to lower July-August precipitation are larger than yield gains due to higher precipitation.

Adjusting model implications to reflect this asymmetric yield response lowers expected yields. A weighted average of soybean yield estimates for alternative levels of July-August precipitation within 1 standard deviation of its average results in a 0.1-bushels-per-acre lower mean expected soybean yield compared to an expected yield evaluated at the mean for average July-August precipitation. Average July-August precipitation is assumed to have a statistically normal distribution in the weighting of alternative soybean yields. The soybean yield adjustment is relatively smaller than the similar adjustment for corn, suggesting less soybean yield variability due to weather than for corn.

Figure 18

Soybean yield model

Asymmetric yield response to July-August precipitation



Note: Based on sample period mean for average July-August temperatures in the 7-State region.

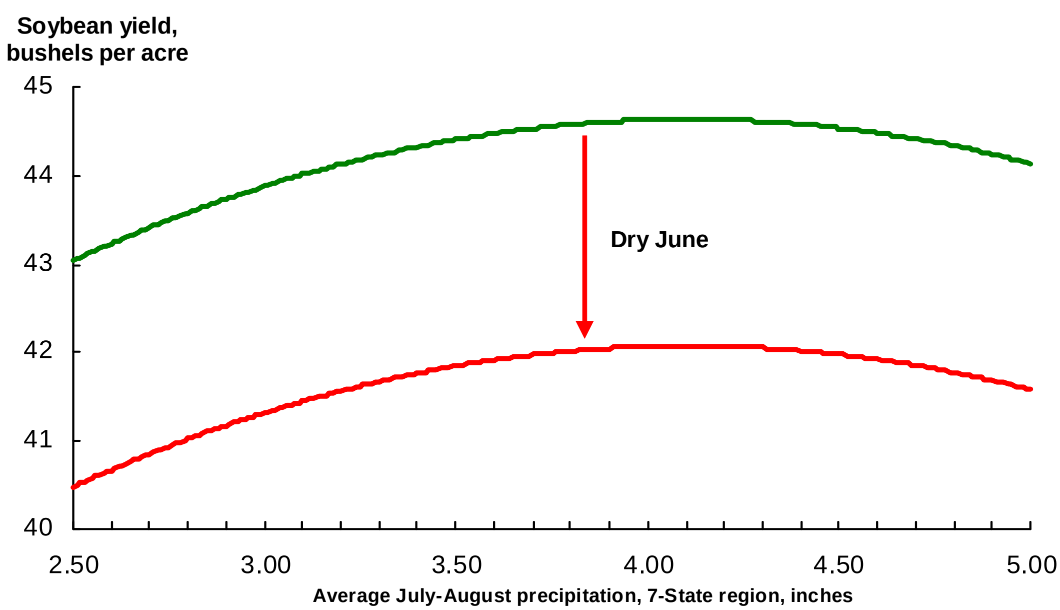
Soybean Yield Response to Dry Weather in June

As for corn, the soybean yield model includes an adjustment to account for effects of June precipitation when conditions are exceptionally dry in that month, such as the extremely dry Junes of 1988 and 2012. Figure 19 shows the effects on soybean yield expectations should there be another such year. The higher curve is the same expected soybean yield result for different levels of July-August precipitation shown in figure 18. The lower curve shows soybean yields if June precipitation is 2 inches below the 4.41 inch average for the 7 selected soybean producing States. A minimum of a 1.91 inch shortfall in June precipitation is needed to trigger this variable in the model. The shortfall was 2.01 inches in June 2012 and 3.05 in June 1988. With the coefficient in the model for this term of -1.279, for the 2 inch shortfall shown in figure 19, soybean yields are reduced by 2.56 bushels per acre.

Figure 19

Soybean yield model

Yield response to very dry June

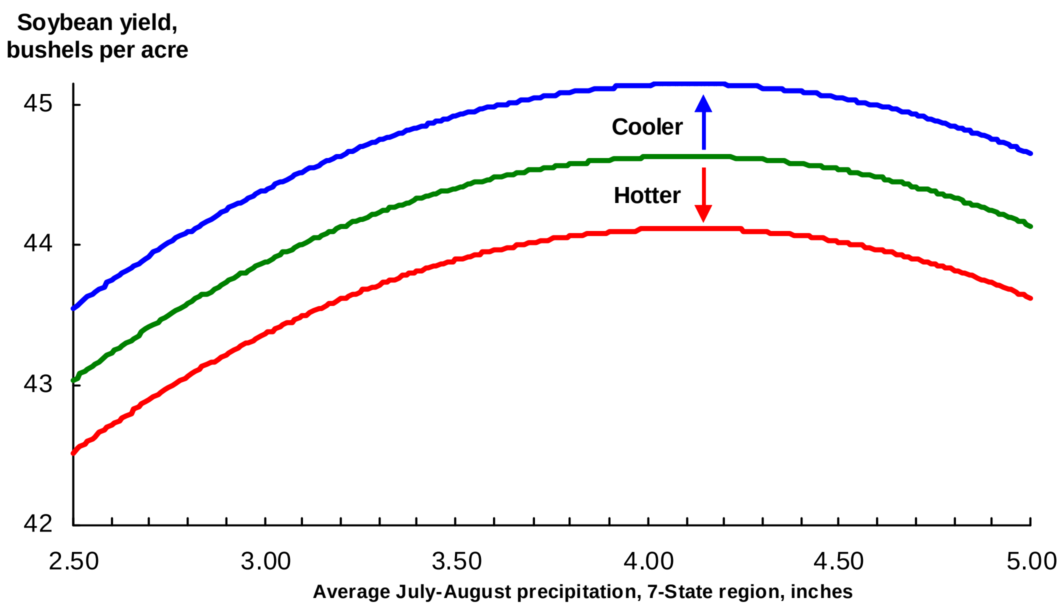


Note: Based on sample period mean for average July-August temperatures in the 7-State region.

Soybean Yield Response to July-August Temperature

Average temperature in July-August for the 7 selected soybean producing States is included as an explanatory variable in the soybean yield model. The effects of hotter and cooler temperatures on soybean yields are shown in figure 20. The middle curve again represents soybean yield expectations for different amounts of July-August precipitation and the sample mean for the average temperature in July-August. If average temperature is cooler, yield expectations are raised, while hotter temperatures lower expected soybean yields. With the coefficient in the model for the temperature variable of -0.514, the 1 degree cooler and 1 degree hotter scenarios shown in the figure raise and lower expected yields by 0.5 bushels per acre.

Figure 20
Soybean yield model
Yield response to July-August temperature



Note: Middle curve assumes sample period mean for average July-August temperatures in the 7-State region.

How Weather Affected 2012 Yields

The yield models can be used to show how weather in 2012 affected yield outcomes. These effects are first illustrated for corn. Similar effects on 2012 yields of variables in the soybean model follow.

2012 Corn Yield Developments

- The **initial expectation** for 2012 corn yields with this model is 161.7 bushels per acre, accounting for the asymmetric yield response to July precipitation within 1 standard deviation of the mean (figure 21). This model estimate is somewhat lower than the implication of a 1990-2010 simple trend for corn yields that was the basis of USDA's February 2012 projection of 164.0 bushels per acre at last year's Agricultural Outlook Forum.

- **Advanced planting progress** in the spring of 2012 raised early-season corn yield expectations. With 92 percent of the corn crop planted in the 8 selected corn producing States by the middle of May, yield expectations based on the corn yield model increase to 165.1 bushels per acre (figure 22). This model estimate is somewhat lower than the adjusted corn yield projection of 166.0 bushels per acre in USDA's May 2012 WADSE report.

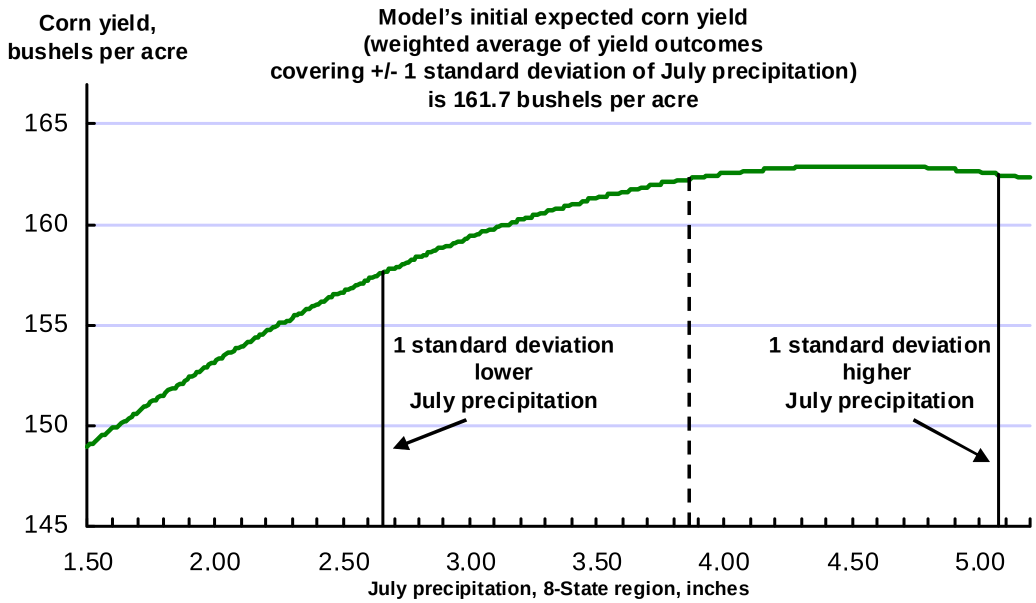
- **Dry June** weather lowered the model's expected 2012 corn yield by 18.7 bushels per acre, down to 146.4 (figure 23). This compares with USDA's July 2012 WASDE corn yield projection of 146.0 bushels per acre.

- **Hot and dry weather in July** further lowered expected corn yields for 2012, reducing the model's yield estimate by 22.7 bushels per acre to 123.7 (figure 24). That compares with the latest USDA estimate of 123.4 bushels per acre from the January 2013 *Crop Production—2012 Summary* report. The reduction due to July weather breaks into two parts in figure 24. First is the reduction in yield due to high temperatures, which shifts the yield curve down 13 bushels per acre. The second part of the yield reduction reflects low July precipitation, which is represented by a downward movement along the lowered yield curve in the figure, accounting for a net reduction of 9.7 bushels per acre.

Figure 21

Corn yield model

2012 developments—initial expectation

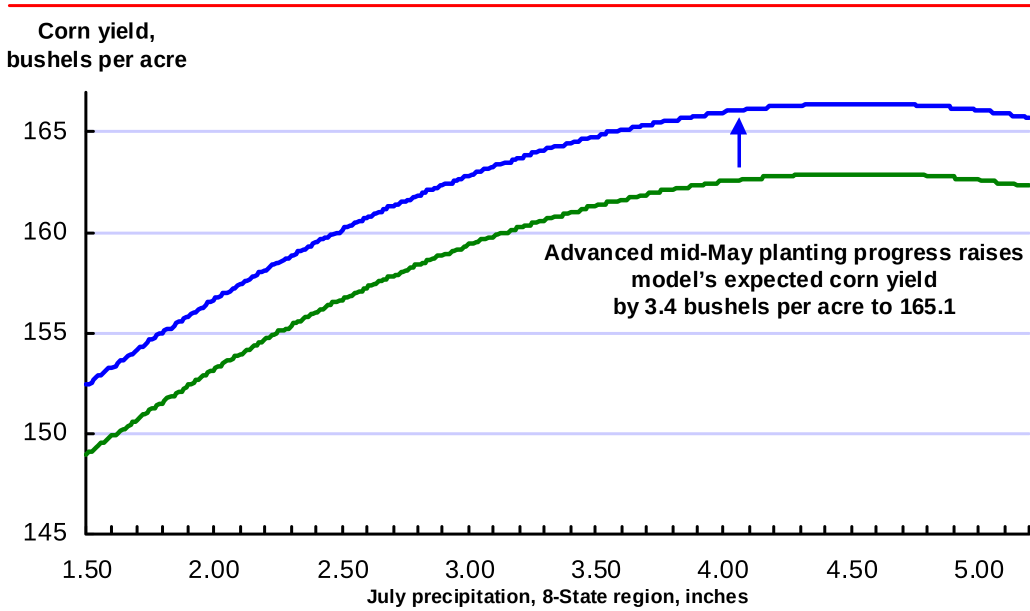


Note: Based on sample period average for July temperatures and 80 percent mid-May planting progress in the 8-State region.

Figure 22

Corn yield model

2012 developments—planting progress

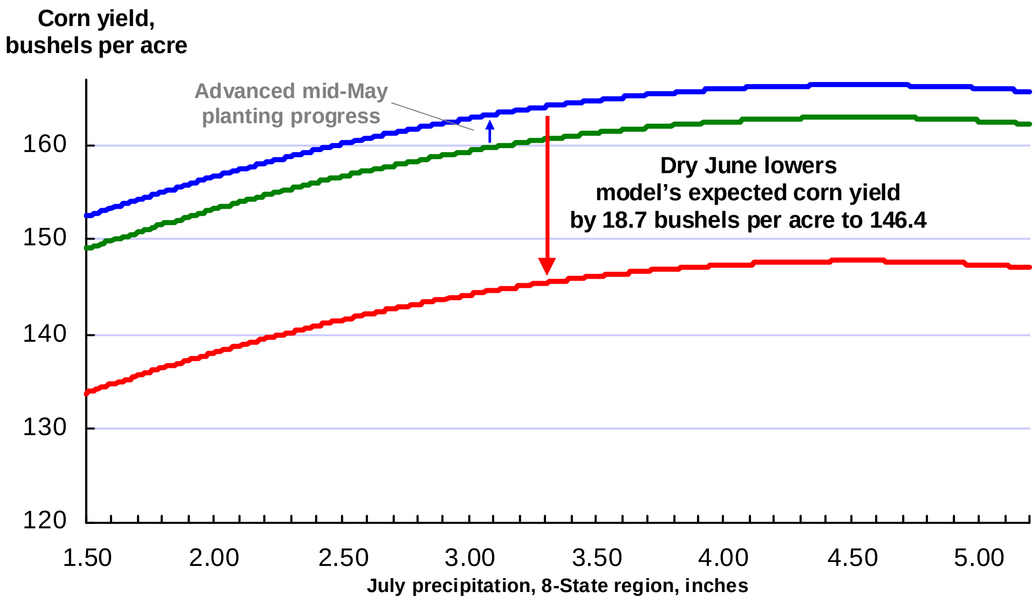


Note: Based on sample period average for July temperatures in the 8-State region. Mid-May planting progress of 92 percent in 2012 for the 8-State region, compared with a 10-year average of 80 percent.

Figure 23

Corn yield model

2012 developments—dry June

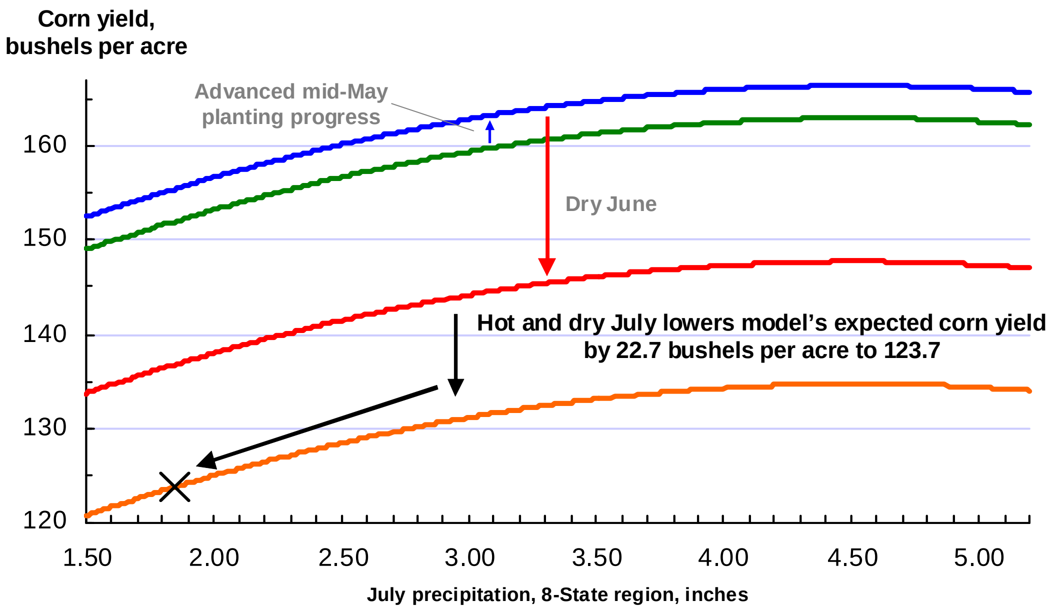


Note: Based on sample period average for July temperatures in the 8-State region.

Figure 24

Corn yield model

2012 developments—hot and dry July



Note: Hot July weather lowered the yield curve; dry July moved yields down along the lowered curve.

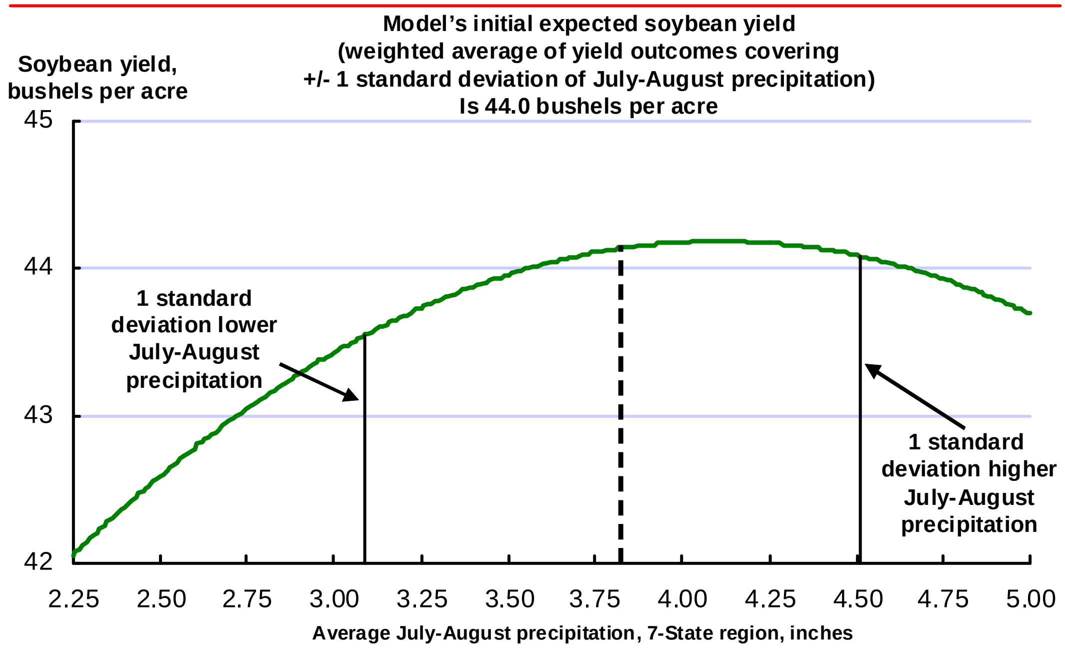
2012 Soybean Yield Developments

- The **initial expectation** for 2012 yields with the soybean model is 44.0 bushels per acre, accounting for part of the asymmetric yield response to variation in July-August average monthly precipitation within 1 standard deviation of the mean (figure 25). That model estimate is close to USDA's soybean yield projection of 43.9 bushels per acre from the February 2012 Agricultural Outlook Forum and the May 2012 WASDE report.

- **Dry June** weather lowered the expected yield for soybeans in 2012, reducing the model's yield estimate by 2.5 bushels per acre to 41.5 (figure 26). That compares with USDA's July 2012 WASDE soybean yield projection of 40.5 bushels per acre.

- **Hot and dry weather in July and August** further lowered the model's expected 2012 soybean yield estimate by 3.1 bushels per acre, down to 38.4 (figure 27). That compares with the latest USDA estimate of 39.6 bushels from the January 2013 *Crop Production—2012 Summary* report. The July-August weather effects reflect two parts in figure 27. The yield curve shifts down by 1.4 bushels per acre because of the effects of high temperatures. A further net reduction in the model's soybean yield of 1.7 bushels per acre reflects low July-August precipitation, which is reflected by moving down along the lowered yield curve in the figure.

Figure 25
Soybean yield model
2012 developments—initial expectation

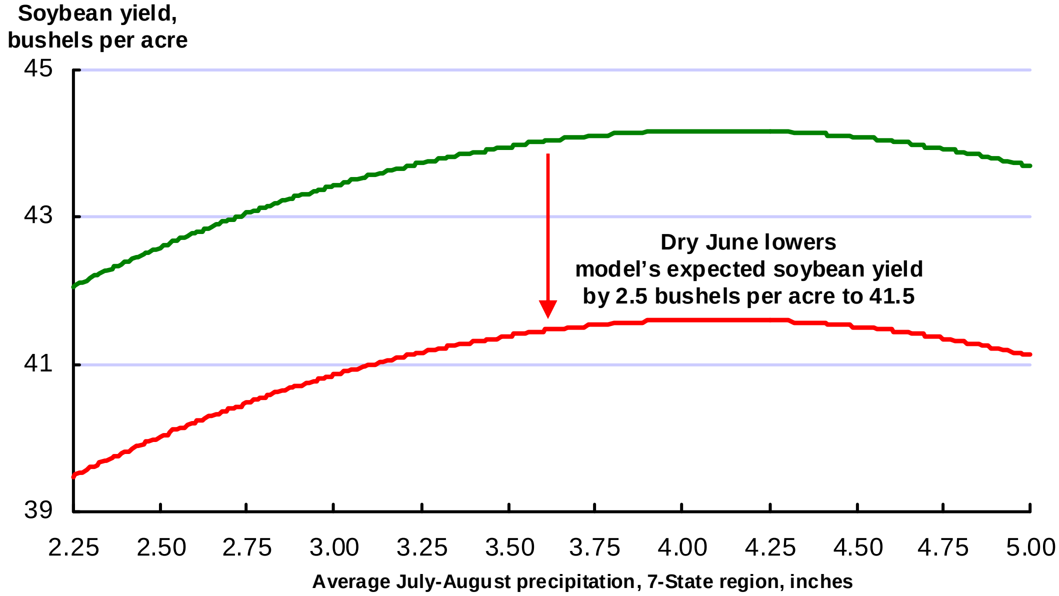


Note: Based on sample period mean for average July-August temperatures in the 7-State region.

Figure 26

Soybean yield model

2012 developments—dry June

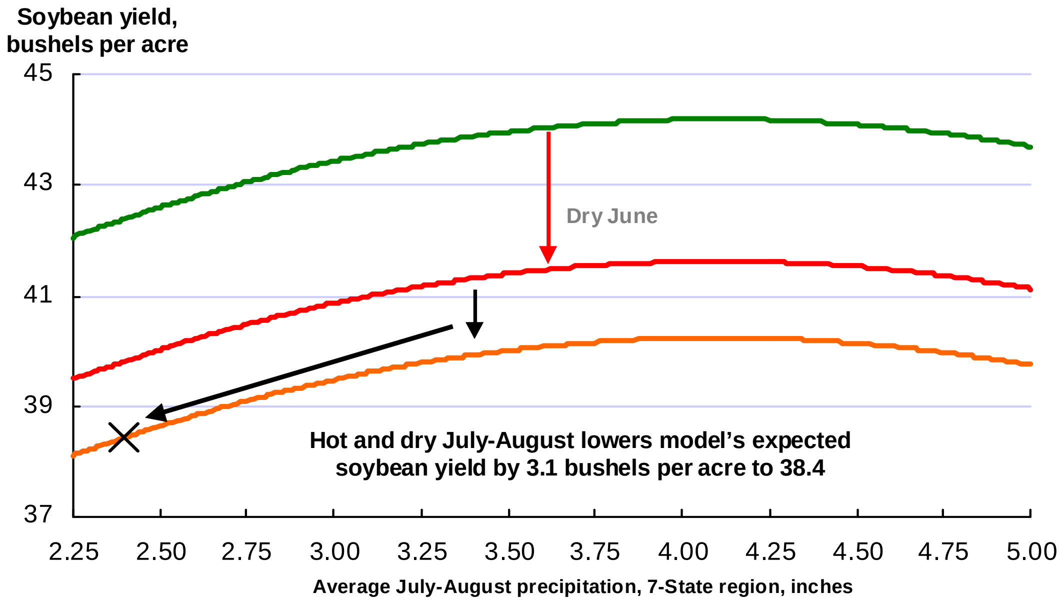


Note: Based on sample period mean for average July-August temperatures in the 7-State region.

Figure 27

Soybean yield model

2012 developments—hot and dry July-August



Note: Hot July-August weather lowered the yield curve; dry July-August moved yields down along the lowered curve.

Expected Yields for 2013 and Beyond

The yield models can be used to provide initial forecast of expected yields for corn and soybeans for the upcoming 2013 season and projections of yields for later years.

Implications for 2013 Corn Yields

Assuming that corn planting progress by the middle of May 2013 is at the average over the past 10 years of 80 percent, that June weather is not extremely dry, and that average weather occurs in July, the corn model suggests a 2013 yield of 164.3 bushels an acre. However, to reflect the asymmetric response of corn yields to different amounts of rainfall in July, the weighted average of corn yield estimates for alternative levels of July precipitation within one standard deviation of its average lowers the expected corn yield to 163.6 bushels per acre (figure 28).

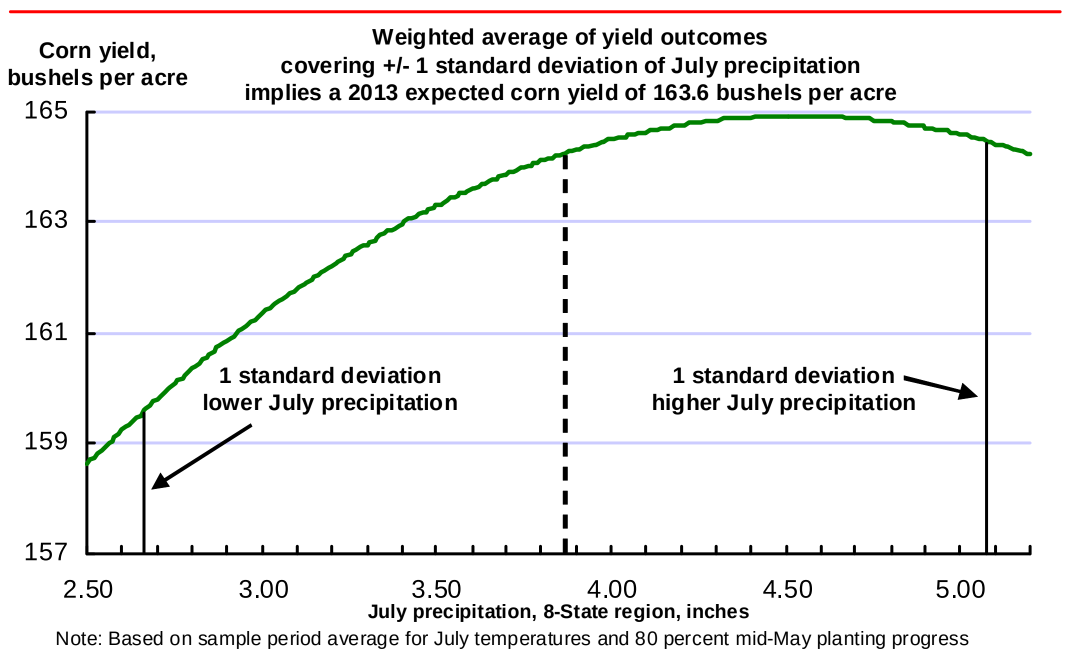
Implications for 2013 Soybean Yields

Similarly, with average July-August weather and June weather that is not extremely dry, the soybean model suggests a 2013 yield of 44.6 bushels an acre. The weighted average of soybean yield estimates for alternative levels of July-August precipitation within one standard deviation of its average results in a lower mean expected soybean yield for 2013 of 44.5 bushels per acre (figure 29).

Figure 28

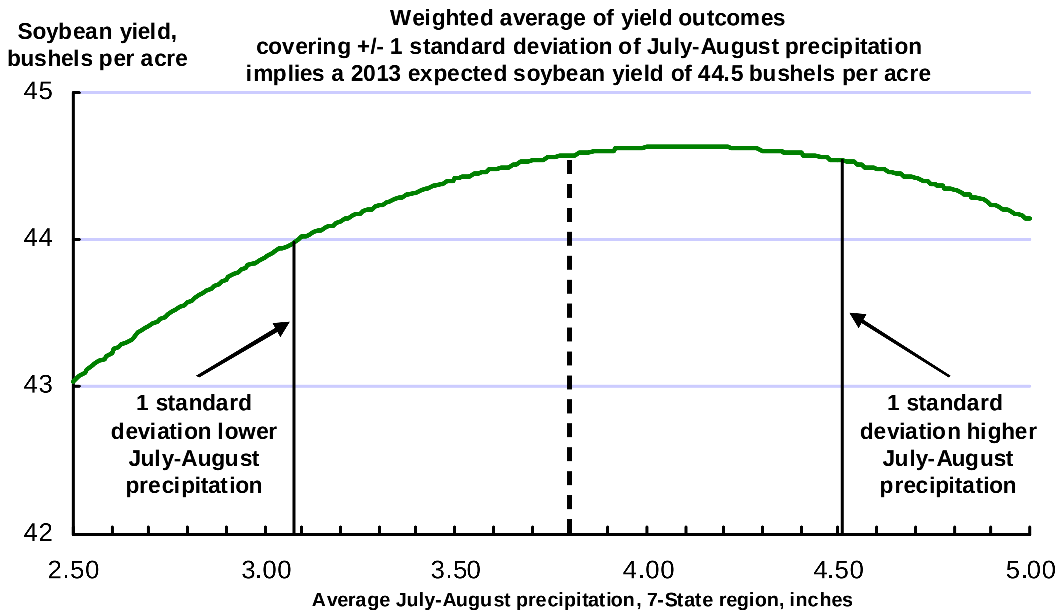
Corn yield model

2013 initial yield expectation



Note: Based on sample period average for July temperatures and 80 percent mid-May planting progress in the 8-State region.

Figure 29
Soybean yield model
2013 initial yield expectation



Note: Based on sample period mean for average July-August temperatures in the 7-State region.

Post-drought Yield Drag

Following the drought in 2012, one issue for the upcoming 2013 season is whether there are any carryover effects on yields from the previous year's weather. This is of particular concern because of potential implications of current conditions indicated by various drought measures.

The Palmer Modified Drought Index (PMDI) is a measure of long-term drought which reflects both current and past weather. Table 8 shows historical rankings of the January 2013 PMDI for the top 10 corn producing States compared with the January value of the index in each year since 1895. For four of the States shown, the January 2013 PMDI ranks in the lowest 10 values for Januarys since 1895. The January 2013 PMDI indicates extreme drought in Nebraska and severe drought in Iowa, Kansas, Minnesota, and South Dakota.

To assess the potential effect of this factor on yields in the upcoming growing season, the corn and soybean yield models previous discussed were augmented by different variables involving the PMDI. Alternatives examined included the January PMDI, the May PMDI, and each of those indexes only in years when the index value was extremely low (when the index value was in the lowest 10-percent tail of its statistical distribution). None of these alternatives gave a statistically significant result.

Similarly, cumulative precipitation over the months prior to plantings provides a measure of soil moisture recharge. Both the corn and soybean yield models were augmented by precipitation totals for the preceding October through March and the preceding October through May to assess the potential impact of this factor. Again, none of these alternatives gave a statistically significant result.

Table 8

Palmer Modified Drought Index (PMDI)
January 2013 ranking

State	2011 corn production rank	January 2013 PMDI low ranking since1895
Iowa	1	10
Illinois	2	45
Nebraska	3	5
Minnesota	4	13
Indiana	5	64
South Dakota	6	6
Wisconsin	7	38
Ohio	8	91
Kansas	9	9
Missouri	10	14

Note: Extreme drought indicated for Nebraska; severe drought indicated for Iowa, Kansas, Minnesota, and South Dakota.

Adjusting for Developments during the 2013 Growing Season

As the planting and growing seasons for corn and soybeans progress, updates of the models' 2013 yield expectations can be made as data for mid-May corn planting progress and July and August weather become available. Additionally, the models provide a framework for assessing reductions in expected yields should June 2013 weather be extremely dry, such as in 2012 and 1988.

USDA's first survey-based estimates of corn and soybean yields for 2013 will be released by the National Agricultural Statistics Service in the August *Crop Production* report.

Longer Term Implications for Corn and Soybean Yields

The 2013 adjusted yields from the models can be used as starting points for corn and soybean yield projections for years beyond 2013, as well. The mean expected corn yield for 2013 of 163.6 bushels per acre would be incremented each subsequent year by the 1.95-bushel trend coefficient in the corn yield model. The adjusted 2013 soybean yield estimate of 44.5 bushels per acre would be incremented in each following year by the soybean yield model's trend coefficient of 0.45.

Concluding Comments

Weather during the growing season is critical for corn and soybean yield development. Adjusting for weather in analysis of historical U.S. corn and soybeans yields is important for determining underlying trends and future yield expectations.

The corn and soybean yield models developed here have a similar general structure with differences in the explanatory variables used related to the timing and length of the reproductive periods of the crops. The corn model includes mid-May planting progress and July weather variables. The soybean model includes July-August weather variables. Both models include a variable for weather in June when it is extremely dry.

Yield responses in both models are asymmetric for variations in summer precipitation. Yield reductions for below-average rainfall are larger than yield increases for equal-sized above-average rainfall. This asymmetric property has implications for formulating mean expected yields for the upcoming crops.

The corn model's mean expected yield for 2013 is 163.6 bushels per acre. The mean expected 2013 yield based on the soybean model is 44.5 bushels per acre.

The potential for a post-drought drag on yields in the following year was examined using various measures, including the Palmer Modified Drought Index and cumulative monthly precipitation leading up to plantings. None provided a statistically significant effect when augmented to the corn and soybean yield models developed. While such measures will be important to monitor over the next several months as we move toward plantings, the overall results point to the dominance of summer weather in the determination of corn and soybean yields.