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

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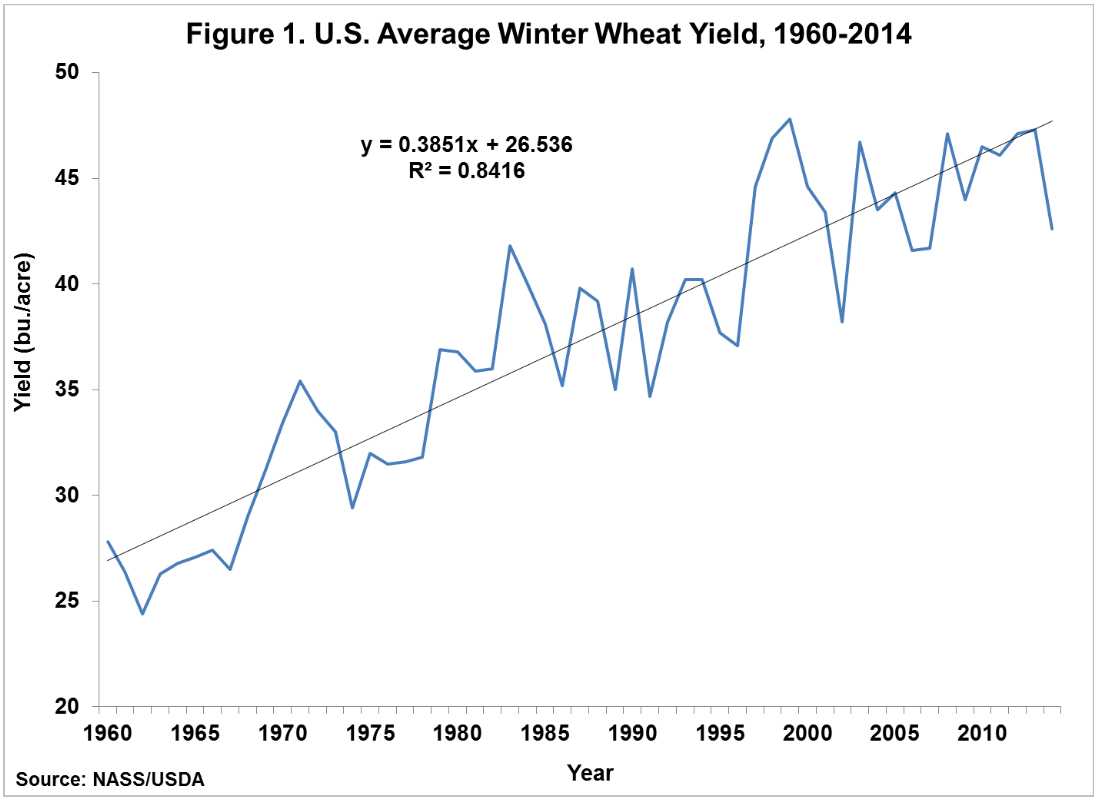
The USDA's January 12, 2015 *Winter Wheat Seedings* report indicated that 40.452 million acres of winter wheat were seeded last fall. That is 1.947 million fewer acres seeded in the previous fall and 2.778 million fewer acres than seeded in the fall of 2012. The size of the 2015 winter wheat crop will depend on the magnitude of harvested acres and the average yield. Updated forecasts of seeded acreage will be revealed in USDA's March 31 *Prospective Plantings* report. The USDA's May 12 *Crop Production* report will reveal expected harvested acreage, yield, and production.

The main factors determining winter wheat yield will unfold over the next two 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. This raises the perennial issue of what, if anything can be learned from the historical trends and patterns of U.S. average winter wheat yields. Here, we examine the history of winter wheat yields from 1960 through 2014 as a basis for forming an expectation of the U.S. average yield in 2015. The analysis follows the same format as our *farmdoc daily* articles on 2015 corn yields (February 26, 2015) and 2015 soybean yields (March 19, 2015) and also updates our analysis of winter wheat yields in this earlier article (February 23, 2012).

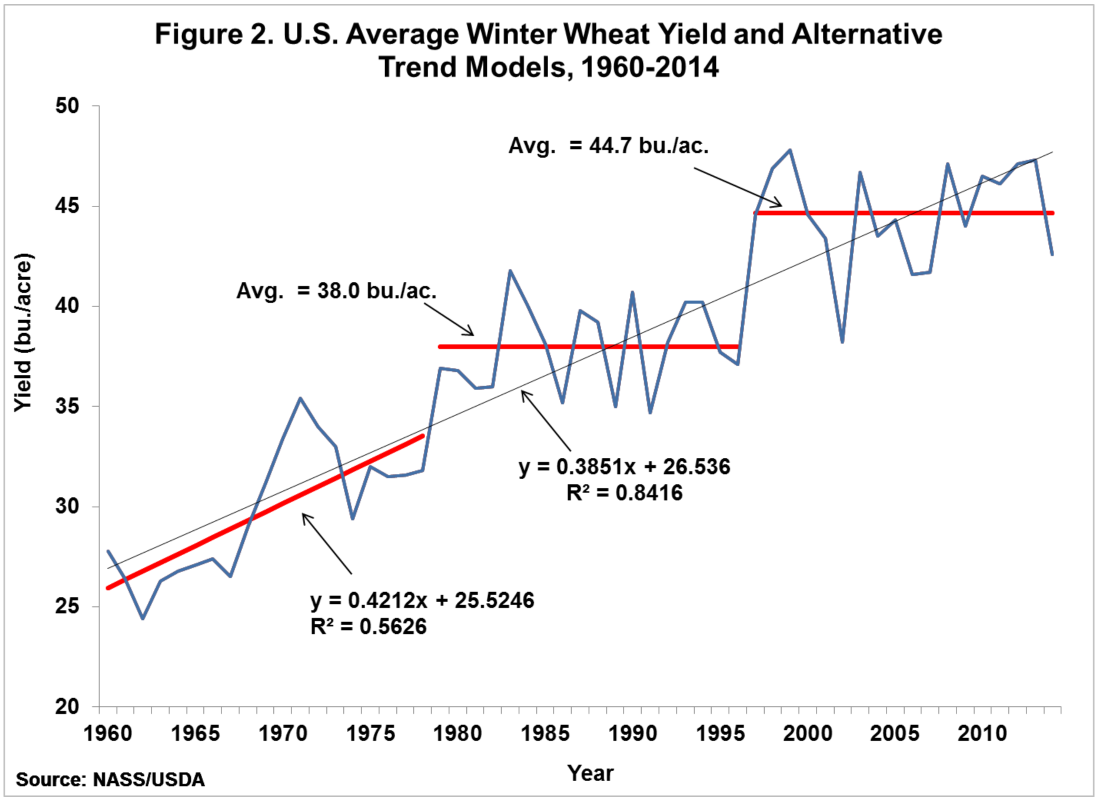
Historical Trends and Patterns

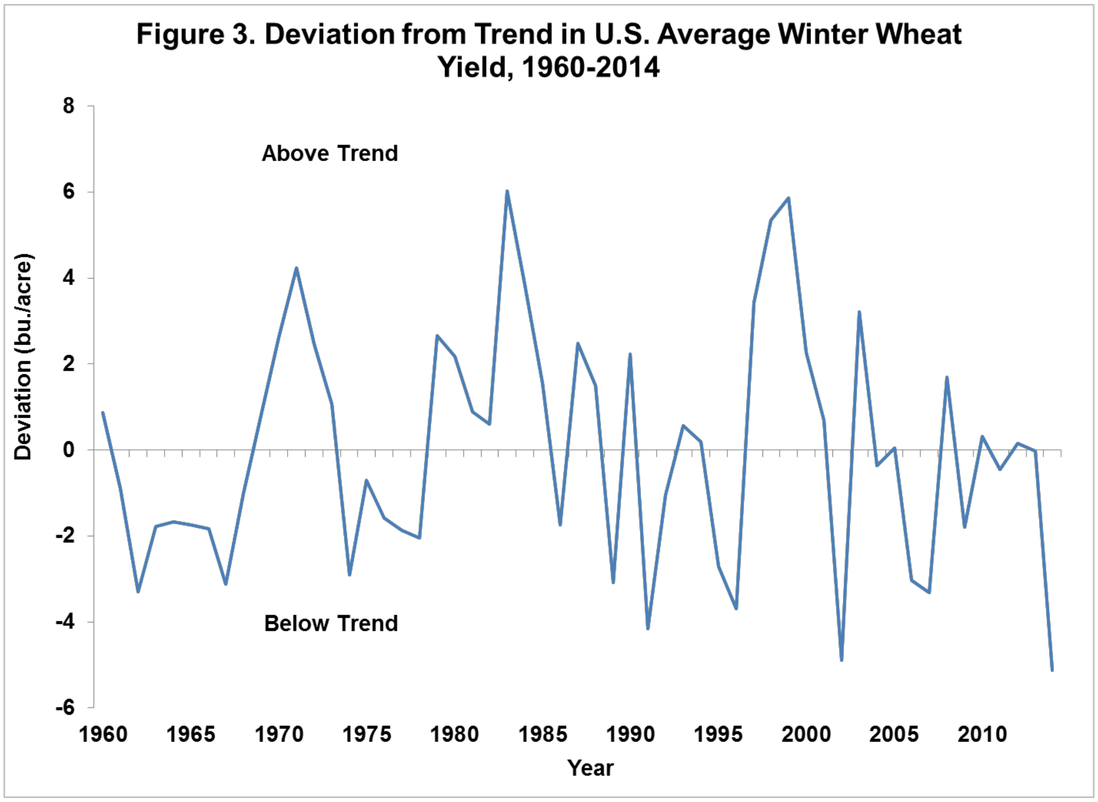
As shown in Figure 1, U.S. average winter yields have trended higher since 1960. Note that the USDA winter wheat yield used here is actually a weighted-average of the different types of winter wheat grown in the U.S., such as hard and soft red winter and hard and soft white winter. A linear trend of actual average yields over that period explains 84.2 percent of the variation in annual average yields and estimates that yields have increased at a rate of 0.3851 bushels per acre per year. An alternative to a linear trend that is 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 winter wheat yields since 1960.



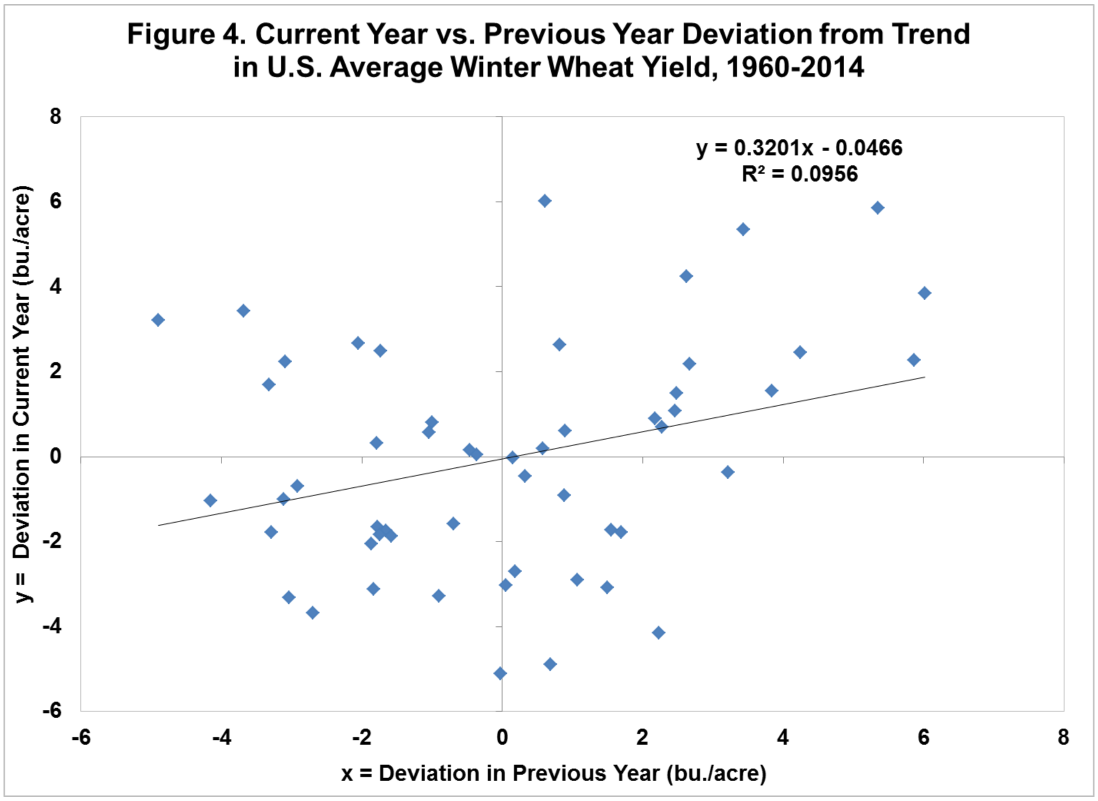
The linear trend of actual yields explains a smaller portion of the annual variation in yields than is the case for corn (88.6 percent) and soybeans (88.4 percent). A closer examination of Figure 1 suggests that that the long-term trend increase in winter wheat yields consists of a linear increase from 1960 through 1978, a step-up in yield in 1979 followed by a relatively flat pattern through 1996, and another step-up in 1997 followed by a relatively flat pattern through 2014 (Figure 2). There is clearly room to debate the best approach to projecting the trend in winter wheat yields in the U.S. We argue in favor of the long-term linear trend since we are not aware of an obvious reason why winter wheat yields would plateau over an extended period. Nonetheless, it will be important to monitor the evolution of winter wheat yields over the next few years in order to assess this issue.

Figure 3 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 51 percent of the years and below the trend in 49 percent of the years, a much more even split than is found for corn (58/42) and soybeans (60/40). Since all deviations from a linear trend must sum to zero, this means that in the 51 percent of years with an above trend yield the deviations were on average about equal the deviations in the 49 percent of years when yields were below trend. Specifically, the average deviation above trend was 2.1 bushels while the average deviation below trend was 2.2 bushels. The largest deviation above trend was 6.0 bushels (1983) while the largest deviation below trend was 5.1 bushels (2014). The frequency and magnitude of positive and negative yield deviations for winter wheat have been markedly different than for corn and soybeans. The pattern of deviations of winter wheat yields from trend does not reveal the asymmetric impact of good (normal) weather and poor weather that was found for corn and soybeans. In addition, the frequency of good (normal) and poor weather conditions for wheat production appears to have been more evenly divided than has been the case for corn and soybeans.





The 51/49 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 4 shows that there is a small positive correlation (0.0956) between the yield deviation in the previous year and the current year (correlations can vary between -1 and +1, with zero indicating no relationship). While relatively small, the correlation is larger than was found for corn (-0.0159) and soybeans (-0.002). There is a slight tendency for a negative winter wheat yield deviation to be followed by a positive deviation in the next year and *vice versa.*



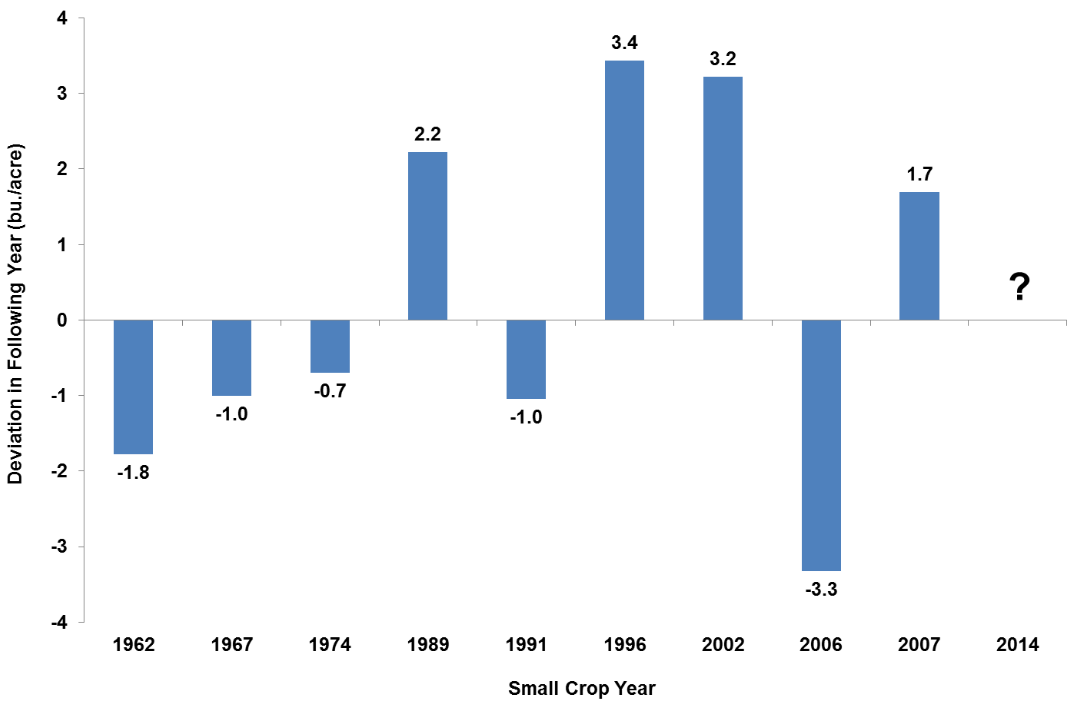
The correlation in Figure 4 is based on comparing deviations in pairs of adjacent years. It is also interesting to examine whether longer "runs" in the deviations occur. The distribution of runs of consecutive positive or negative yield deviations is summarized in Table 1. There were seven single year runs with positive deviations and six single year runs of negative deviations. This simply means that a positive deviation was followed by a negative deviation and *vice versa* in these 13 years. Negative deviations had one run of eight years (1961-1968) and one run of five years (1974-1978). Positive deviations had one run of seven years (1979-1985) and two runs of five years (1969-1973 and 1997-2001).

Since 2014 was a year of a large negative deviation from trend winter wheat yield, a related issue is the historical pattern of yield deviations in years following large negative trend deviations. The 2014 average yield of 42.6 bushels was 5.1 bushels below trend, the largest negative deviation since 1960. The previous nine years that round out the top ten years with the largest negative deviation (in descending order) were 2002, 1991, 1996, 2007, 1962, 1967, 1989, 2006, and 1974. The negative yield deviations ranged from 4.9 bushels in 2002 to 2.9 bushels in 1974, and averaged 3.5 bushels. Figure 5 shows the deviation from trend yield in the nine years following those years with large negative deviations. Four of the years had positive deviations and five had negative deviations from trend. Three of the nine years had large deviations from trend that exceeded three bushels. The negative deviations averaged 1.6 bushels and the positive deviations averaged 2.6 bushels. For the nine years, the average yield was 0.3 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.

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

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

Figure 5. Trend Deviation for U.S. Average Winter Wheat Yield in Years Following Small Crop Years, 1960-2014



What About 2015?

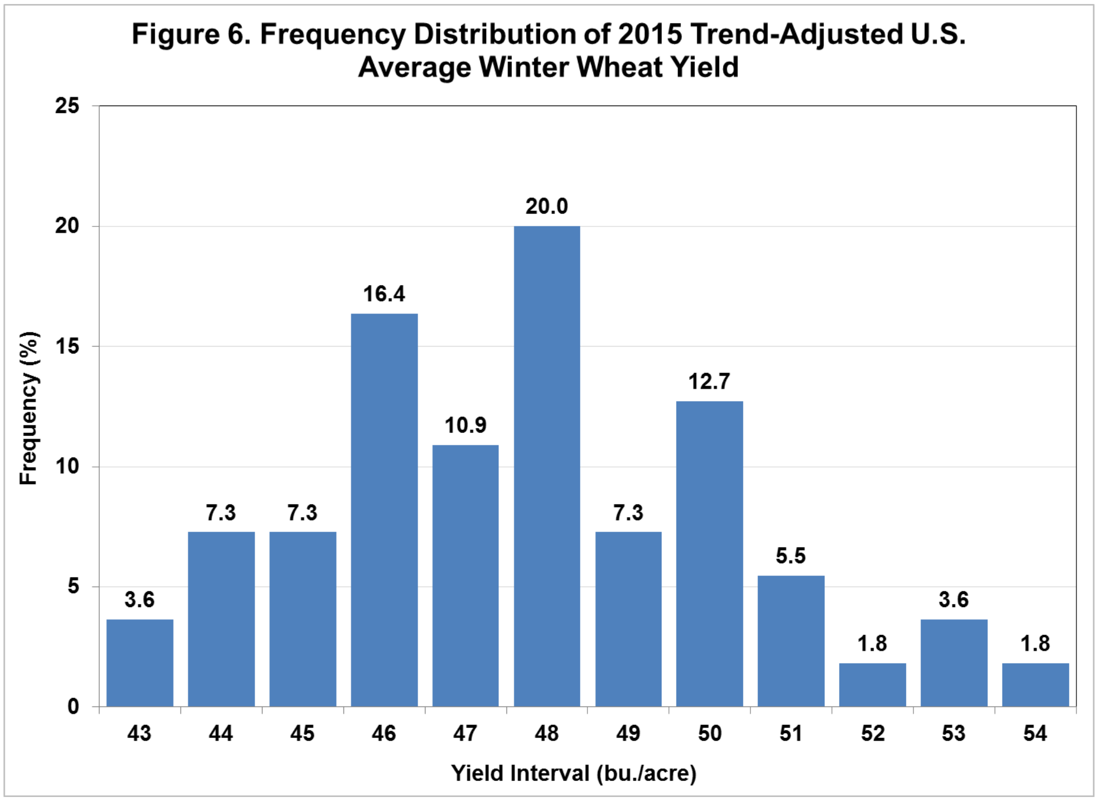
The analysis of winter wheat yields presented to this point reveals considerable diversity in yield patterns since 1960, most clearly depicted in Figure 3. Average yields have shown large positive and negative deviations from trend, the duration of consecutive years with above- or below-trend yields has varied considerably, the correlation between yield deviations in consecutive years is relatively small, and the pattern of yield deviations following years of very large negative 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 noted earlier, there is some evidence that winter wheat yields have "flattened" since 1997 so we calculated the 2015 trend yield based on the 1960-2014 linear trend as well as the 1997-2014 linear trend. The first calculation results in a 2015 trend projection of 48.1 bushels and the second results in a 2015 trend calculation of only 45.1 bushels. Given the flat-line in yields over 1997-2014, it is not surprising that the time trend explains less than one percent of the variation in annual yields over that period. But, it still would be a reasonable alternative if one could make a good argument to support what is basically a simple projection of the average yield due to the absence of technological change. A key unknown is the degree to which the flattening of yield over 1997-2014 was due to a good weather early in the period and poor weather more recently. A third alternative considered is the 1988-2014 linear trend of actual yields, which is consistent with the time period used by USDA for corn and soybean yields. A linear trend over that period results in a 2015 trend yield calculation of 47.2 bushels, but explains only 46 percent of the variation in annual yields.

Given the alternatives, we maintain that current 2015 winter wheat yield expectations should be based on the longest sample of data with a stable trend yield component. Since we are unable to identify a clearly acceptable alternative, we argue that a linear trend over 1960-2014 best meets this criterion. This results in an "unconditional" trend calculation for 2015 of 48.1 bushels. In our recent *farmdoc daily* articles on corn and soybean trend yields (February 26, 2015; March 19, 2015), we argued that this methodology actually results in a slight under-estimate of the true trend yield due to the asymmetric effect of weather on actual yields. That is, poor weather reduces corn and soybean 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. Consequently, we used our previous research on crop weather models to adjust for the downward bias in unconditional corn and soybean trend yield estimates associated with the asymmetric effect of weather on yields. A similar bias adjustment is not made to the unconditional 2015 winter wheat trend yield estimate for two reasons. First, the trend deviations in winter wheat yield shown in Figure 1 or Figure 2 do not appear to exhibit the type of asymmetric good versus bad weather effect that is so evident in corn and soybeans. Second, we have not developed crop weather models for winter wheat, and therefore, do not have the needed research to make the same bias adjustment as we did for corn and soybeans.

It is clear that a range of winter wheat trend yield projections are plausible, depending on the sample period used and the functional form of the trend model. This was highlighted for corn and soybeans by comparing our 2015 trend yield estimates to the projections released by the USDA at last month's Ag Outlook Forum. Unfortunately, a similar comparison is not possible for winter wheat because the USDA only released a 2015 trend yield estimate for "all wheat," which is a weighted-average of all major types of wheat grown in the U.S. The USDA all wheat yield projection for 2015 is 45.2 bushels.

Like corn and soybeans, it is important to keep in mind the substantial yield risk that exists when considering winter wheat trend projections. We argue that the distribution of expected yields around the trend should reflect the distribution of actual annual deviations from trend yield for the period 1960 through 2014. The resulting distribution of likely winter wheat yields, with a mean (expected value) of 48.1 bushels, is shown in Figure 6. 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 45 bushel interval indicates there is a 7.3 percent chance of yields being more than 44 bushels and less than or equal to 45 bushels. The outcomes range from a low of 43.2 bushels to a high of 54.3 bushels, with a higher probability of a below-trend yield than an above-trend yield. The historic yield distribution suggests a 10.9 percent probability of an average yield below 44 bushels and a 12.7 percent probability of an average yield above 50 bushels. The middle 50 percent of the expected yield distribution is 46.5 to 50.5 bushels.



Implications

The U.S. average winter wheat 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 relatively small, and iv) the pattern of yield deviations following years of very large negative 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 and the functional form of the trend model. 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 a clearly acceptable alternative, we argue that a linear trend over 1960-2014 best meets this criterion. The best linear fit of actual yields in the U.S. from 1960 through 2014 results in a trend yield projection for 2015 of 48.1 bushels per acre. 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-nine chance of the U.S. average winter wheat yield falling below 44 bushels and a one-in-eight chance of yield being above 50 bushels.

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