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What’s Driving the Non-Linear Trend in U.S. Average Soybean Yields?

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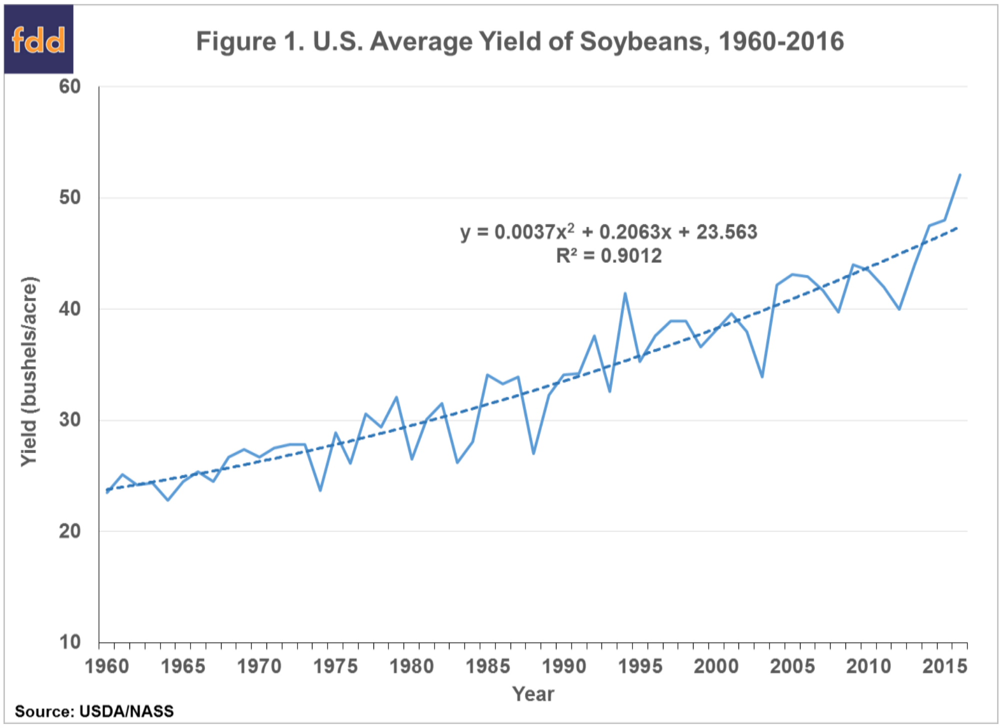
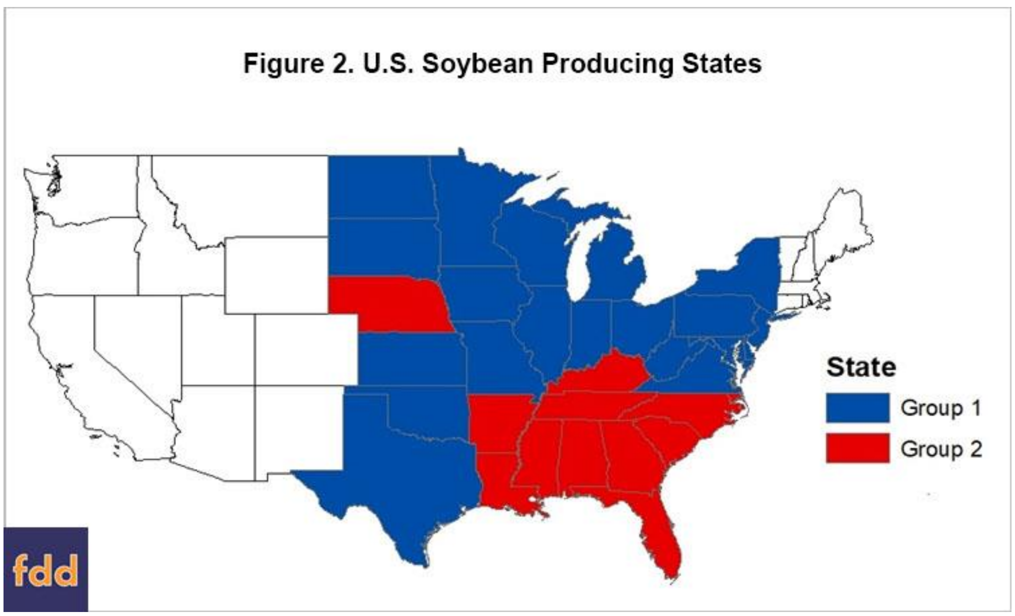
In the *farmdoc daily* articles of April 19, 2017 and May 3, 2017 we began to address the potential reasons behind the observation that U.S. average soybean yields in 2014, 2015, and especially 2016, were well above the long-term linear trend values for those years. We found that yields appear to have actually increased at an increasing rate over the last several years rather than at a constant rate in bushel terms (Figure 1). In other words, a quadratic equation provides a moderately better fit to U.S. average yields from 1960 through 2016 than does a linear equation. We also found there is an interesting spatial pattern in trends across states and by production practices. It turns out that a linear trend is still the best fit to actual yields for many states in the U.S. However, a quadratic trend provides a better fit than a linear trend for a number of states, particularly in the Southeastern portion of the U.S. and in Nebraska. We also find that yields on irrigated production have been increasing at a faster rate than for non-irrigated production. The purpose of today’s article is to directly examine whether the non-linearity in U.S. average trend yield for soybeans is driven by trends in the Southeast, Nebraska, and irrigated production.

Analysis

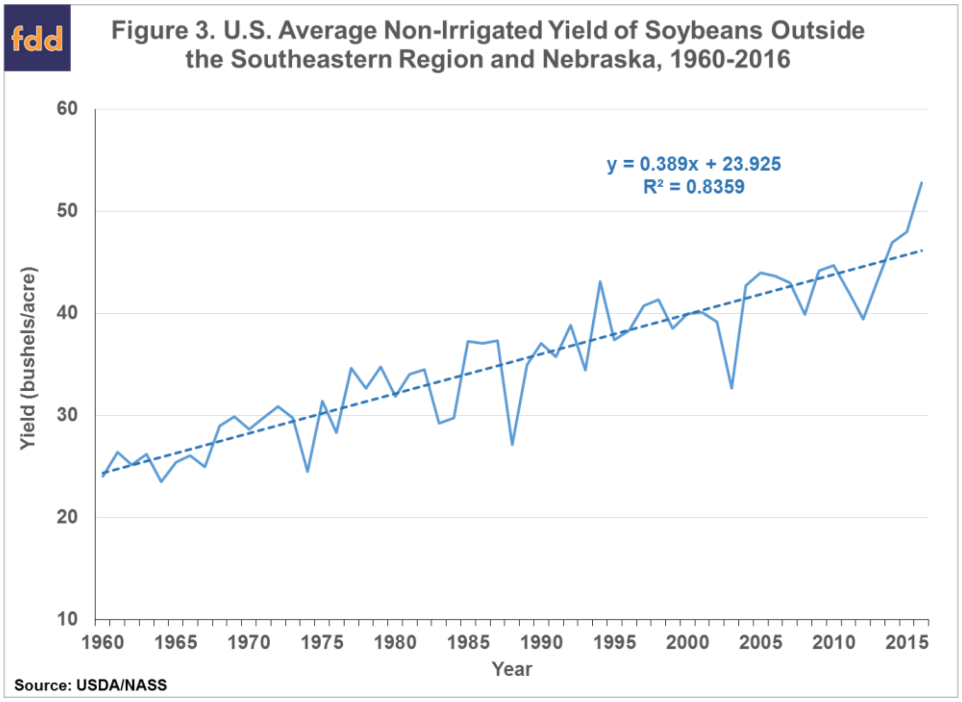
Based on our previous analysis (*farmdoc daily*, April 19, 2017; May 3, 2017), we divide the U.S. soybean production area into two groups: i) non-irrigated production outside of the Southeastern U.S. and Nebraska; and ii) non-irrigated and irrigated production in the Southeastern U.S. and Nebraska. Note that we ignore the small amount of irrigated production outside of the Southeast and Nebraska in the first group of states. Figure 2 provides a map of the U.S. with the assumed groupings. Our hypothesis is that the non-linearity in U.S average trend yields is driven by non-linearity in trend yields in the second group.

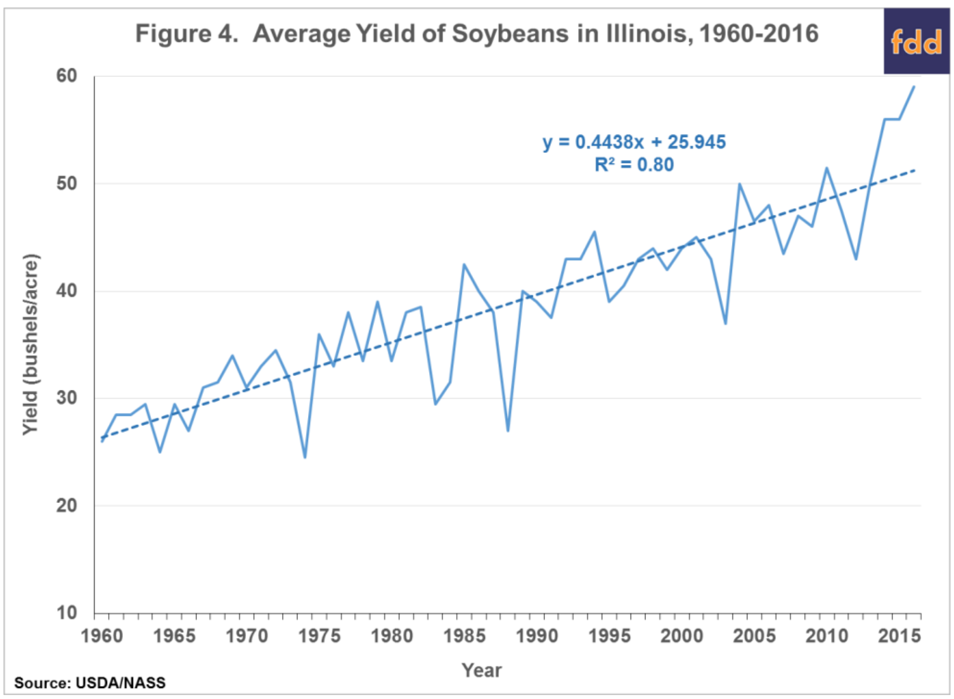
We start with an examination of the soybean yield trend for the first group of states that include all non-irrigated production in U.S states excluding the Southeastern region and Nebraska. Annual average yields for that production group for the period 1960 through 2016 are presented in Figure 3. A linear trend provides the best fit of those yields, with the trend explaining 84 percent of the variation in annual yields over the 57-year period. We also fit a quadratic trend regression to the yields in Figure 3 and find that the quadratic term is statistically insignificant. On average, yields have increased at a rate of 0.39 bushels per acre per year. Yields have occasionally been well-above and well-below the linear trend values, with 2012 and 2016 being the most recent examples. While 2016 is indeed the largest deviation above-trend in this sample period, it is only about a bushel larger than the next highest in 1994. Also, the absolute magnitude of the negative deviations in 1988 and 2003 were even larger than the magnitude of the 2016 deviation, which shows that deviations of the 2016 magnitude are not entirely unprecedented.



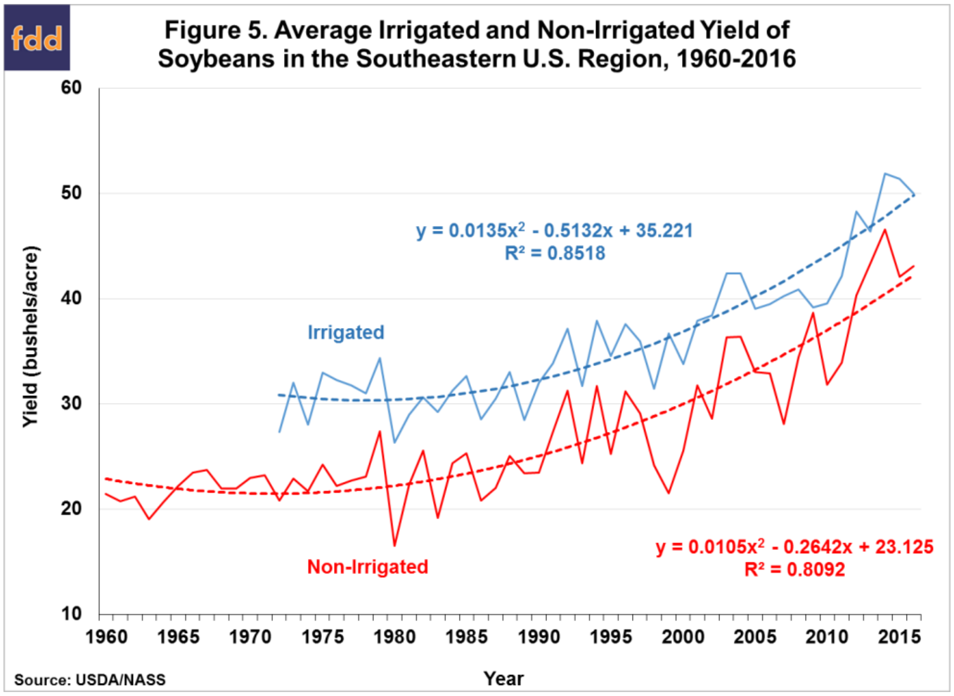


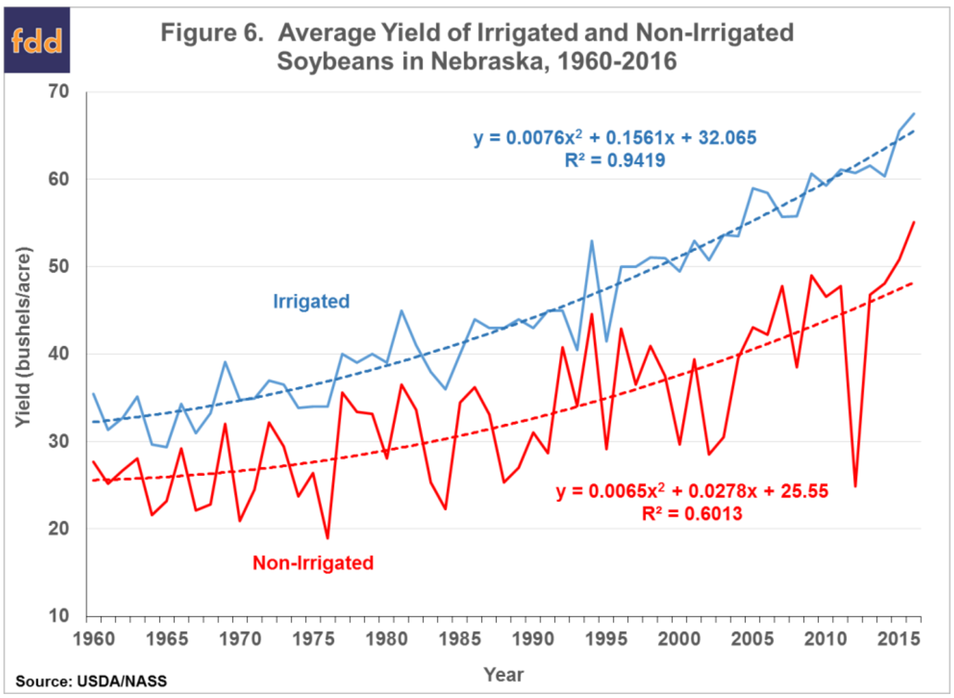
As would be expected, the yield pattern for individual states that are major producers has been similar to patterns for production in the first group of states. Yields in Illinois, as an example, are presented in Figure 4. A linear trend is the best fit for those yields with the trend explaining 80 percent of the variation in annual yields over the 57-year period. We fit a quadratic trend regression to the yields in Figure 4 and again find that the quadratic term is statistically insignificant. On average, Illinois yields have been higher than the average yield for the region and have increased at a slightly higher rate of 0.44 bushels per acre per year. Illinois experienced exceptionally good yields in 2014, 2015, and 2016; a degree of good fortune not experienced even in neighboring states (*farmdoc daily*, May 2, 2017).





We next examine the soybean yield trend for the second group that includes non-irrigated and irrigated production in the Southeastern region and Nebraska over the same 57-year period. Note that irrigated production in the Southeast as reported by NASS is limited to Arkansas. As shown in Figure 5, a quadratic trend provides the best fit for Southeastern region yields, with the trend explaining 81 percent of the variation in average non-irrigated yields over the period and 85 percent of the irrigated yields. The quadratic term is statistically significant in explaining the pattern of yields in both cases, which indicates that the non-linear curvature of the trend regressions is unlikely to be due to random chance. Figure 6 shows non-irrigated and irrigated yields for Nebraska, and, once again, a quadratic trend provides the best fit, with the trend explaining 60 percent of the variation in average non-irrigated yields over the period and 94 percent of the irrigated yields. The quadratic term is statistically significant in both cases. The increase in non-irrigated yields in Nebraska since 2014 is truly impressive.





The analysis reveals that the trend of soybean yields increasing at an increasing rate in Southeastern states and Nebraska in recent years, then, is not just the result of yield increases for irrigated production, but for non-irrigated production as well. While irrigated yields are higher than non-irrigated yields, the pattern of yields for non-irrigated production in the Southeast region and Nebraska has been surprisingly similar to the pattern of yields for irrigated production. This is important because it means that non-linearity of trend yields in these areas is not driven by something unique to irrigated production, but rather, some factor common to both production systems in the Southeast and Nebraska.

It should now be clear that soybean yields have been increasing at an increasing rate for both non-irrigated and irrigated production in the Southeast and Nebraska. The question is whether that growth is sufficient to explain the increasing rate of growth in overall U.S. average soybean yields. Figure 7 provides the answer. This chart shows the average yields for the two groups of U.S. soybean production states. The yields and linear trend for non-irrigated production in states outside of the Southeast and Nebraska is the same as that presented earlier in Figure 3. The yields and quadratic trend for non-irrigated and irrigated production in the Southeast and Nebraska represent the acre-weighted average of the data presented in Figures 5 and 6. The catchup of the Southeast and Nebraska with the rest of U.S. producing states is striking. In fact, the trend yield in the Southeast and Nebraska now exceeds that of the rest of the country. Since the national average yield of soybeans in the U.S. is approximately equal to an acre-weighted average of the yields for the two groups, the fact that trend growth is linear outside of the Southeast and Nebraska means that the quadratic growth in the Southeast and Nebraska must be driving the non-linearity in overall U.S. average trend yields. Further perspective is provided by Figure 8, which shows the share of harvested soybean acreage in the Southeast and Nebraska. While the combined harvested acreage in those two areas declined from about 35 percent of the total U.S. acreage in the late 1970's and early 1980's to only about 15 percent in the early 2000's, it has recently increased to near 20 percent. This magnitude of acreage is sufficient to shift the U.S. yield trend from linear to moderately quadratic.

Figure 7. U.S. Average Non-Irrigated Yield of Soybeans Outside of Southeastern Region and Nebraska versus Non-Irrigated Yield in the Southeast Plus Nebraska, 1960-2016

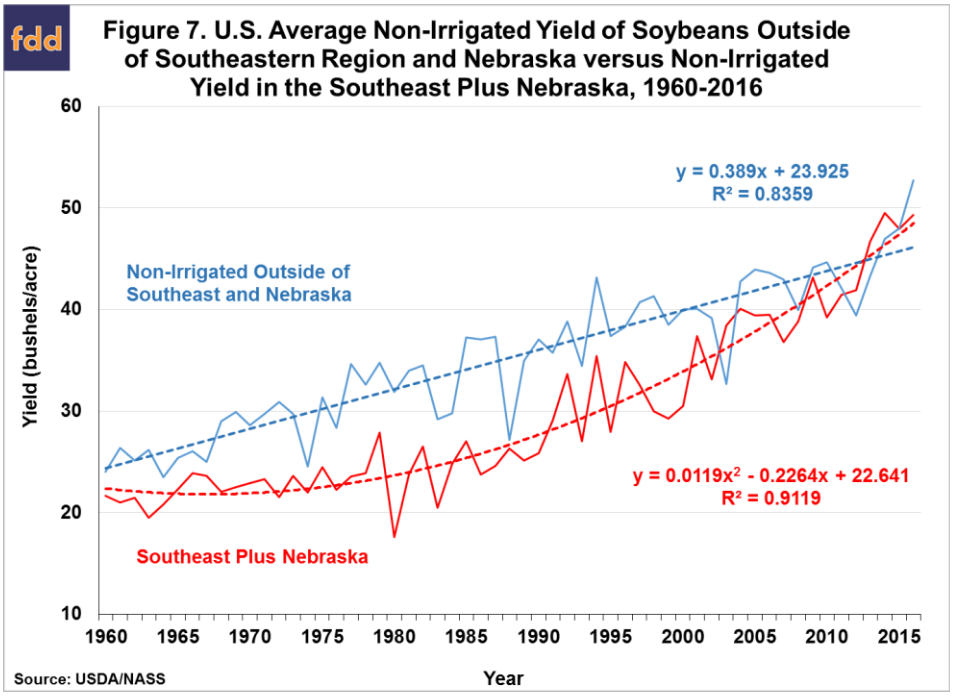
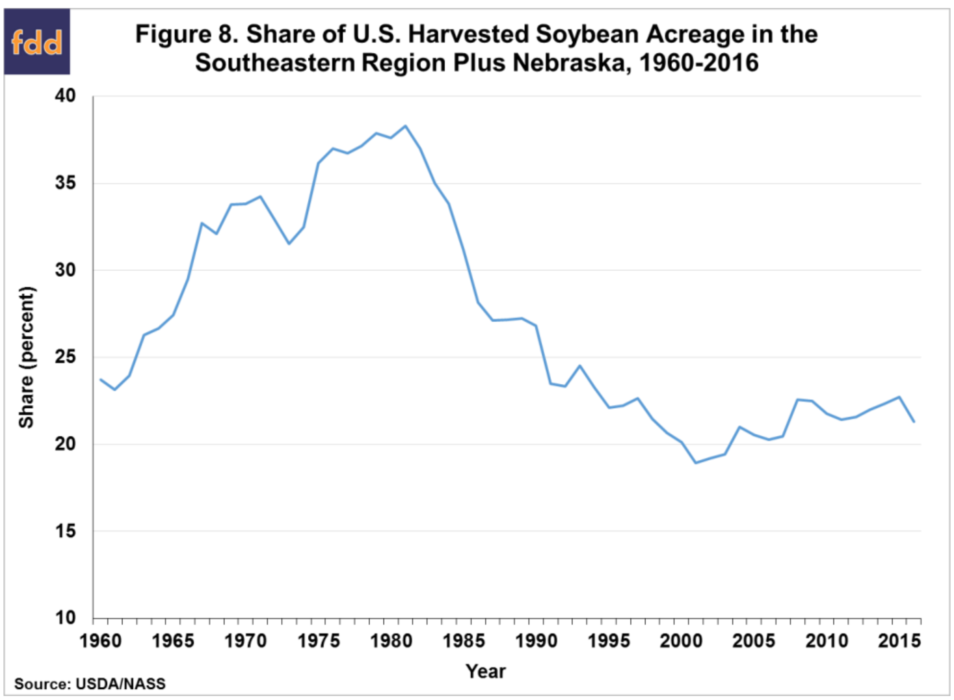
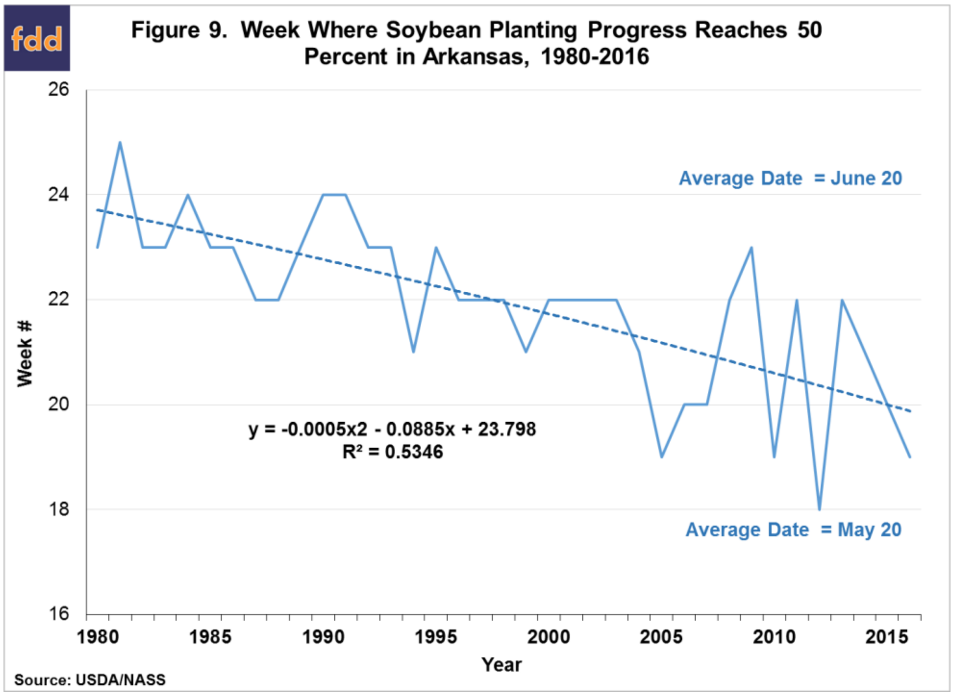


Figure 8. Share of U.S. Harvested Soybean Acreage in the Southeastern Region Plus Nebraska, 1960-2016



The next obvious question is why soybean yields have been growing at a more rapid rate in the Southeast and Nebraska than in the rest of the country in recent years. We have identified a few possible explanations for the more rapid increase in yields in the Southeast, but not in Nebraska. These explanations fall in the realm of production or management practices rather than in the realm of technological developments ("new seeds"). First, there has been a trend toward earlier planting of the soybean crop in the Southeast region. That trend is illustrated in Figure 9, which indicates the calendar week in which soybean planting progress in Arkansas exceeded 50 percent, as reported in the USDA's weekly *Crop Progress* report, for the period 1980 through 2016. There has been a clear trend towards planting reaching the halfway point earlier in the year, from around week 23 in the early 1980's to week 20 in the past decade. On average, planting has exceeded the 50 percent mark 0.1 week earlier per year since 1980. The earlier planting dates in the Southeast also appear to be associated with fewer acres of soybeans planted following another crop in the Southeast (at least in recent years), as reported by USDA (see page 16 of the USDA's June 2016 Acreage report). Early planting of the soybean crop implies that a smaller percentage of the crop is planted late after the window for optimum yields.



A second production practice thought to contribute to higher yields in the Southeast is the trend towards planting earlier maturing varieties. Early maturing varieties offer two potential yield-enhancing benefits. Those varieties tend to mature before the onset of the hot, dry weather in late summer and those varieties have benefited from breeding. We are not able to document the exact timeline and extent of adoption of early maturing varieties in the Southeast, but this factor is commonly cited as enhancing yield potential improvements (e.g., Nafziger, p. 28).

A third factor sometimes cited that has increased soybean yields in the Southeast in recent years is reduced cotton acreage that has allowed more soybeans to be planted on highly productive soils. While that factor is difficult to verify or quantify, cotton acreage in the Southeast did decline substantially from 2006 through 2016.

Implications

There is a sharp difference in the pattern of soybean yield trends for different parts of the U.S. Non-irrigated production in states outside of the Southeast and Nebraska maintain a linear trend that has long been the best fit for overall U.S. soybean yields. Non-irrigated and irrigated production in the Southeast and Nebraska have a sharply quadratic trend, which means that trend yields in these areas have been increasing at an increasing rate. This has two important implications. First, since the national average yield of soybeans in the U.S. is approximately equal to an acre-weighted average of the yields for the two groups of states, the fact that trend growth is linear in the first group means that the quadratic growth in the second group (Southeast and Nebraska) must be driving the non-linearity in overall U.S. average trend yields. Second, since a linear trend is still the best fit for yields in much of the country, it follows that there has been no newly adopted technological development ("new seeds") that has contributed to an increasing rate of yield growth in the U.S. Instead, the yield growth, at least in the Southeast, appears to be associated with production practices, particularly the trend towards early planting and the use of earlies maturing varieties. It is not clear why yield trend growth in Nebraska has been outpacing neighboring states.

In sum, the higher rate of recent growth in U.S. soybean trend yields is explained by yield growth in the Southeast and Nebraska. Still the exceptionally high U.S. average yield in 2016 was well above the quadratic trend value (similar to that of 1994). That large positive yield deviation provides additional uncertainty in anticipating yields this year. In addition, it is not prudent to expect the rapid growth in average yields in the Southeast and Nebraska relative to the rest of the country to continue indefinitely. That is, we would not expect average yield in the Southeast to catch up to the higher average in Illinois, for example. It is more likely that the rate of yield increases in the Southeast and Nebraska will moderate if those increases have in fact been associated with changes in production practices. If this happens, the recent non-linearity in overall U.S. average soybean trend yields will diminish.

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