Why Is It Important to Forecast U.S. Corn and Soybean Yields?

The price level and seasonal price pattern of corn and soybeans are determined by a wide array of factors that influence the global supply and consumption of grains and oilseeds. As a result, prices of those crops show a striking amount of variability from year-to-year and within a crop marketing year. The U.S. is the number one producer of corn in the world, accounting for 37 percent of world corn production and 28 percent of world coarse grain production in 2013-14. Similarly, the U.S. is the number one soybean producer, comprising 31 percent of world soybean production and 18 percent of world oilseed production in 2013-14. The size of the U.S. crops is one of the most important factors influencing annual world grain and oilseed supplies, and therefore, the price of those commodities.

The size of U.S. corn and soybean crops is unknown until the harvest is complete. As yield-influencing factors unfold, expectations about the size of those crops change during the planting and growing season that extends from April to October. The changing expectations and uncertainty surrounding production prospects often result in large price changes and provide a risky environment for producers, processors, exporters, consumers, input suppliers, and crop insurers, as well as those who have a purely speculative motive for trading these commodities. Figures 1 and 2 illustrate the magnitude of price changes during the planting and growing season from 2010 through 2013.

Decision-making by market participants can be improved if U.S. average yields can be accurately forecast in advance of harvest. The earlier in the growing season that the level of yields can be reasonably anticipated, the more valuable are the yield
forecasts. This value explains why considerable public and private resources are devoted to corn and soybean yield forecasting.

**Why Are Corn and Soybean Yields So Variable?**

U.S. average corn and soybean yields have trended higher for several decades. As revealed in Figure 3 and 4, trend increases have been relatively constant and linear since about 1960. Yields trend upward for two basic reasons: i) plant modification via conventional breeding and genetic manipulation, and ii) improvement in production management practices (Egli, 2008). These changes often are complementary over time.

Figures 3 and 4 also reveal that annual corn and soybean yields have varied considerably around the long-term trend. Corn yields have been as much as 25% below and 15% above trend yield. Likewise, soybean yields have been as much as 19% below and 16% above trend.

The annual variability in corn and soybean yields results from a complex array of agronomic, management, and weather factors. Crop scientists have spent decades studying the interaction of these factors with yields. Bio-physical models of corn and soybean growth reflect scientific understanding of the most important of these biological processes (e.g., Yang et al. 2004; Setiyono et al., 2010). The response of plant photosynthesis to temperature is a common element in these models. Figure 5, adapted from Cassman, Grassini, and van Wart (2010), provides a typical example for corn.

Note that the response to temperature in the model is assumed to be positive for low growing season temperatures, optimal for moderate temperatures, and negative for high temperatures.

More generally, the scientific literature shows that variability in growing season weather (precipitation and temperature) accounts for much of the annual variation in
corn and soybean yields. Adequate precipitation and normal temperatures throughout the growing season contribute to “normal” yields. Both excessive and insufficient precipitation, as well as above average temperatures, tend to lower yields. Slightly above average precipitation and moderate summer temperatures are most favorable for yields. The most critical weather periods are during the reproduction and grain filling stages of crop development. That is generally July and August for much of the corn and soybean production area.

How Well Does USDA Forecast Corn and Soybean Yields?

The U.S. Department of Agriculture (USDA) is the main public source of corn and soybean yield forecasts for the U.S. The first forecast is issued in May of each year and prepared by the World Agricultural Outlook Board (WAOB) of the USDA. These early season forecasts are largely trend forecasts with some adjustment for other factors such as planting progress. Minimal changes are typically made to the forecasts in June and July.

The National Agricultural Statistics Service (NASS) of the USDA uses a complex and comprehensive methodology to forecast U.S. average corn and soybean yields during August through November (NASS/SMB, 2006; Good and Irwin, 2011). That methodology involves collecting yield related data from a number of locations in the largest producing states (objective yield survey) as well as collecting yield expectations from a survey of producers of these crops (farm operator survey). These two sources of data are combined to form a U.S. average yield forecast, as well as yield forecasts for individual states and crop reporting districts within states. Yield forecasts are published between the 9th and 12th of each month.

NASS also provides the official final yield estimate in January after harvest is complete. The final yield estimate released in January includes a measurement of “harvest loss” at the locations where yield data are collected and reflects a much larger farmer survey than used in August through November.

Assuming the USDA’s final yield estimate in January is the actual yield, the monthly USDA forecasts of U.S. average yields tend to become progressively more accurate from May through November. This is evident in Figures 6 and 7, where the top vertical line shows the largest underestimate for a given release month, the bottom vertical line shows the largest overestimate, and the box represents the middle 50% of the under- and over-estimates (25th to 75th percentile).
It is not surprising that errors tend to diminish since information on crop production prospects improves across the forecasting cycle. By November harvest is usually complete and USDA forecasting errors are minimal.\(^1\)

It is also clear that USDA forecast errors during the growing season have sometimes been quite large. For example, the USDA August corn yield forecasts over the 21 years from 1993 through 2013 were as much as 15 percent above and 7 percent below the final yield estimate. The August soybean yield forecast was as much as 16 percent above and 10 percent below the final yield estimate. In the current era of very tight U.S. and global grain stocks, even small errors in yield forecasts can have large price impacts (Wright, 2011).

**What Makes YieldCast™ Corn and Soybean Forecasts Valuable?**

The challenge for private forecasters is to provide early and accurate yield forecasts, especially in comparison to those provided by USDA. YieldCast\(^\text{™}\) provides weekly updates of U.S. average corn and soybean yield forecasts from April through early October. Yield forecasts are updated weekly based on growing conditions to date and proprietary T-storm Weather\(^\text{®}\) forecasts of likely conditions during the remainder of the growing season.

Five characteristics of YieldCast\(^\text{™}\) corn and soybean forecasts stand out. First, the “reduced-form” statistical models used to generate forecasts reflect the main biological pathways between weather and yields. This provides a rigorous scientific foundation for the forecasts. Second, the forecasts are generated by robust and data-intensive statistical models. Robust models are time-tested and reliable in a wide-variety of conditions. Less robust models tend to be overly complex and increase the chance of “over-fitting” the data (Armstrong, 2001). Third, the forecasts are objective, which means users can be confident that a consistent methodology is used to generate forecasts across the growing season. Model forecasts will be subjectively adjusted only under very rare and unusual weather conditions. Fourth, forecasts are not based on a single model. Instead, an average of forecasts from several models is used, which captures the well-documented accuracy advantage of composite forecasts (Timmerman, 2006). Fifth, forecasts reflect short- to intermediate-term weather forecasts. Rather than simply accumulating weather observations up to a point in the growing season and assuming “average” or “normal” weather for the remainder, YieldCast\(^\text{™}\) is forward-looking and always incorporates state-of-the-art weather forecasts for the rest of the growing season.

In sum, several factors are responsible for the YieldCast\(^\text{™}\) advantage in forecasting U.S. average corn and soybean yields. The forecasts rely on well-researched and statistically accurate crop-weather models, reflect the strength of composite forecasting, and incorporate growing season weather forecasts.

**What is the Track Record of YieldCast™ Corn and Soybean Forecasts?**

The YieldCast\(^\text{™}\) methodology (with the exception of incorporating weather forecasts) was applied to previous years in order to provide an indication of historical performance across a wide range of growing season conditions. This simulation analysis over 1993 through 2009 provides a

\(^{1}\) October 2013 USDA forecasts for both corn and soybeans are not available due to the federal government shutdown.
benchmark for expectations about the real-time forecasting performance of YieldCast™ relative to the USDA. One would expect that future real-time forecasting results, on average, should be consistent with historical simulation performance. As shown in Figures 8 and 9, the average (absolute) accuracy of YieldCast™ forecasts over 1993-2009 was superior to USDA forecasts during the critical months of July, August, and September for both corn and soybeans.

Real-time forecasts were provided by YieldCast™ for the first time in 2010. Forecasting was very challenging in 2010 because of the highly unique growing conditions, generally characterized by above average summer temperatures and too much summer precipitation in many areas. Forecasting was equally challenging in 2011 due to very late planting, particularly in the eastern Corn Belt, and widely varying summer weather conditions. Forecasting, however, was particularly challenging in 2012 due to the extremely early planting progress and then the development of widespread and severe drought conditions during the summer, among the worst of the last century. Forecasting in 2013 was presented with the challenge of very late planting in parts of the Corn Belt and then a record-setting late season heat wave. The wide-ranging conditions in the last four growing seasons provide a strong test of the real-time performance of corn and soybean yield forecasts.

Figures 10 through 17 present the weekly U.S. average corn and soybean yield forecasts provided by YieldCast™ and the monthly forecasts provided by USDA in 2010-2013. Note that the last forecasts provided by YieldCast™ each season were released in early October. Analysis of historical errors indicates USDA’s October and November yield forecasts tend to be more accurate than our model forecasts. This is sensible because both yield indicators used in the USDA October and November forecasts (objective yield and farm operator survey) generally reflect actual yields on acreage already harvested. Of course, YieldCast™ forecasts in these months may be equal to or more accurate than USDA forecasts in some years.

The USDA’s final 2010 U.S. average yield estimate for corn was 152.8 bushels per acre, well below their August, September, and October forecasts of 165, 162.5, and 155.8 bushels, respectively (Figure 10). In contrast, YieldCast™ signaled problems with the 2010 corn crop far in advance of the decline in USDA forecasts. The YieldCast™ forecast of the U.S. average corn yield moved below the USDA beginning on May 11th and began forecasting a yield below 160 bushels on
June 29th. While the USDA and most of the trade was forecasting a corn yield in the mid- to upper-160s in early August, YieldCast™ was nearly alone in forecasting a yield of 158 bushels. The final YieldCast™ corn forecast was within 4.5 bushels (2.9 percent) of the final USDA estimate.

The USDA’s final 2010 U.S. average yield estimate for soybeans was 43.5 bushels per acre, below their August, September, and October forecasts of 44, 44.7, and 43.7 bushels, respectively (Figure 11). Weekly YieldCast™ forecasts began on April 27th and were never more than 0.9 bushels different than the USDA’s final estimate. The difference never exceeded 0.5 bushel from July 7th through October 5th. YieldCast™ soybean forecasts in 2010 were more accurate than USDA’s August, September and October forecasts. The final YieldCast™ forecast was only 0.3 bushel (0.7 percent) larger than the final USDA estimate.

The USDA’s final 2011 U.S. average yield estimate for corn was 147.2 bushels per acre, well below their August forecast of 153 bushels, marginally lower than the September and October forecasts (Figure 12). YieldCast™ once again signaled problems with the 2011 corn crop well in advance of the decline in USDA forecasts. In particular, YieldCast™ began signaling a precipitous decline in crop prospects in the first week of July. The YieldCast™ forecast of U.S. average corn yield was below the USDA forecast every week until September and was basically equal to USDA forecast beginning in September. The final YieldCast™ corn forecast was 0.9 bushel (0.6 percent) larger than the final USDA estimate.

The USDA’s final 2011 U.S. average yield estimate for soybeans was 41.5 bushels per acre (Figure 13). The forecast was very consistent from August through October. YieldCast™ forecasts were consistent with USDA early forecasts, but declined less in August. The final YieldCast™ forecast was 0.6 bushel (1.4 percent) larger than the final USDA estimate.

The USDA’s final 2012 U.S. average yield estimate for corn was 123.4 bushels per acre, equal to their August forecast and only marginally higher than the September, and October forecasts (Figure 14). YieldCast™ signaled problems with the 2012 corn crop beginning in June, well ahead of USDA’s revised forecast released in the July WASDE report. The YieldCast™ forecast of U.S. average corn yield was very near the USDA forecasts from August through early October. The final YieldCast™ corn forecast in October was 1.5 bushels (1.2 percent) smaller than the USDA’s October forecast and 2.9 bushels (2.4 percent) smaller than the final USDA estimate.

The USDA’s final 2012 U.S. average yield estimate for soybeans was 39.6 bushels per acre (Figure 15). The forecast was 3.5 bushels higher than the August forecast and 1.8 bushels higher than the October forecast. YieldCast™ forecasts signaled problems with the crop beginning in July, but, importantly, remained above the USDA forecasts in August and September. This provided an important signal that the 2012 soybean crop had not been as badly damaged by the heat and dryness as was widely perceived. The final YieldCast™ forecast in October was 0.5 bushel (1.3 percent) smaller than the USDA’s October forecast and 2.3 bushels (5.8 percent) smaller than the final USDA estimate.

The USDA’s final 2013 U.S. average yield estimate for corn was 158.8 bushels per acre (Figure 16). The final estimate was 4.4 bushels above their August forecast and 3.5 bushels above the September forecast, but 1.6 bushels below the November forecast.
No USDA forecast was released in October due to the partial shutdown of the federal government. YieldCast™ forecasts of the average yield during the growing season were above the USDA forecasts and above the final USDA estimate until late August (Figure 16). High temperatures in late August and early September signaled potentially lower yields. The YieldCast™ forecast of the U.S. average corn yield was very near the USDA forecast in September. The final YieldCast™ corn forecast in October was 0.9 bushels (0.6 percent) larger than the USDA's September forecast and only 2.6 bushels (1.6 percent) smaller than the final USDA estimate. The final YieldCast™ forecast signaled that the USDA's November forecast was too high.

The USDA's final 2013 U.S. average yield estimate for soybeans was 43.3 bushels per acre (Figure 17). The forecast was 0.7 bushels higher than the August forecast, 2.1 bushels higher than the September forecast, and 0.3 bushels higher than the November forecast. No USDA forecast was released in October due to the partial shutdown of the federal government. YieldCast™ forecasts were below USDA forecasts during the growing season and closer to the USDA final yield estimate through late August. The YieldCast™ forecast dropped below the USDA forecast and final yield estimate in late August as model output over-responded to very high temperatures in late August and early September. The final YieldCast™ forecast in October was 1.4 bushel (3.4 percent) smaller than the USDA’s September forecast and 3.5 bushels (8.1 percent) smaller than the final USDA estimate.

Figures 18 and 19 summarize the real-time forecasting track record of YieldCast™ over 2010-2013. The four-year average (absolute) forecast errors for YieldCast™ and the USDA in corn and soybeans are presented for the critical growing season months of July, August, and September. For corn, the four-year average (absolute) errors were smaller for YieldCast™ than the USDA in July and August, but slightly larger in September. The average accuracy advantage of YieldCast™ corn forecasts in August was 0.6 percentage points. For soybeans, the four-year average (absolute) errors were smaller for YieldCast™ than for the USDA in all three months. In September the YieldCast™ accuracy advantage was an eye-popping 1.7 percentage points.

While one must keep in mind that these results reflect only four years, it is nonetheless striking how well the real-time...
The performance of YieldCast™ corn and soybean forecasts mirrors the simulated historical performance shown in Figures 8 and 9. The simulation results predicted that YieldCast™ forecasts would consistently have an accuracy advantage over USDA forecasts, and this was confirmed in five of the six real-time forecasting comparisons presented in Figures 18 and 19. This provides confirmation of the value and reliability of the YieldCast™ methodology and allows one to have confidence in our ability to continue providing early and accurate corn and soybean yield forecasts in the future.

What are the Credentials of YieldCast™ Principals?

YieldCast™ combines the expertise of Darrel Good, Professor Emeritus, Department of Agricultural and Consumer Economics at the University of Illinois; Scott Irwin, Professor and Laurence J. Norton Chair of Agricultural Marketing, Department of Agricultural and Consumer Economics at the University of Illinois; and Mike Tannura, Meteorologist, Agricultural Economist, and Owner of T-storm Weather in Chicago, Illinois.

Darrel Good is recognized in academia and industry world-wide as a leading expert in grain markets. When Illinois and Midwest crop producers market billions of dollars worth of commodities each year, they turn to him for objective market information and analysis. He has conducted research on a wide-variety of topics in grain markets and served as the leader of the price analysis and marketing program at the University of Illinois for over 30 years.

Scott Irwin is a leading expert on the economics of commodity markets. His research is widely-cited by other academic researchers and is in high demand among market participants and policy-makers across the world. He is widely quoted as a leading authority on commodity markets in the agricultural and financial press (Farm Journal, Successful Farming, Barron’s, The Economist, New York Times, and The Wall Street Journal). He also has served as the leader of the award-winning farmdoc project at the University of Illinois since its inception.

Mike Tannura’s weather forecasts are among the most widely respected and followed at the Chicago Mercantile Exchange Group with subscribers throughout the U.S., Europe, and Asia. He
holds degrees in Meteorology and Agricultural Economics. He was certified by the American Meteorological Society in 2000 for excellence in scientific competence and communication skills for television weather broadcasts. In 2006, he started T-storm Weather® to help buyers and sellers of grains and oilseeds use weather and weather forecasts to make financial decisions in futures markets.
References


