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Forming Expectations for the 2016 U.S. Average Soybean Yield: What About El Niño?

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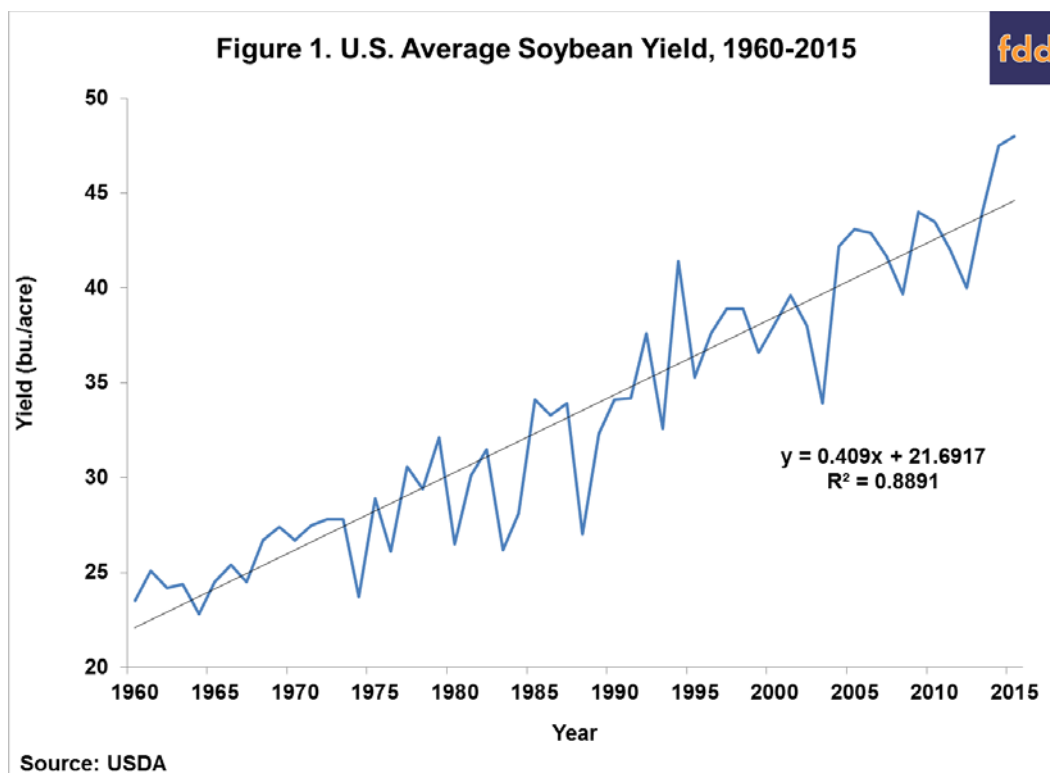
There continues to be a lot of discussion about the likely magnitude of U.S. soybean production in 2016, with much of current focus on planted acreage. Low commodity prices, along with the 2.8 million acre reduction in winter wheat seedings and the likelihood that there will be fewer prevented plantings in 2016, create uncertainty about the likely magnitude of total acreage of spring planted crops, as well as uncertainty about the acreage of individual crops. For the most part, current expectations are that total planted acreage may decline from that of 2015, but expectations for soybean acreage are very mixed. [The Grains and Oilseeds Outlook](#) at last week's USDA Outlook Forum projected plantings of the 8 major crops would decline by 5.5 million acres (2.2 percent) in 2016/17 and that soybean acreage would decline by 0.2 million acres (0.2 percent) to a total of 82.5 million acres. The USDA will release the results of its March survey of 2016 planting intentions in the *Prospective Plantings* report to be released on March 31.

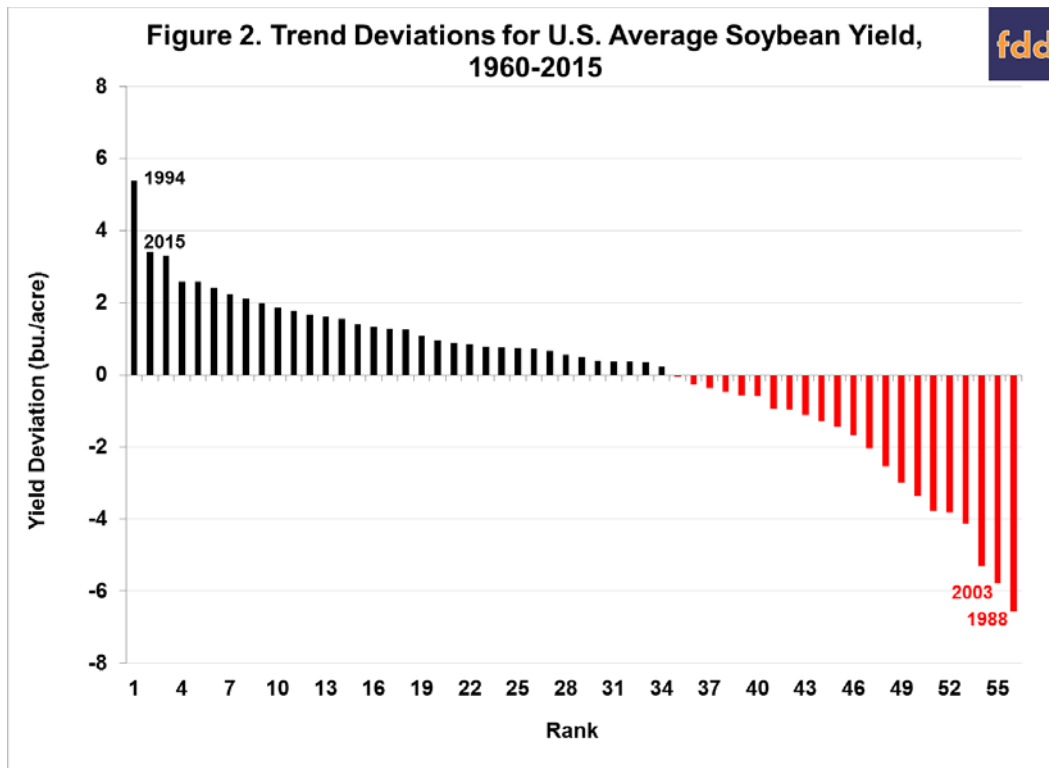
In addition to the magnitude of planted acreage, the size of the 2016 soybean crop will obviously be determined by the average yield of the crop. Factors determining yield will unfold over the next six months. For the time being, yield expectations are generally based on trend yield analysis. For example, the USDA projected a 2016 U.S. average soybean yield of 46.7 bushels per acre at last week's Outlook Forum, compared to the 2015 average of 48.0 bushels. This raises the perennial issue of what, if anything can be learned from the historical trends and patterns of U.S. average soybean yields. In addition, there is the question of whether the trend yield calculation should be altered by information that would influence expectations about weather during the upcoming growing season. This year, for example, there is particular interest in whether the current El Niño episode should influence expectations about 2016 growing season weather and any resulting deviation from trend yield. Here, we first briefly review the history of soybean yield trends and patterns from 1960 through 2015 as a basis for calculating a trend yield for 2016 and potential deviation from trend yield. We then review soybean yields in other years of strong El Niño episodes to determine if the expectation of trend yield or potential deviation from trend should be altered due to the current El Niño episode. A similar analysis for corn in 2016 can be found in the *farmdoc daily* article of [March 3, 2016](#).

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Historical Yields and Patterns

We provided a detailed analysis of historical U.S. average soybean yields in the *farmdoc daily* article of [March 19, 2015](#). That analysis is not repeated, but is briefly summarized here as a starting point in forming yield expectations for 2016. We continue to maintain that U.S. average soybean yield expectations should be based on the longest sample of data with a stable trend yield component. We argue that the period of 1960-2015 best meets this criterion. As shown in Figure 1, U.S. average soybean yields have trended higher since 1960. We found that a linear trend is the best fit to actual average yields over that period, explaining 88.9 percent of the variation in annual average yields. Yields have increased at a rate of 0.41 bushels per acre per year, but there has been substantial year-to-year variation from trend yield, as shown in Figure 2. Over the 56-year period, the average yield was above the trend yield in 61 percent of the years and below the trend in 39 percent of the years. Since all deviations from a linear trend must sum to zero, this means that in the 39 percent of years with a below trend yield the deviations were on average larger than the deviations in the more frequent years when yields were above trend. Specifically, the average deviation below trend was 2.3 bushels while the average deviation above trend was 1.5 bushels. The largest deviation below trend was 6.6 bushels (1988) while the largest deviation above trend was 5.4 bushels (1994). The deviation below trend yield equaled or exceeded 2.0 bushels in 10 years, or 18 percent of the time, and the deviation above trend equaled or exceeded 2.0 bushels in nine years, or 16 percent of the time. The frequency and magnitude of deviations are logical for the following reasons: good (normal) growing season weather occurs more frequently than poor weather and good growing season weather helps soybean yields less than poor weather hurts yields due to the non-linearity of the relationship between soybean yields and precipitation (e.g., [Tannura, Irwin, and Good, 2008](#); [Irwin, Good, and Tannura, 2009](#)).





In addition to showing large positive and negative deviations from trend, the previous analysis (*farmdoc daily*, [March 19, 2015](#)) found that the duration of consecutive years with above- or below-trend yields has varied considerably and the correlation between yield deviations in consecutive years is negligible. This diverse and largely random set of yield patterns suggests that the most objective early-season yield expectation for any year, including 2016, should be based on the trend of actual yields. Figure 1 indicates that the best linear fit of actual yields in the U.S. from 1960 through 2015 results in an “unconditional” trend calculation for 2016 of 45.0 bushels. This methodology actually results in a slight under-estimate of trend yield due to the asymmetric effect of weather on actual yields (as indicated above) so that the impact of technology (trend) is under-estimated due to sharp reductions in yield from poor weather years, such as 1974, 1983, 1988, 1993, 1995, and 2012. Our previous research on crop weather models that adjust for the asymmetric effect of weather on crop yields indicates the downward bias is about 0.02 bushel for trend coefficients ([Irwin, Good, and Tannura, 2009](#)). This translates into a downward bias in unconditional trend yield forecasts at the national level of about 0.2 bushel per acre. If we add this bias estimate to the unconditional trend yield estimate of 45 bushels per acre the result is a soybean trend yield projection of 45.2 bushels for 2016. Based on historical yield deviations from the unconditional trend, the probability of yield being below (above) trend in 2016 is 39 (61) percent. The probability of yields being below (above) the unconditional trend by two bushels or more is about 18 (16) percent. Note that our trend yield estimate of 45.2 bushels is 1.5 bushels lower than the USDA estimate of 46.7 bushels released during the [Grains and Oilseeds Outlook](#) at last week’s USDA Outlook Forum. The USDA uses a different sample period and a crop weather model to generate trend yield estimates for soybeans, so it is not surprising that differences emerge, but the difference is rather large.

What About El Niño?

There is considerable discussion about the potential impact of the current El Niño episode on U.S. summer weather and the resulting effect on soybean yields. The question is: Should the trend yield expectation, as well as the probabilities of above or below trend yield, be adjusted due to this episode? We start with a brief discussion of what constitutes an El Niño episode and then examine the historical record of soybean yields in years with events similar to the current one.

As defined by the [National Oceanic and Atmospheric Administration](#) (NOAA), “El Niño and La Niña are opposite phases of a natural climate pattern across the tropical Pacific Ocean that swings back and forth every 3-7 years on average. Together, they are called ENSO, which is short for El Niño-Southern Oscillation. The ENSO pattern in the tropical Pacific can be in one of three states: El Niño, Neutral, or La Niña. El Niño (the warm phase) and La Niña (the cool phase) lead to significant differences from average

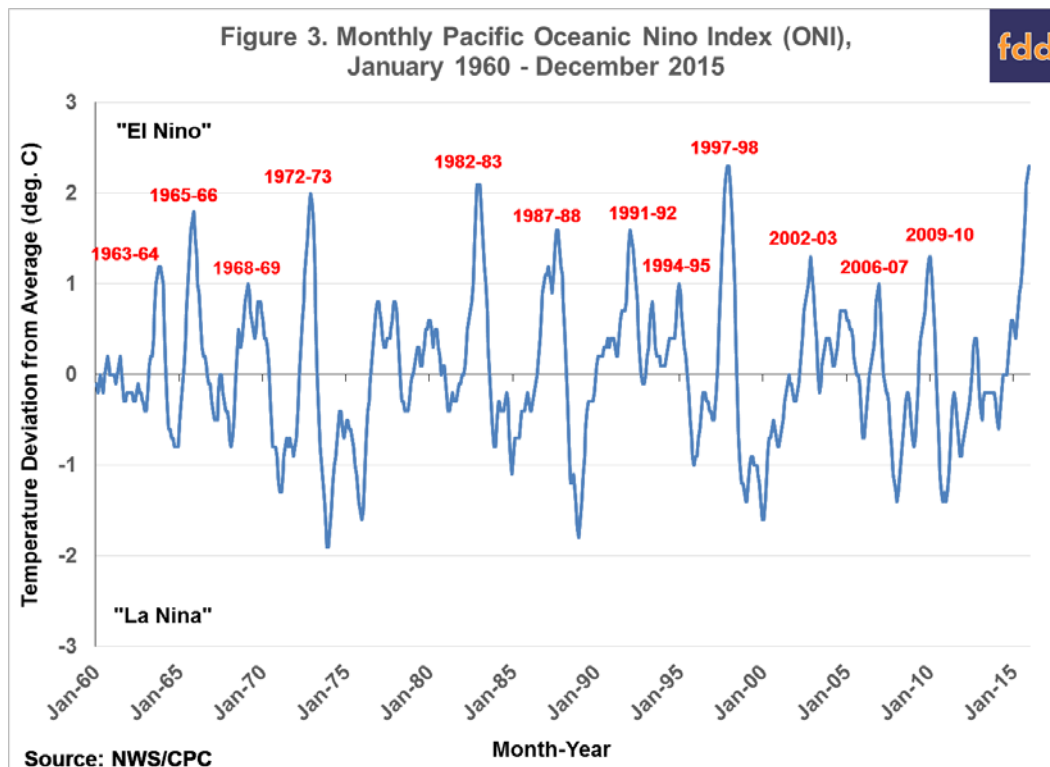
ocean temperatures, winds, surface pressure, and rainfall across parts of the tropical Pacific. Neutral indicates that conditions are near their long-term average.” The definition encompasses four weather factors (temperature, wind, rainfall and surface pressure) and a rather vague description of the geographical location of these factors. The definitions are further refined by [L'Heureux \(2014\)](#) as:

El Niño: A warming of the ocean surface, or above-average sea surface temperatures (SST), in the central and eastern tropical Pacific Ocean. Over Indonesia, rainfall tends to become reduced while rainfall increases over the tropical Pacific Ocean. The low-level surface winds, which normally blow from east to west along the equator (“easterly winds”), instead weaken or, in some cases, start blowing the other direction (from west to east or “westerly winds”).

La Niña: A cooling of the ocean surface, or below-average sea surface temperatures (SST), in the central and eastern tropical Pacific Ocean. Over Indonesia, rainfall tends to increase while rainfall decreases over the central tropical Pacific Ocean. The normal easterly winds along the equator become even stronger.

Neutral: Neither El Niño or La Niña. Often tropical Pacific SSTs are generally close to average

These definitions center on sea surface temperatures in the eastern and central Pacific Ocean and are the popular way to describe the ENSO episodes. For our purposes, then, El Niño episodes occur when the Oceanic Niño Index (ONI-three month running mean) in that central and eastern Pacific region (Niño 3.4 region) reaches 0.5°C above average. The strength of the El Niño is measured by the magnitude of the deviation in the three-month running mean temperature from the average temperature, where average temperature is based on centered 30-year base periods updated every five years. Figure 3 shows the [official ONI data](#) from January 1960 through December 2015. The current El Niño episode is considered one of the strongest episodes since 1960, with the three-month mean temperature exceeding the average temperature by 2.3°C in the three months ending January 2016.



Since our interest is in “strong” El Niño episodes that precede the U.S. soybean growing season, like the present one, we specifically consider episodes that occur in the portion of the pre-plant period extending from September of the previous calendar year to March of the current year, regardless of how and when the episode eventually transitioned to either neutral or La Niña conditions. We further define strong El Niño episodes as those in which the peak actual three-month running mean temperature exceeded the long run average temperature by at least 1°C. The 12 El Niño episodes that meet these two criteria are labeled in Figure 3. (This includes one additional episode compared to the original version of our article on corn of

March 2, 2016. We mistakenly omitted 1968-69 from the original analysis for corn. A corrected version of the article has been posted.) The three previous episodes that most closely resemble the current episode occurred in 1972-73, 1987-88, and 1997-98. Readers should note that there are other measures of “strong” El Niño episodes that we have not considered, and these other measures may result in a different set of analog years to 2016.

Table 1 presents more detail on the conditions during each of the 12 previous El Niño episodes that meet our definition of strong, and the trend deviation for the average U.S. soybean yield in the second year of each pair. Specifically, for each of those episodes, we show the peak temperature anomaly (ranked from lowest to highest), the month of the peak anomaly, the crop year following the peak anomaly, and the yield deviation from trend in those crop years. We also calculate the average yield deviation from trend for all years with a peak anomaly of at least 1°C, at least 1.5°C, and at least 2°C.

Episode	Peak Temperature Anomaly (deg. C)	Month of Peak	Crop Year	Yield Deviation from Trend (bu./ac.)
1968-69	1.0	Feb-69	1969	1.6
1994-95	1.0	Dec-94	1995	-1.1
2006-07	1.0	Dec-06	2007	0.4
1963-64	1.2	Nov-63	1964	-0.9
2002-03	1.3	Nov-02	2003	-5.8
2009-10	1.3	Jan-10	2010	0.9
1987-88	1.6	Sep-87	1988	-6.6
1991-92	1.6	Jan-92	1992	2.4
1965-66	1.8	Nov-65	1966	0.8
1972-73	2.0	Nov-72	1973	0.4
1982-83	2.1	Jan-83	1983	-5.3
1997-98	2.3	Dec-97	1998	1.3
Average trend deviation:				
	Peak temperature ≥ 1.0			-1.0
	Peak temperature ≥ 1.5			-1.2
	Peak temperature > 2.0			-1.2
2015-16	2.3	Dec-15	2016	?

Note: Peak temperature anomaly is reported as deviation from average temperature.

The pattern of U.S. average soybean yields in years following such strong El Niño episodes paints a mixed picture:

- 1) The average yield in those years was 1.0 bushels below trend, regardless of how the years are grouped by strength of the El Niño.
- 2) The deviation from trend ranged from -6.6 bushels to 2.4 bushels.
- 3) The average yield was below trend 42 percent of the time (five years), compared to the 1960-2015 unconditional average of 39 percent. The yield was more than two bushels below trend 25 percent of the time (three years), compared to the 1960-2015 unconditional average of 18 percent.

- 4) Of the eight years since 1960 that the U.S. average yield was at least three bushels below trend, 3 followed a strong El Niño. Of the four years since 1960 that the U.S. average yield was at least four bushels below trend, 3 followed a strong El Niño.
- 5) The average yield was above trend 58 percent of the time (seven years), compared to the 1960-2015 unconditional average of 61 percent. The yield was more than two bushels above trend 8 percent of the time (one year), compared to the 1960-2015 unconditional average of 16 percent.
- 6) Of the three years since 1960 when the average yield was at least three bushels above trend, none followed a strong El Niño episode.
- 7) In the three years with a peak temperature anomaly of at least 2°C, yield exceeded trend in two years by an average of 0.85 bushel, but was below trend by 5.3 bushels in one year. This suggests, in conditional terms, about a two-thirds chance of a normal crop in 2016 and a one-third chance of a very poor crop. Based on the 2016 trend estimate of 45.2 bushels, yield outcomes would range from 39.9 to 46.5 bushels per acre.

Finally, it should be noted that yield performance in 2003 was likely adversely affected by a late season, widespread outbreak of soybean aphids. We have not attempted to isolate the impact of that outbreak from the impact of weather conditions. As a result, the yield impact attributed to El Niño in that year may be overstated.

Implications

With current U.S. and world soybean supplies in surplus, the size of the 2016 U.S. crop will be very important in determining the direction of soybean prices over the next year or more. With small changes in soybean acreage anticipated, the U.S. average yield will become the focus of the soybean market as the planting and growing season progresses. With planted acreage of 82.5 million acres, as suggested by USDA analysts, harvested acreage would likely be near 81.6 million acres. An average yield near our calculated trend value of 45.2 bushels per acre would result in a crop near 3.688 billion bushels, 242 million bushels smaller than the 2015 crop, but large enough to keep soybean supplies in surplus for another year due to large old crop stocks and keep prices near or below current levels.

We find that the history of soybean yields conditioned on a strong El Niño episode, such as the one currently underway, does not provide a definitive indication of the direction or magnitude of the trend deviation to expect in 2016. However, that history does point to an “elevated” risk of the average yield being below trend when compared to the unconditional risk of a yield below trend. For example, in the three previous episodes most closely resembling the current episode, yield exceeded trend in two years by an average of 0.85 bushels, but was below trend by 5.3 bushels in one year. Very little yield risk is reflected in the current price structure, and if recent years are a guide, the market will likely continue to take a “wait and see” attitude relative to soybean yield expectations. This attitude is likely reinforced by the size of the current soybean surplus and perhaps by trend yield expectations that may be too high. For example, the recent USDA soybean balance sheet projections for the 2016-17 marketing show year-ending stocks of 440 million bushels. A 2016 soybean yield of 45.5 bushels (1.2 bushels below the USDA projection) would result in a year-ending stocks projection of 342 million bushels. However, a 2016 soybean yield of 44 bushels, 1.2 bushels below our calculated trend, would point to year-ending stocks of only 220 million bushels. Variations in ending stocks value of this magnitude have significant price implications. It seems prudent to give consideration to managing the elevated risk of below-trend soybean yields in 2016, despite the current market structure of prices.

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