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Forming Expectations for the 2015 U.S. Average Soybean Yield: What Does History Teach Us?

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There has been a lot of discussion about the likely magnitude of planted acreage of soybeans in the U.S. in 2015. For the most part, current expectations are that acreage will increase as acreage of other crops that have higher production costs and/or lower potential net returns are reduced. Those expectations are not universal. Analysis prepared by the USDA's Wheat, Feed Grains, Rice, and Oilseeds Interagency Commodity Estimates Committees and presented at last month's USDA Outlook Forum projected plantings at 83.5 million acres, 200,000 fewer acres than planted in 2014. The USDA will release the results of its survey of 2015 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 2015 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 that might also incorporate specific views on prospects for growing season weather. For example, the USDA has projected a 2015 U.S. average soybean yield of 46 bushels per acre. This raises the perennial issue of what, if anything can be learned from the historical trends and patterns of U.S. average soybean yields. Here, we examine the history of soybean yields from 1960 through 2014 as a basis for forming an expectation of the U.S. average soybean yield in 2015. The analysis follows the same format as our *farmdoc daily* article last week on 2015 corn yields (February 26, 2015) and also updates our analysis of soybean yields in this earlier article (February 8, 2012).

Historical Trends and Patterns

As shown in Figure 1, U.S. average soybean yields have trended higher since 1960. We find that a linear trend is the best fit to actual average yields over that period, explaining 88.4 percent of the variation in annual average yields, and that yields have increased at a rate of 0.4027 bushels per acre per year. An alternative sometimes considered is the log-linear trend model (take the natural logarithm of yield before regressing on a time index), but this model also implies that the range of trend yield deviations in bushels should expand across time which clearly does not happen. It should also be noted that an important property of the linear trend model is that the percentage change in trend yields declines over time as the same bushel increase in trend yield is divided by a larger and larger base. This is consistent with the history of U.S. average soybean yields since 1960.

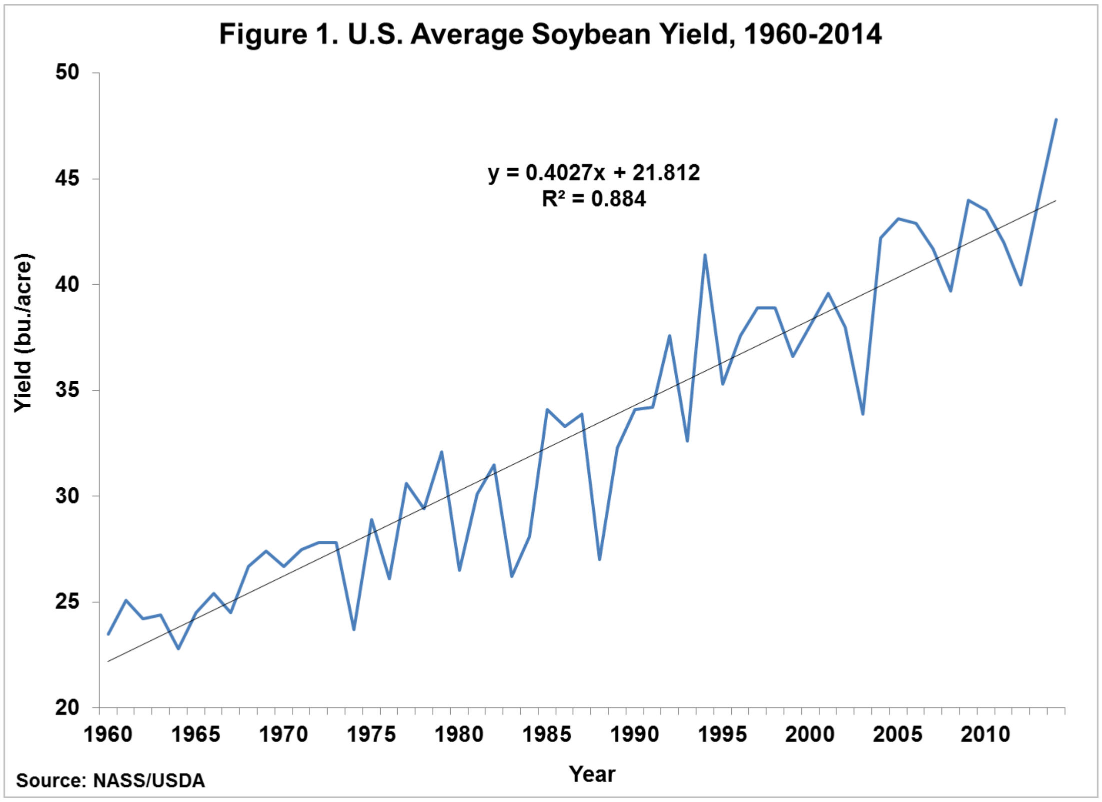


Figure 2 shows the deviations of actual yields from the estimated 1960-2014 trend in yield. Obviously, there has been substantial deviation from the trend yield in individual years. Over the 55-year period, the average yield was above the trend yield in 60 percent of the years and below the trend in 40 percent of the years. Since all deviations from a linear trend must sum to zero, this means that in the 40 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 2.2 bushels while the average deviation above trend was 1.5 bushels. The largest deviation below trend was 6.5 bushels (1988) while the largest deviation above trend was 5.5 bushels (1994). 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. Further discussion of this topic can be found in our earlier report on crop weather modeling (Tannura, Irwin, and Good, 2008b).

The 60/40 split between above and below trend yields discussed above is a general statement that applies to any year in the sample. A different, but related, question is whether there is a marked correlation between deviations from year-to-year. In other words, is there a tendency towards continuation or reversal of deviations? Figure 3 shows that there is an extremely small negative correlation (-0.002) between the yield deviation in the previous year and the current year (correlations can vary between -1 and +1, with zero indicating no relationship). For all practical purposes this correlation is indistinguishable from zero, which means that a negative yield deviation last year does not necessarily tend to be followed by a positive deviation this year and *vice versa*.

Figure 2. Deviation from Trend in U.S. Average Soybean Yield, 1960-2014

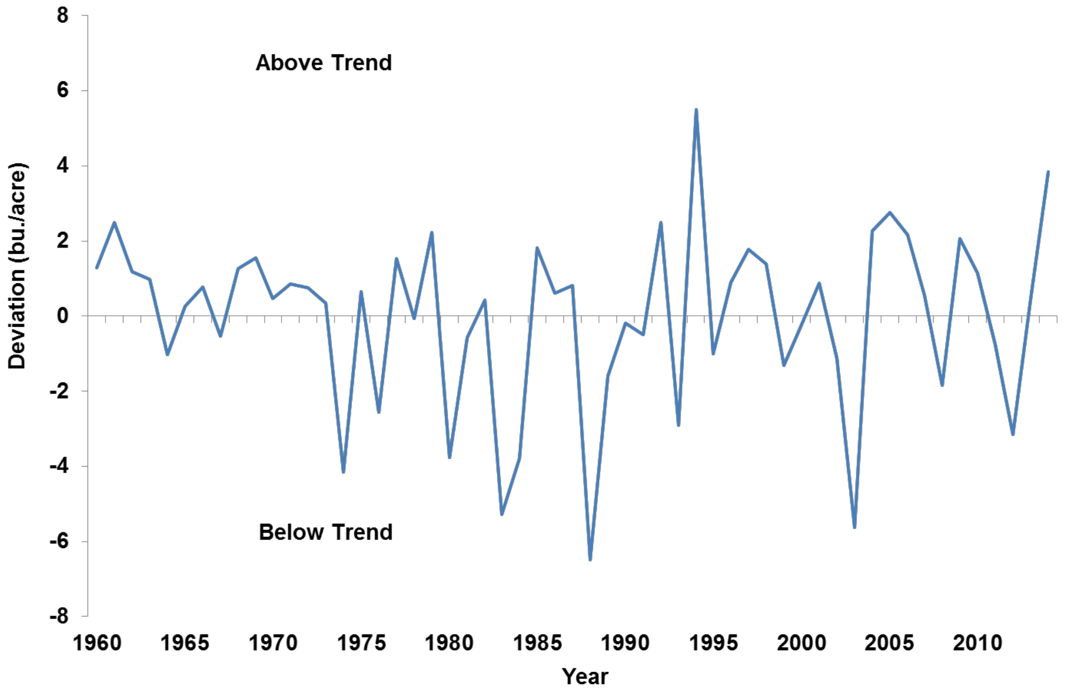
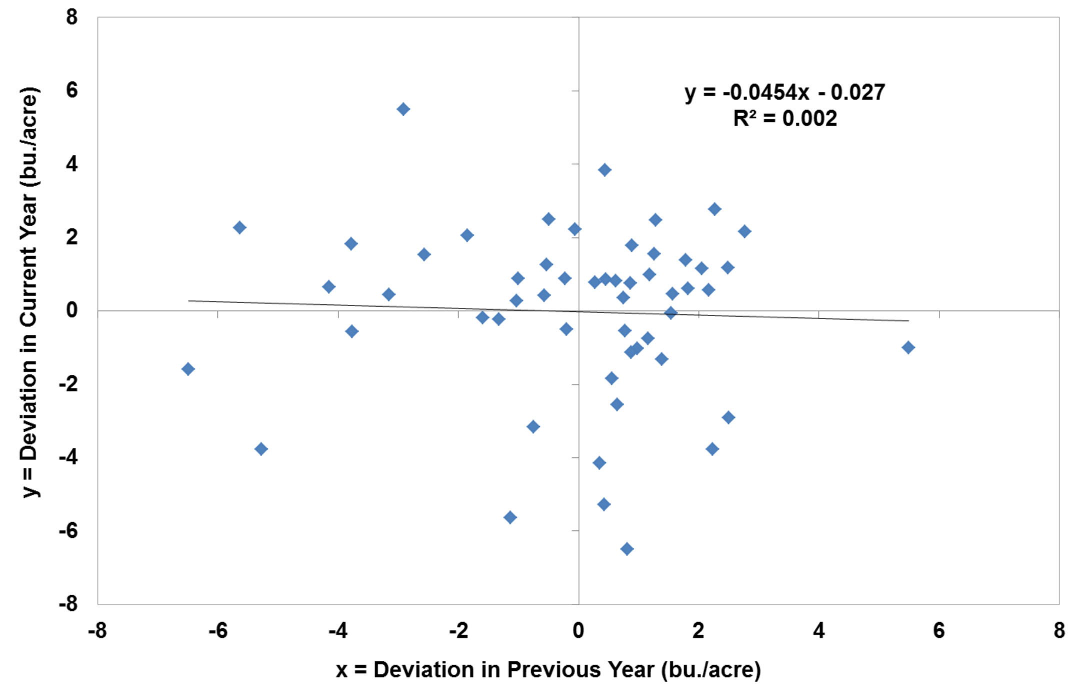


Figure 3. Current Year vs. Previous Year Deviation from Trend in U.S. Average Soybean Yield, 1960-2014



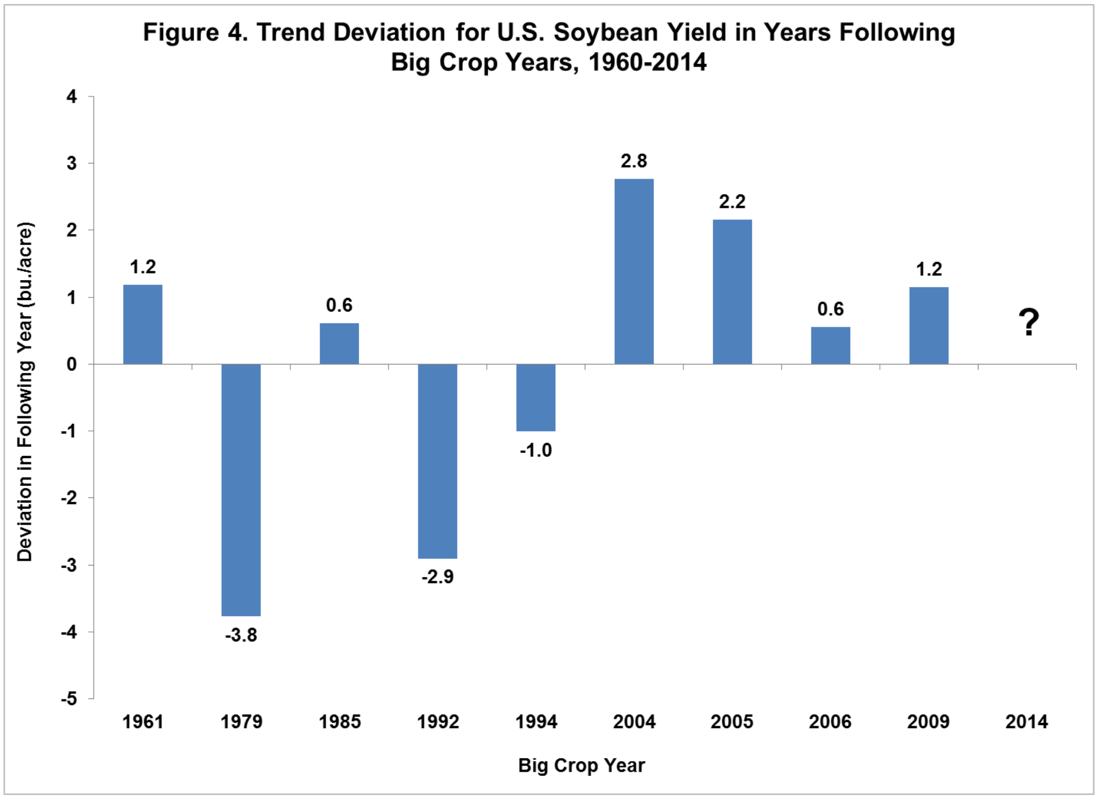
The correlation in Figure 3 is based on comparing deviations in pairs of adjacent years. It is also interesting to examine whether longer "runs" in the deviations occur. The distribution of runs of consecutive positive or negative yield deviations is summarized in Table 1. There were seven single year runs with positive deviations and eight single year runs of negative deviations. This simply means that a positive deviation was followed by a negative deviation and *vice versa* in these 15 years. The longest run of negative deviations was four years (1988-1991), while positive deviations had two runs of three years (1985-1987 and 1996-1998), two runs of four years (1960-1963 and 2004-2007), and a run of six years (1968-1973). Since positive deviations are more common than negative deviations, it is logical that more and longer runs of positive yield deviations have occurred.

Table 1. Distribution of Runs in Deviation above and below Trend for U.S. Soybean Yield, 1960-2014

	Frequency (#)	
Length of Run	**Above Trend**	**Below Trend**
1 year	7	8
2 years	3	5
3 years	2	0
4 years	2	1
5 years	0	0
6 years	1	0

In our previous analysis of corn yields (*farmdoc daily*, February 26, 2015), we found an interesting connection between the runs of positive corn yield deviations and growing season weather. Specifically, the run of positive yield deviations from 1965 through 1969 led some to conclude that technological improvements had resulted in reduced risk of low corn yields, and therefore, had increased the trend. As it turned out, those yields instead reflected a period of generally favorable weather and not an increase in the underlying trend (see the final section of Tannura, Irwin, and Good (2008a) for a more detailed discussion). The run of positive yield deviations from 1998 through 2001 and the unprecedented run from 2003 through 2009 once again led some to conclude that the underlying corn trend yield had shifted higher. That period was also one of generally favorable weather, but as noted earlier, some had also argued (and continue to argue) that the trend indeed had shifted due to improved technology, particularly improved drought tolerance. A similar connection can be identified for the runs of positive soybean yield deviations and favorable growing season weather in 1968-1973 and 2004-2007. However, the argument that technological improvements had resulted in reduced risk of low soybean yields was never made as strong as for corn yields.

Since 2014 was a year of a large positive deviation from trend yield, a related issue is the historical pattern of yield deviations in years following large positive trend deviations. The 2014 average yield of 47.8 bushels was 3.8 bushels above trend, the second largest positive deviation since 1960. The previous nine years that round out the top ten years with the largest positive deviation (in descending order) were 1994, 2005, 1992, 1961, 2004, 1979, 2006, 2009, and 1985. The positive yield deviations ranged from 5.5 bushels in 1994 to 1.8 bushels in 1985, and averaged 2.6 bushels. Figure 4 shows the deviation from trend yield in the nine years following those years with large positive deviations. Somewhat surprisingly, five of the nine years had large yield deviations from trend. Not surprisingly, the negative deviations (on average) were larger (2.6 bushels) than the positive deviations (1.4 bushels). For the nine years, the average yield was 0.1 bushels above trend. Given the small sample of years and variation across the nine years, these results provide little direction for 2015 U.S. average yield expectations.



What About 2015?

The analysis of soybean yields presented to this point reveals considerable diversity in yield patterns since 1960, most clearly depicted in Figure 2. Average yields have shown large positive and negative deviations from trend, the duration of consecutive years with above- or below-trend yields has varied considerably, the correlation between yield deviations in consecutive years is negligible, and the pattern of yield deviations following years of very large positive deviations (like 2014) is quite mixed. This diverse and largely random set of patterns suggests that the most objective early-season yield expectation for any year, including 2015, should be based on the trend of actual yields.

As we noted above, some have suggested that the trend may have increased at a faster rate in recent years, so we calculated 2015 trend yield based on the 1960-2014 period as well as more recent time periods. The period of 1988-2014 is selected since it is the period used by the USDA in making its trend projection for 2015. The period 1995-2014 is used to represent the recent "biotech" era. Since two of the three alternative periods begins with low yielding years (1988, and 1995), trends are also calculated for periods starting in 1989 and in 1996. Table 2 contains a summary of the calculation of the annual trend increase and the 2015 trend yield based on the five alternative periods for calculation. There is similarity among the trend calculations, with the trend being lowest for the period starting in 1960 and highest for the period starting in 1988. The calculation of the 2015 trend yield for the five alternative time periods ranges from 44.4 bushels to 45.4 bushels.

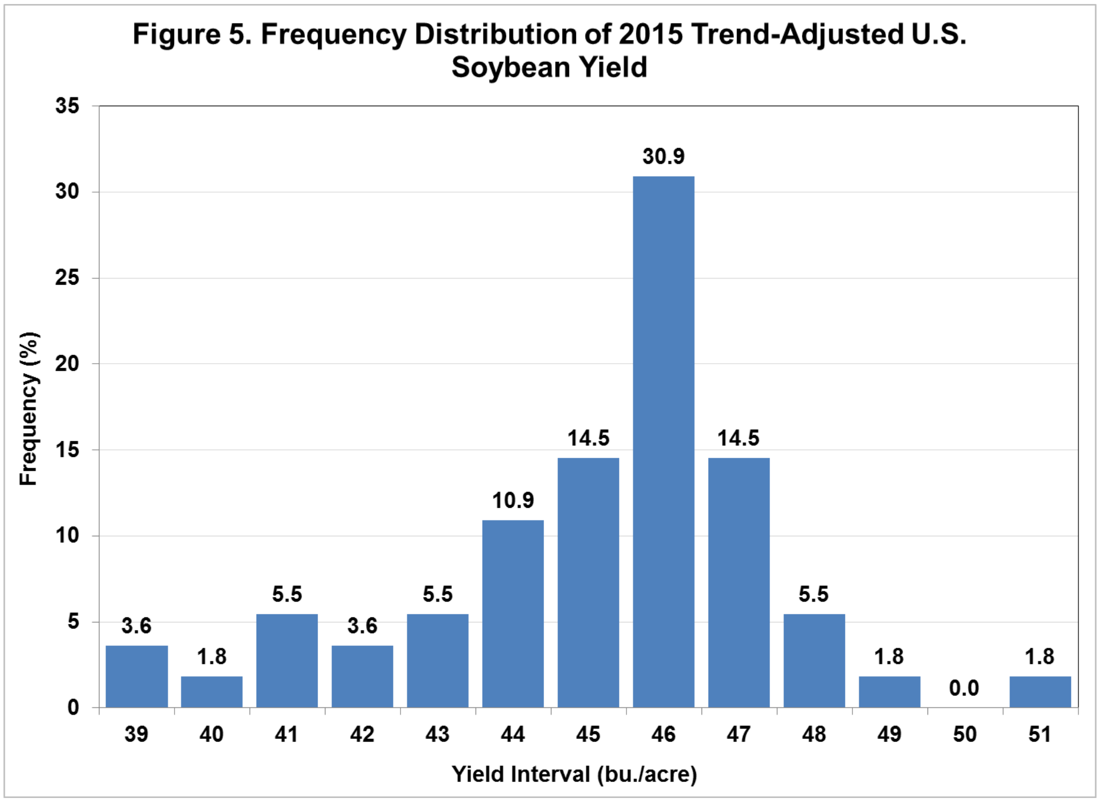
Table 2. Alternative Trend Models for U.S. Soybean Yield

Estimation Sample	Annual Trend	2015 Trend Yield
1960-2014	0.40	44.4 bu.
1988-2014	0.47	45.4 bu.
1989-2014	0.42	44.9 bu.
1995-2014	0.44	45.0 bu.
1996-2014	0.42	44.9 bu.

Given the various alternatives, we maintain that current 2015 soybean yield expectations should be based on the longest sample of data with a stable trend yield component. Since we have been unable to find significant evidence of trend yield shifts since 1960, we argue that the period of 1960-2014 best meets this criterion. Table 2 indicates that the best linear fit of actual yields in the U.S. from 1960 through 2014 results in an "unconditional" trend calculation for 2015 of 44.4 bushels. This methodology actually results in a slight under-estimate of trend yield due to the asymmetric effect of weather on actual yields (Swanson and Nyankori, 1979; Tannura, Irwin, and Good, 2008a). That is, poor weather reduces yields more than good weather improves yields so that the impact of technology (trend) is under-estimated due to sharp reductions in yield from poor weather years, such as 1974, 1980, 1983, 1984, 1988, 2003, and 2012 (for those with a statistical bent this is more formally known as an omitted variables bias). 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 44.4 bushels per acre the result is a soybean trend yield projection of 44.6 bushels for 2015.

It should be obvious at this point that a range of trend yield projections are plausible depending on the sample period used, the functional form of the trend model, and whether a bias adjustment is considered or not. As we noted in the introduction, the USDA trend yield projection for soybeans released last month is 46 bushels per acre, 1.4 bushels above our projection. While this is not a large disparity it could result in ending stock projections that differ by as much as 100 million bushels or more. Since this could have a market impact, it is useful to understand why the USDA projection is higher. We believe that two factors likely explain the difference. The first is that the USDA crop weather model used to make their trend projection is estimated over 1988-2014. We demonstrated in Table 2 how starting the sample in a year of extreme drought can lead to a higher trend yield projection. In essence, the extreme drought year pulls down the trend line during the early years of the sample. The second has to do with the methodology the USDA currently uses to generate trend yield projections from the crop weather model it started using in 2013 (Westcott and Jewison, 2013). The trend projection methodology imposes on the crop weather model the assumption of average weather over 1988-2014 along with the average portion of the crop planted in a timely manner over that period. In technical terms, this is a "certainty-equivalent" approach because it is assumed with certainty that average weather and planting progress will occur. This pushes up trend yield projections compared to a procedure that does not assume average values, again due to the asymmetric effect of weather on yields (Irwin, Good, and Tannura, 2009). That is, the assumption of average weather does not fully reflect the large negative yield effects of poor weather relative to the smaller positive effects of good weather.

Finally, it is important to keep in mind the substantial yield risk that exists when considering trend projections. We argue that the distribution of expected yields around that average should reflect the distribution of actual annual deviations from trend yield for the period 1960 through 2014. The resulting distribution of likely yields, with a mean (expected value) of 44.6 bushels, is shown in Figure 5. Note that each interval refers to the frequency of yields greater than the previous interval yield but less than or equal to the indicated yield level. For example, the 44 bushel interval indicates there is a 9.1 percent chance of yields being more than 43 bushels and less than or equal to 44 bushels. The outcomes range from a low of 38.1 bushels to a high of 50.1 bushels, with a higher probability of an above-trend yield than a below-trend yield. The distribution is skewed to the left since extreme negative trend yield deviations have been larger than extreme positive yield deviations, which also implies that the mean (44.6 bushels) is slightly less than the median (45.1 bushels). The historic yield distribution suggests an 11 percent probability of an average yield below 41 bushels and an 11 percent probability of an average yield above 47 bushels. The middle 50 percent of the expected yield distribution is 43.6 to 45.9 bushels.



Implications

The U.S. average soybean yield since 1960 has shown: i) large positive and negative deviations from trend, ii) the duration of consecutive years with above or below trend yields has varied considerably, iii) the correlation between yield deviations in consecutive years is negligible, and iv) the pattern of yield deviations following years of very large positive deviations (like 2014) is quite mixed. This diverse and largely random set of patterns suggests that the most objective early-season yield expectation for any year, including 2015, should be based on the trend of actual yields. A range of trend yield projections is plausible depending on the sample period, the functional form of the trend model, and whether a bias adjustment is considered or not. Given the various alternatives, we maintain that yield expectations should be based on the longest sample of data with a stable trend yield component. Since we have been unable to find significant evidence of trend yield shifts since 1960, we argue that the period of 1960-2014 best meets this criterion. After adjusting for bias, the best linear fit of actual yields in the U.S. from 1960 through 2014 results in a trend yield projection for 2015 of 44.6 bushels per acre. This is 1.4 bushels less than the USDA's 2015 trend yield projection for soybeans of 46 bushels. The higher trend projection by the USDA is likely due to a sample that starts in the drought year of 1988 and a "certainty-equivalent" approach that assumes with certainty average weather and planting progress will occur in 2015. Regardless of which trend projection is considered, there is, as usual, large risk of deviations from the projection. For example, we estimate there is roughly a one-in-ten chance of the U.S. average soybean yield falling below 41 bushels and a one-in-ten chance of yield rising above 47 bushels. As indicated in the analysis for corn yields, it really is no wonder that weather forecasters are in such high demand.

References

Irwin, S., and D. Good. "Forming Expectations for the 2015 U.S. Average Corn Yield: What Does History Teach Us?" *farmdoc daily* (5):36, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 26, 2015.

Irwin, Scott, and Darrel Good. "The Historic Pattern of U.S Soybean Yields, Any Implications for 2012?" *farmdoc daily* (2):25, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 8, 2012.

Irwin, S., D. Good, and M. Tannura. "Early Prospects for 2009 Soybean Yields in Illinois, Indiana, and Iowa." Marketing and Outlook Brief 2009-02, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, July 2009.

Swanson, E.R., and J.C. Nyankori. "Influence of Weather and Technology on Corn and Soybean Yield Trends." *Agricultural Meteorology* 20(1979):327-342.
http://www.sciencedirect.com/science/article/pii/0002157179900074

Tannura, M., S. Irwin, and D. Good. "Are Corn Trend Yields Increasing at a Faster Rate?" Marketing and Outlook Brief 2008-02, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 2008a.

Tannura, M., S. Irwin, and D. Good. "Weather, Technology, and Corn and Soybean Yields in the U.S. Corn Belt." Marketing and Outlook Research Report 2008-01, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 2008b.

USDA Agricultural Outlook Forum 2015. "*Grain and Oilseeds Outlook.*" February 20, 2015. 2015.
http://www.usda.gov/oce/forum/2015_Speeches/Grains_Oilseeds.pdf. Accessed March 18, 2015.

USDA Agricultural Outlook Forum 2015. "*Grain and Oilseeds Outlook.*" Released February 20, 2015, and accessed March 19, 2015. http://www.usda.gov/oce/forum/2015_Speeches/Grains_Oilseeds.pdf

Westcott, P.C., and M. Jewison. "Weather Effects on Expected Corn and Soybean Yields." FDS-13g-01, Economic Research Service, U.S. Department of Agriculture, July 2013. Accessed March 19, 2015.
http://www.ers.usda.gov/publications/fds-feed-outlook/fds-13g-01.aspx