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Forming Expectations for 2016 U.S. Average Winter and Spring Wheat Yields: What About El Niño?

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Recent weather events, including some flooding in the Mississippi Delta, frost in the Plains states, and dryness in some parts of the Great Plains have elevated the discussion about the likely magnitude of U.S. wheat production in 2016. The USDA's *Winter Wheat Seedings* report released on January 12, 2016 indicated that producers have seeded 36.609 million acres of winter wheat, 2.852 million fewer acres than seeded the previous year. Estimates of winter wheat seedings will be updated in USDA's *Prospective Plantings* report to be released on March 31 and the *Acreage* report to be released on June 30. For the most part, current expectations are that total planted acreage of all classes of wheat will be less than planted for harvest in 2015. The Grains and Oilseeds Outlook at the USDA Outlook Forum, for example, projected plantings at 51 million acres 3.6 million fewer than planted a year earlier.

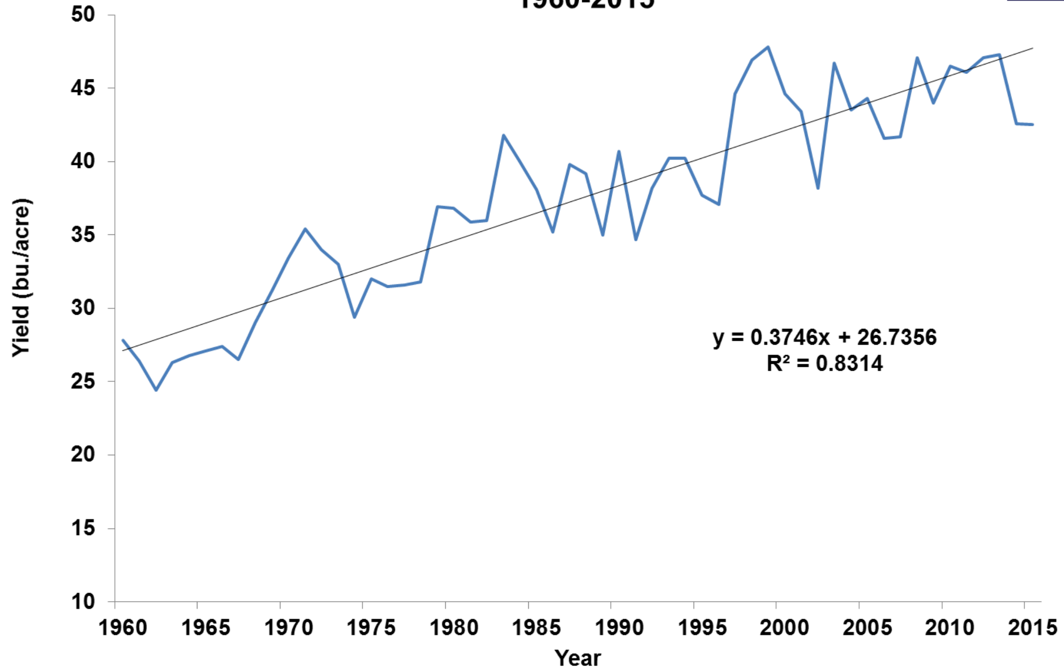
In addition to the magnitude of planted and harvested acreage, the size of the 2016 wheat crop will obviously be determined by the average yield of the various classes of wheat. Factors determining yield will unfold over the next few months. The first yield and production forecast for winter wheat will come with the USDA's May *Crop Production* report and the first forecast of spring wheat yield and production will come with the July *Crop Production* report. For the time being, yield expectations are generally based on trend yield analysis. This raises the perennial issue of what, if anything can be learned from the historical trends and patterns of U.S. average wheat 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 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 winter wheat and spring wheat (excluding durum wheat) yield trends and patterns from 1960 through 2015 as a basis for calculating trend yields for 2016 and potential deviation from trend yields. We then review wheat 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 or the potential transition status of the current El Niño episode to neutral or La Niña conditions. Similar analysis for corn and soybeans can be found in the *farmdoc daily* articles of March 2, March 9, and March 16, 2016. That analysis indicated downside yield risks for corn and soybeans in 2016 are elevated because of the strong ongoing El Niño episode.

Historical Yields and Patterns

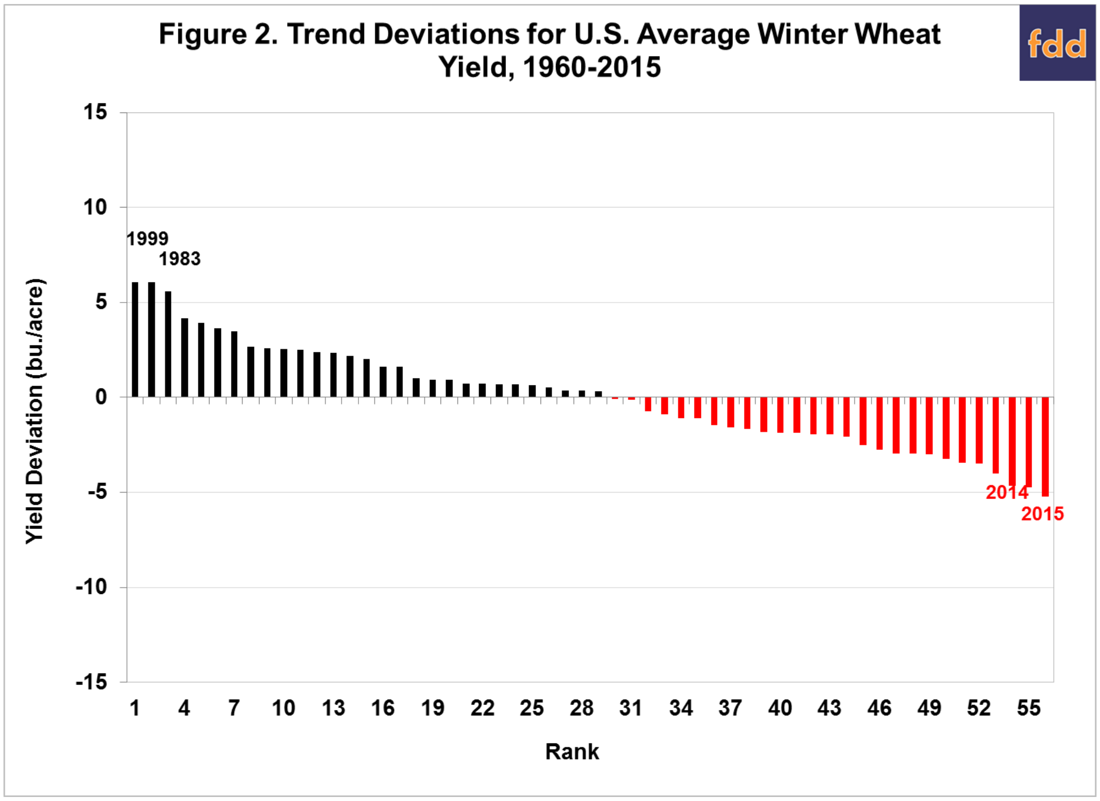
We provided a detailed analysis of historical U.S. average winter and spring wheat yields in *farmdoc daily* articles of March 26, 2015 and April 23, 2015, respectively. That analysis is not repeated, but is briefly summarized here as a starting point in forming yield expectations for 2016. It should be noted that the USDA winter wheat and spring wheat yields used here are weighted-averages of the different types of winter and spring wheat (excluding durum) grown in the U.S.

As before, we maintain that U.S. average winter and spring wheat yield expectations should be based on the longest sample of data with a stable trend yield component. We continue to argue that the period of 1960-2015 best meets this criterion. As shown in Figure 1, U.S. average winter wheat yields have trended higher since 1960. We found that a linear trend is the best fit to actual average yields over that period, explaining 83.1 percent of the variation in annual average yields. Yields have increased at a rate of 0.375 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 below the trend yield in 48 percent of the years and above the trend in 52 percent of the years. Since all deviations from a linear trend must sum to zero, this means that in the 48 percent of years with a below trend yield the deviations were, on average, slightly larger than the deviations in the 52 percent of the years when yields were above trend. The average deviation below trend was 2.3 bushels and the average deviation above trend was 2.2 bushels per acre. The largest deviation below trend was 5.2 bushels (2015) while the largest deviation above trend was 6.1 bushels (1999). The deviation below trend yield equaled or exceeded 3.0 bushels in 10 years, or 18 percent of the time, and the deviation above trend equaled or exceeded 3.0 bushels in seven years, or 13 percent of the time. In addition to showing large positive and negative deviations from trend, our previous analysis of winter wheat yields (*farmdoc daily*, March 26, 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.

Figure 1. U.S. Average Winter Wheat Yield, 1960-2015



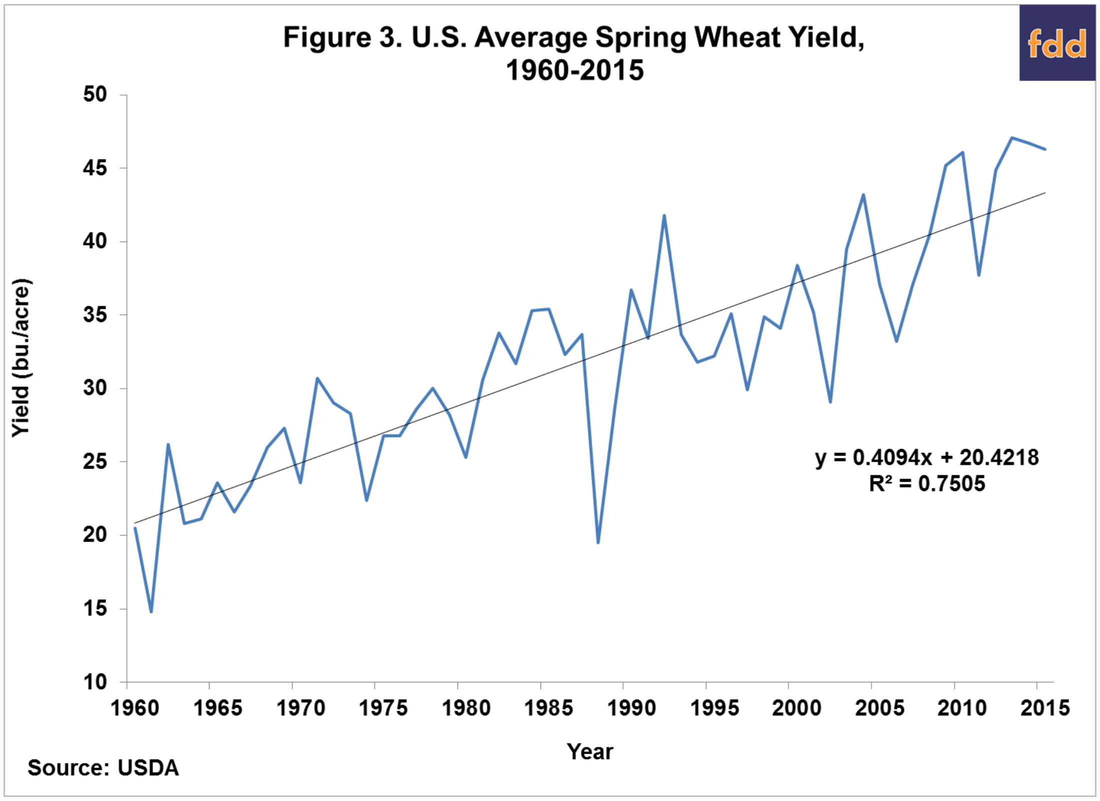
Source: USDA

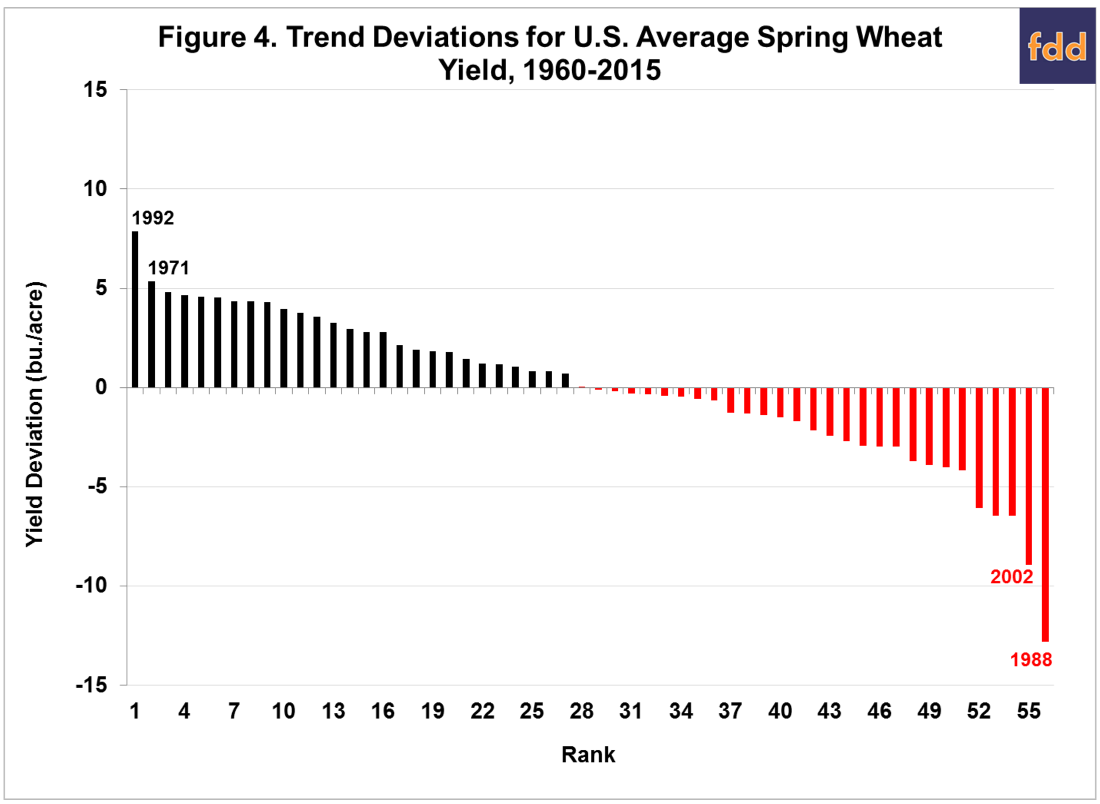


This diverse and largely random set of winter wheat yield patterns suggests that the most objective early-season yield expectation for any year, including 2016, should be based on the trend of actual yields. Figure 1 indicates that the best linear fit of actual winter wheat yields in the U.S. from 1960 through 2015 results in an "unconditional" trend calculation for 2016 of 48.1 bushels. For corn and soybean yields, 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. We used our previous research on crop weather models to adjust for the downward bias in unconditional trend yield estimates associated with the asymmetric effect of weather on yields. A similar bias adjustment is not made to the unconditional 2016 winter wheat trend yield estimate for two reasons. First, the trend deviations in winter wheat yield shown in Figure 1 do not exhibit the type of asymmetric good versus bad weather effect that is 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.

Based on historical winter wheat yield deviations from the unconditional trend, the probability of yield being below (above) the trend estimate of 48.1 bushels in 2016 is 48 (52) percent. The probability of yields being below (above) the unconditional trend by three bushels or more is about 18 (13) percent. Finally, note that in our earlier analysis of winter wheat yields (*farmdoc daily*, March 26, 2015), we indicated that there are alternative ways to view the trend. An analysis of those alternatives might result in somewhat different conclusions then those based on a linear trend over 1960-2015.

As shown in Figure 3, U.S. average spring wheat yields have trended higher since 1960. We also found that a linear trend is the best fit to actual average yields over that period, explaining 75.1 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 4. Over the 56-year period, the average yield was below the trend yield in 50 percent of the years, equal to trend two percent of the time (one year) and above the trend in 48 percent of the years. The average deviation below trend was 3.0 bushels and the average deviation above trend was 3.1 bushels per acre. The largest deviation below trend was 12.8 bushels (1988) while the largest deviation above trend was 7.9 bushels (1992). The deviation below trend yield equaled or exceeded 3.0 bushels in 12 years, or 21 percent of the time, and the deviation above trend equaled or exceeded 3.0 bushels in 14 years, or 25 percent of the time. In addition to showing large positive and negative deviations from trend, our previous analysis of spring wheat yields (*farmdoc daily*, April 23, 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 spring wheat yield expectation for any year, including 2016, should be based on the trend of actual yields. Figure 3 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 43.8 bushels. Based on historical spring wheat yield deviations from the unconditional trend, the probability of yield being below (above) trend in 2016 is 50 (48) percent. The probability of yields being below (above) the unconditional trend by three bushels or more is about 21 (25) percent. Like winter wheat, a bias adjustment is not made to the unconditional 2016 spring wheat trend yield estimate because the trend deviations in spring wheat yield do not exhibit asymmetric good versus bad weather effects and we have not developed the crop weather models for spring wheat needed to make the bias adjustment.

What About El Niño?

There is on-going discussion about the potential impact of the current El Niño episode on U.S. spring and summer weather and the resulting effect on wheat yields. The question is: Should trend yield expectations, as well as the probabilities of above or below trend yields, 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 wheat 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 here 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 centered running mean) in that central and eastern Pacific region (Niño 3.4 region) reaches 0.5 degrees Celsius above average. The strength of the El Niño is measured by the magnitude of the deviation in the three-month mean temperature from the average temperature, where average temperature is based on centered 30-year base periods updated every five years. La Niña episodes occur when the Oceanic Niño Index in Niño 3.4 region is 0.5 degrees Celsius below average, and neutral conditions occur for temperatures between 0.5 degrees Celsius above average and 0.5 degrees below average. An accessible discussion of the definitions can be found in L'Heureux (2014). Figure 5 shows the official ONI data from January 1960 through January 2016. 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 2.2 degrees Celsius in the three months ending February 2016.

Since our interest is in "strong" El Niño episodes that precede or occur during the U.S. wheat growing season, like the present one, we first consider episodes that occur in the 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 degree Celsius. The 12 El Niño episodes that meet these two criteria are labeled in Figure 5. 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.

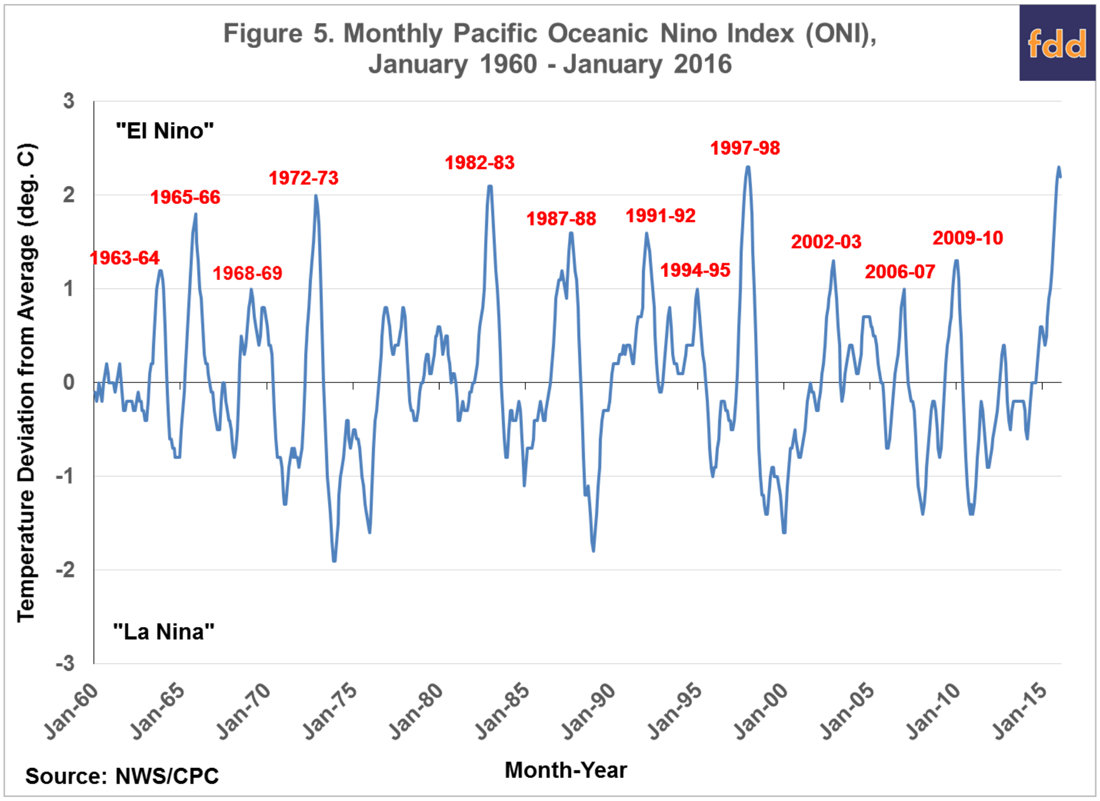


Table 1 presents more detail on the conditions during each of the 12 previous El Niño episodes that meet our definition of strong, and the trend deviation for the average U.S. winter and spring wheat yields in the second year of each pair. Specifically, for each of those episodes, we show the peak temperature anomaly (ranked from lowest to highest), the month of the peak anomaly, the crop year following the peak anomaly, and the yield deviations 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 degree Celsius, at least 1.5 degrees Celsius, and at least 2 degrees Celsius. The pattern of U.S. average wheat yields in years following such strong El Niño episodes indicates:

1. The average winter yield in those years was 0.7 to 4.2 bushels above trend, depending on how the years are grouped by strength of the El Niño. The average spring yield in those years was 0.8 bushels below trend to 0.7 bushels above trend, depending on how the years are grouped by strength of the El Niño.

2. Winter wheat yields ranged from 3.0 bushels below trend to 6.1 bushels above trend and spring wheat yields ranged from 12.8 bushels below trend to 7.9 bushels above trend.

3. The average winter yield was below trend 42 percent of the time (five years), compared to the 1960-2015 unconditional average of 48 percent. The yield was three bushels or more below trend eight percent of the time (one year), compared to the 1960-2015 unconditional average of 18 percent. The average spring wheat yield was below trend 50 percent of the time (six years), equal to the 1960-2015 unconditional average. The yield was three bushels or more below trend 25 percent of the time (three years), compared to the 1960-2015 unconditional average of 21 percent.

4. Of the 10 (12) years since 1960 that the U.S average winter (spring) yield was at least three bushels below trend, one (three) followed a strong El Niño episode.

5. The average winter (spring) yield was equal to or above trend 58 (50) percent of the time compared to the 1960-2015 unconditional average of 52 (48) percent. The winter (spring) yield was three bushels or more above trend 25 (17) percent of the time compared to the 1960-2015 unconditional average of 13 (25) percent.

6. Of the seven (14) years since 1960 when the average winter (spring) wheat yield was at least three bushels above trend, three (two) followed a strong El Niño episode.

7. In the three years with a peak temperature anomaly of at least 2 degrees Celsius, winter wheat yields exceeded trend in all three years by an average of 4.2 bushels. In the same years, spring wheat yields exceeded trend in two years by an average of 1.8 bushels and was below trend in one year by 1.5 bushels. This analysis suggests, in conditional terms, that the current strong El Niño episode points to a 2016 winter wheat yield above trend, possibly well-above, and a two-thirds chance of the average spring wheat yield to be modestly above trend and a one-third chance of being modestly below trend.

Table 1. Major El Niño Episodes During the Preseason Period (September-March) and Trend Yield Deviations for U.S. Winter and Spring Wheat, 1960-2015

Episode	Peak Temperature Anomaly (deg. C)	Month of Peak	Crop Year	Winter Wheat Yield Deviation from Trend (bu./ac.)	Spring Wheat Yield Deviation from Trend (bu./ac.)
1968-69	1.0	Feb-69	1969	0.7	2.8
1994-95	1.0	Dec-94	1995	-2.5	-3.0
2006-07	1.0	Dec-06	2007	-3.0	-3.0
1963-64	1.2	Nov-63	1964	-1.8	-1.4
2002-03	1.3	Nov-02	2003	3.5	1.1
2009-10	1.3	Jan-10	2010	0.7	4.8
1987-88	1.6	Sep-87	1988	1.6	-12.8
1991-92	1.6	Jan-92	1992	-0.9	7.9
1965-66	1.8	Nov-65	1966	-2.0	-1.7
1972-73	2.0	Nov-72	1973	1.0	2.1
1982-83	2.1	Jan-83	1983	6.1	1.5
1997-98	2.3	Dec-97	1998	5.6	-1.5
Average trend deviation:					
Peak temperature ≥ 1.0				0.7	-0.3
Peak temperature ≥ 1.5				1.9	-0.8
Peak temperature ≥ 2.0				4.2	0.7
2015-16	2.3	Dec-15	2016	?	?

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

The previous analysis and conclusions did not consider the pattern of the transition of the El Niño episodes, which we recently examined for corn and soybeans in the *farmdoc daily* article of March 16, 2016. To determine if winter and spring wheat yield expectations are influenced by the nature of the transition of the El Niño episode, we parse the historical observations according to the status of the episode (remaining in El Niño, neutral conditions, or La Niña conditions) for the four months of May, June, July, August, and September in the second year of the episode. We included months following the normal harvest period for winter wheat in order to depict the speed of the transition of the El Niño episode. Those observations are summarized in Appendix Tables 1 through 4, with each table associated with the status of the episode by May, June, July, August in the second year of the pair of years for each of the strong El Niño episodes. For each of those ending months, the data in the tables include: the twelve years of the El Niño episodes divided according to ending status, the strength of the El Niño (peak temperature anomaly), the month of the peak anomaly, the magnitude of the anomaly in the ending month, the crop year, and both the winter and spring wheat yield deviation from trend in that crop year. We do not further divide the observations by strength of the El Niño episode, but consider all strong episodes with a peak temperature anomaly of at least 1 degree Celsius. Finally, it is important to remember that we start with a total of only twelve observations, so parsing the data as we do by transition status will result in a small number of years in one or more of the transition categories. This suggests treating the resulting estimates of yield performance in each category with some degree of caution. Those results are summarized in Table 2. The following observations can be made based on this summary of results for winter wheat:

1. The existence of El Niño conditions in May, June, July, or August was associated with an average yield below trend (0.9 bushels) in only one year.

2. Half of the 12 years experienced neutral conditions in May, June, and July and one-third of the years experienced neutral conditions in August. Half of those neutral years had an average yield below trend, compared to the 1960-2015 unconditional average of 48 percent. On average, yields were within 0.5 bushels of trend, except when neutral conditions were experienced in August and the average yield was 1.7 bushels above trend.

3. La Niña conditions were experienced in only two years for May and three years for June. However, La Niña conditions were experienced in five years in July and seven years in August. Yields were below trend in one year in each instance, except for August when yields were below trend in three years. On average, yields were within 0.3 bushels of trend, except when La Niña conditions were experienced in July and the average yield was 1.4 bushels above trend.

Table 2. Major El Niño Episodes During the Preseason Period (September-March), Transition Status by Spring/Summer of the Second Year, and U.S. Trend Yield Deviations for Winter and Spring Wheat, 1960-2015

	By May			By June			By July			By August		
Crop/ Transition	Total # of Years	# of Years Below Trend	Average Trend Yield Deviation (bu./ac.)	Total # of Years	# of Years Below Trend	Average Trend Yield Deviation (bu./ac.)	Total # of Years	# of Years Below Trend	Average Trend Yield Deviation (bu./ac.)	Total # of Years	# of Years Below Trend	Average Trend Yield Deviation (bu./ac.)
Winter Wheat:												
Continued as El Niño	4	1	2.9	3	1	2.0	1	1	-0.9	1	0	0.7
Transition to Neutral	6	3	-0.4	6	3	0.4	6	3	0.5	4	2	1.7
Transition to La Niña	2	1	-0.1	3	1	0.3	5	1	1.4	7	3	0.2
Spring Wheat:												
Continued as El Niño	4	1	2.7	3	0	4.0	1	0	7.9	1	0	2.8
Transition to Neutral	6	3	0.1	6	4	-0.5	6	3	-0.4	4	1	2.2
Transition to La Niña	2	2	-7.1	3	2	-4.0	5	3	-1.7	7	5	-2.1

In the case of spring wheat:

1. The existence of El Niño conditions in May, June, July, or August was associated with an average yield below trend (1.5 bushels) in only one year.

2. Half of the years with neutral conditions in May and July had yields below trend value, while two-thirds of the years with neutral conditions in June had yields below trend. On the other hand, only 25 percent of the years (one) with neutral conditions in August had a yield below trend. On average, yields were within 0.5 bushels of trend, except when neutral conditions were experienced in August and the average yield was 2.2 bushels above trend.

3. Yields were below trend in both years that La Niña conditions were experienced in May, two-thirds of the years when La Niña conditions were experienced in June, sixty percent of the years when La Niña conditions were experienced in July, and 71 percent of the years when La Niña conditions were experienced in August. The average deviation below trend ranged from 7.1 bushels in May to 1.7 bushels in July.

Implications

With current U.S. and world wheat supplies in surplus, the size of the 2016 U.S crop will be of some importance in determining the direction of wheat prices over the next year or more. Even with planted acreage declining to 51 million acres, as suggested by USDA analysts, and average yields near our calculated trend value of 48.1 bushels per acre for winter wheat and 43.8 bushels for spring wheat would result in a crop (all classes) near 2 billion bushels, large enough to keep wheat 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 winter and spring 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, but it does provide some intriguing clues about yield prospects. In particular, the three years with a peak temperature anomaly of at least 2 degrees Celsius, similar to the current episode, were associated with winter wheat yields exceeding trend in all three years by an average of 4.2 bushels. In the same years, spring wheat yields exceeded trend in two years by an average of 1.8 bushels and were below trend in one year by 1.5 bushels. This suggests that the current strong El Niño episode points to a 2016 winter wheat yield above trend, possibly well-above, and a two-thirds chance of the average spring wheat yield to be modestly above trend. Conversely, there may be elevated risk of below trend yields for spring wheat if the current El Niño episode transitions to La Niña conditions by late spring or summer. For example, spring wheat yields were below trend in both years with large El Niño episodes that transitioned to La Niña conditions by May and the average deviation below trend was 7.1 bushels. The average spring wheat yield was also below trend for the other transition months considered. Since the current El Niño episode is fading fairly rapidly, whether and when it transitions fully to La Niña conditions may have an important impact on spring wheat yield expectations for 2016.

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Table A1. Major El Niño Episodes During the Preseason Period (September-March), Transition Status by May of the Second Year, and U.S. Trend Yield Deviations for Winter and Spring Wheat, 1960-2015

Episode	Peak Temperature Anomaly (deg. C)	Month of Peak	May Temperature Anomaly (deg. C)	Crop Year	Winter Wheat Yield Deviation from Trend (bu./ac.)	Spring Wheat Yield Deviation from Trend (bu./ac.)
Continued as El Niño:						
1991-92	1.6	Jan-92	1.0	1992	-0.9	7.9
1982-83	2.1	Jan-83	1.0	1983	6.1	1.5
1968-69	1.0	Feb-69	0.6	1969	0.7	2.8
1997-98	2.3	Dec-97	0.5	1998	5.6	-1.5
Transition to Neutral:						
1965-66	1.8	Nov-65	0.3	1966	-2.0	-1.7
1994-95	1.0	Dec-94	0.2	1995	-2.5	-3.0
2009-10	1.3	Jan-10	0.0	2010	0.7	4.8
2006-07	1.0	Dec-06	-0.2	2007	-3.0	-3.0
2002-03	1.3	Nov-02	-0.2	2003	3.5	1.1
1972-73	2.0	Nov-72	-0.4	1973	1.0	2.1
Transition to La Niña:						
1963-64	1.2	Nov-63	-0.6	1964	-1.8	-1.4
1987-88	1.6	Sep-87	-0.8	1988	1.6	-12.8
Average Trend Deviation:						
All Years					0.7	-0.3
Continued as El Niño (4 yrs.)					2.9	2.7
Transition to Neutral (6 yrs.)					-0.4	0.1
Transition to La Niña (2 yrs.)					-0.1	-7.1
2015-16	2.3	Dec-15	?	2016	?	?

Note:Temperature anomalies are reported as deviation from average temperature.

Table A2. Major El Niño Episodes During the Preseason Period (September-March), Transition Status by June of the Second Year, and U.S. Trend Yield Deviations for Winter and Spring Wheat, 1960-2015

Episode	Peak Temperature Anomaly (deg. C)	Month of Peak	June Temperature Anomaly (deg. C)	Crop Year	Winter Wheat Yield Deviation from Trend (bu./ac.)	Spring Wheat Yield Deviation from Trend (bu./ac.)
Continued as El Niño:						
1991-92	1.6	Jan-92	0.8	1992	-0.9	7.9
1982-83	2.1	Jan-83	0.7	1983	6.1	1.5
1968-69	1.0	Feb-69	0.5	1969	0.7	2.8
Transition to Neutral:						
1965-66	1.8	Nov-65	0.2	1966	-2.0	-1.7
1994-95	1.0	Dec-94	0.0	1995	-2.5	-3.0
1997-98	2.3	Dec-97	-0.1	1998	5.6	-1.5
2002-03	1.3	Nov-02	-0.1	2003	3.5	1.1
2006-07	1.0	Dec-06	-0.2	2007	-3.0	-3.0
2009-10	1.3	Jan-10	-0.4	2010	0.7	4.8
Transition to La Niña:						
1963-64	1.2	Nov-63	-0.6	1964	-1.8	-1.4
1972-73	2.0	Nov-72	-0.8	1973	1.0	2.1
1987-88	1.6	Sep-87	-1.2	1988	1.6	-12.8
Average Trend Deviation:						
All Years					0.7	-0.3
Continued as El Niño (3 yrs.)					2.0	4.0
Transition to Neutral (6 yrs.)					0.4	-0.5
Transition to La Niña (3 yrs.)					0.3	-4.0
2015-16	2.3	Dec-15	?	2016	?	?

Note:Temperature anomalies are reported as deviation from average temperature.

Table A3. Major El Niño Episodes During the Preseason Period (September-March), Transition Status by July of the Second Year, and U.S. Trend Yield Deviations for Winter and Spring Wheat, 1960-2015

Episode	Peak Temperature Anomaly (deg. C)	Month of Peak	July Temperature Anomaly (deg. C)	Crop Year	Winter Wheat Yield Deviation from Trend (bu./ac.)	Spring Wheat Yield Deviation from Trend (bu./ac.)
Continued as El Niño:						
1991-92	1.6	Jan-92	0.5	1992	-0.9	7.9
Transition to Neutral:						
1968-69	1.0	Feb-69	0.4	1969	0.7	2.8
1982-83	2.1	Jan-83	0.3	1983	6.1	1.5
1965-66	1.8	Nov-65	0.2	1966	-2.0	-1.7
2002-03	1.3	Nov-02	0.1	2003	3.5	1.1
1994-95	1.0	Dec-94	-0.2	1995	-2.5	-3.0
2006-07	1.0	Dec-06	-0.3	2007	-3.0	-3.0
Transition to La Niña:						
1963-64	1.2	Nov-63	-0.7	1964	-1.8	-1.4
1997-98	2.3	Dec-97	-0.7	1998	5.6	-1.5
2009-10	1.3	Jan-10	-0.8	2010	0.7	4.8
1972-73	2.0	Nov-72	-1.0	1973	1.0	2.1
1987-88	1.6	Sep-87	-1.2	1988	1.6	-12.8
Average Trend Deviation:						
All Years					0.7	-0.3
Continued as El Niño (1 yr.)					-0.9	7.9
Transition to Neutral (6 yrs.)					0.5	-0.4
Transition to La Niña (5 yrs.)					1.4	-1.7
2015-16	2.3	Dec-15	?	2016	?	?

Note:Temperature anomalies are reported as deviation from average temperature.

Table A4. Major El Niño Episodes During the Preseason Period (September-March), Transition Status by August of the Second Year, and U.S. Trend Yield Deviations for Winter and Spring Wheat, 1960-2015

Episode	Peak Temperature Anomaly (deg. C)	Month of Peak	August Temperature Anomaly (deg. C)	Crop Year	Winter Wheat Yield Deviation from Trend (bu./ac.)	Spring Wheat Yield Deviation from Trend (bu./ac.)
Continued as El Niño:						
1968-69	1.0	Feb-69	0.5	1969	0.7	2.8
Transition to Neutral:						
1991-92	1.6	Jan-92	0.2	1992	-0.9	7.9
2002-03	1.3	Nov-02	0.2	2003	3.5	1.1
1965-66	1.8	Nov-65	0.1	1966	-2.0	-1.7
1982-83	2.1	Jan-83	0.0	1983	6.1	1.5
Transition to La Niña:						
1994-95	1.0	Dec-94	-0.5	1995	-2.5	-3.0
2006-07	1.0	Dec-06	-0.6	2007	-3.0	-3.0
1963-64	1.2	Nov-63	-0.7	1964	-1.8	-1.4
1997-98	2.3	Dec-97	-1.0	1998	5.6	-1.5
1987-88	1.6	Sep-87	-1.1	1988	1.6	-12.8
2009-10	1.3	Jan-10	-1.1	2010	0.7	4.8
1972-73	2.0	Nov-72	-1.2	1973	1.0	2.1
Average Trend Deviation:						
All Years					0.7	-0.3
Continued as El Niño (1 yr.)					0.7	2.8
Transition to Neutral (4 yrs.)					1.7	2.2
Transition to La Niña (7 yrs.)					0.2	-2.1
2015-16	2.3	Dec-15	?	2016	?	?

Note:Temperature anomalies are reported as deviation from average temperature.