U.S. CORN AND SOYBEAN YIELDS AND YIELD FORECASTING

A White Paper by

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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 nearly 40 percent of world corn production and nearly 30 percent of world coarse grain production. Similarly, the U.S. is the number one soybean producer, comprising over 35 percent of world soybean production and over 20 percent of the world oilseed production. The size of the U.S. crops, then, 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 2008 through 2010.

Figure 1. Daily New Crop (December) Futures Price for Corn During April-October

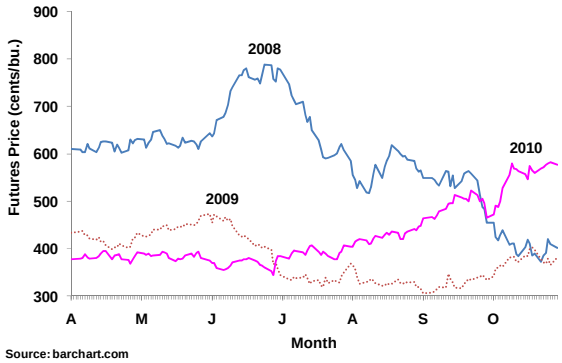
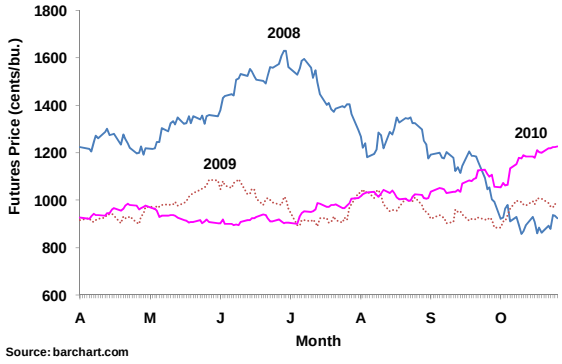


Figure 2. Daily New Crop (November) Futures Price for Soybeans During April-October



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.

Figure 3. U.S. Average Corn Yield, 1960-2010

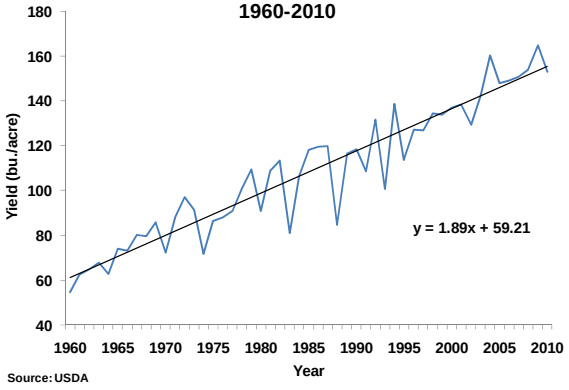
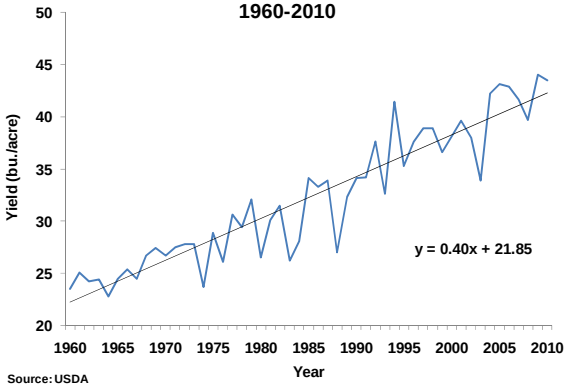


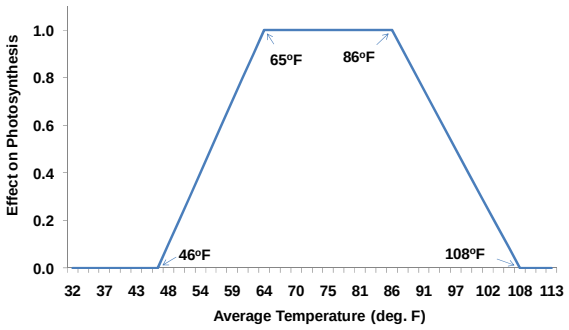
Figure 4. U.S. Average Soybean Yield, 1960-2010



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 26% below and 16% above trend yield. Likewise, soybean yields have been as much as 19% below and 15% 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.

Figure 5. Response of Corn Plant Photosynthesis to Temperature



Adapted from Cassman, Grassini, and van Wart (2010)

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

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?

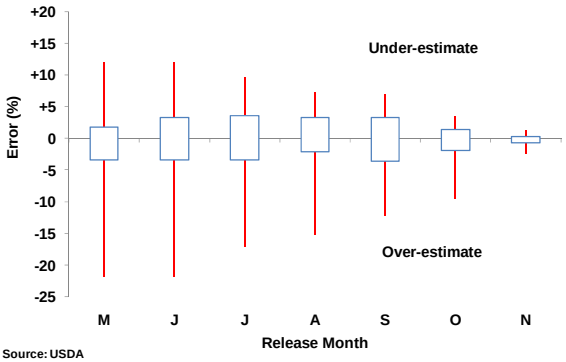
The U.S. Department of Agriculture (USDA) is the main public source of corn and soybean yield forecasts for the U.S. The first forecast is issued in May of each year and prepared by the World Agricultural Outlook Board (WAOB) of the USDA. These early season forecasts are largely trend forecasts with 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). 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.

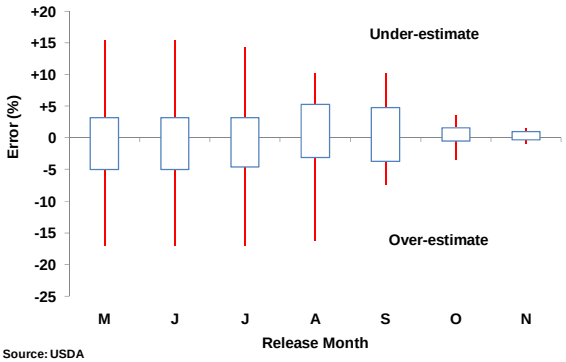
Assuming the USDA's final yield estimate in January is the actual yield, the monthly USDA forecasts of U.S. average yields tend to become progressively more accurate from May through November. This is evident in the following plots, where the top vertical line shows the largest under-estimate for a given release month, the bottom vertical line shows the largest over-estimate, and the box represents the middle 50% of the under- and over-estimates (25th to 75th percentile).

Figure 6. USDA Errors in Forecasting U.S. Average Corn Yield, 1993-2010



Source: USDA

Figure 7. USDA Errors in Forecasting U.S. Average Soybean Yield, 1993-2010



Source: USDA

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.

It is also clear that USDA forecast errors during the growing season have sometimes been quite large. For example, errors associated with August forecasts over the 18 years from 1993 through 2010, have been 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, 2009).

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™ 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® forecasts of likely conditions during the remainder of the growing season.

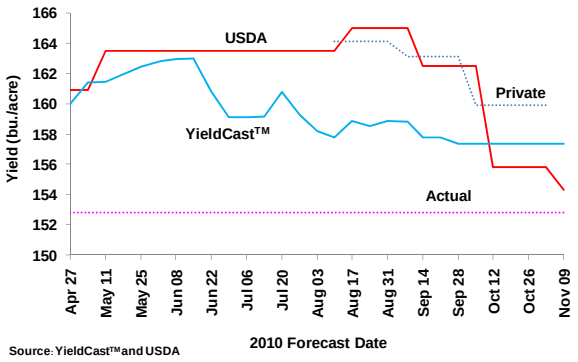
Five characteristics of YieldCast™ corn and soybean forecasts stand out. First, the "reduced-form" statistical models used to generate forecasts reflect the main biological pathways between weather and yields. This provides a rigorous scientific foundation for the forecasts. Second, the forecasts are 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. Model forecasts are not "trimmed" in any manner through subjective adjustments. Users can be confident that a consistent methodology is used to generate forecasts across the growing season. 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 data up to a point in the growing season and assuming "average" or "normal" weather for the remainder, YieldCast™ 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™ 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.

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. Figures 7 and 8 present the weekly U.S. average corn and soybean yield forecasts provided by YieldCast™ and the monthly forecasts provided by USDA. An average of private forecasts before the release of USDA forecasts in August, September, and October is also included for comparison. Note that the last 2010 forecasts provided by YieldCast™ were released on October 5th. Analysis of historical errors indicates USDA's October

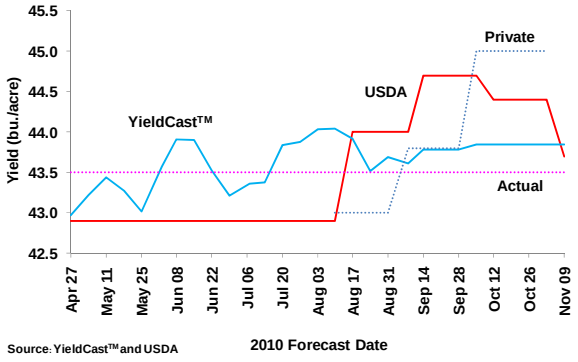
and November yield forecasts tend to be more accurate than our model forecasts. This is sensible because both yield indicators used in the USDA October and November forecasts (objective yield survey and farm operator survey) generally reflect actual yields on acreage already harvested. Of course, USDA forecasts in these months may be less accurate than YieldCast™ forecasts in some years, as was the case in October 2010 for soybeans.

Figure 8. 2010 YieldCast™ and USDA Forecasts of U.S. Average Corn Yield



Source: YieldCast™ and USDA

Figure 9. 2010 YieldCast™ and USDA Forecasts of U.S. Average Soybean Yield



Source: YieldCast™ and USDA

YieldCast™ in 2010 provided early and accurate yield forecasts for both corn and soybeans. The USDA's final 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. Private yield forecasts averaged 164.1, 163.1, and 159.9 bushels in August, September, and October, respectively. The degree to which other private forecasts over-estimated corn yield in October was particularly striking. In contrast, YieldCast™ signaled problems with the 2010 corn crop far in advance of the decline in USDA and other private 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 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. Private yield forecasts averaged 43, 43.8, and 45 bushels in August, September, and October, respectively. Once again, the degree to which other private forecasts over-estimated yield in October was striking. USDA's final soybean yield estimate was 43.5 bushels. 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. Those forecasts were more accurate than USDA's August, September and October forecasts and the average private forecasts in August and October. The final YieldCast™ forecast was only 0.3 bushels larger than the final USDA estimate.

Real-time results for YieldCast™ are only available for 2010. The YieldCast™ methodology (with the exception of incorporating weather forecasts) was applied to previous years (1993 through

2009) in order to provide an indication of historical performance. As shown in Figures 10 and 11, YieldCast™ forecasts were more accurate on average than USDA forecasts during the critical months of August and September.

Figure 10. Average YieldCast™ and USDA Errors in Forecasting U.S. Average Corn Yield, 1993-2009

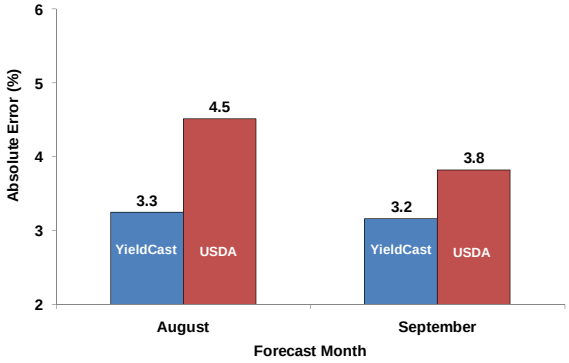
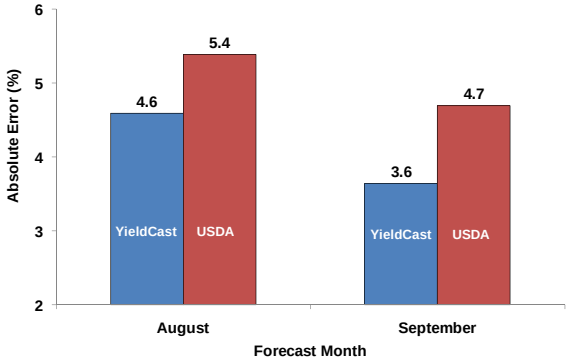


Figure 11. Average YieldCast™ and USDA Errors in Forecasting U.S. Average Soybean Yield, 1993-2009



These results provide additional confidence in the YieldCast™ methodology and the ability to provide early and accurate 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.

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