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Is the Trend Rate of Growth in the U.S. Average Corn Yield Slowing?

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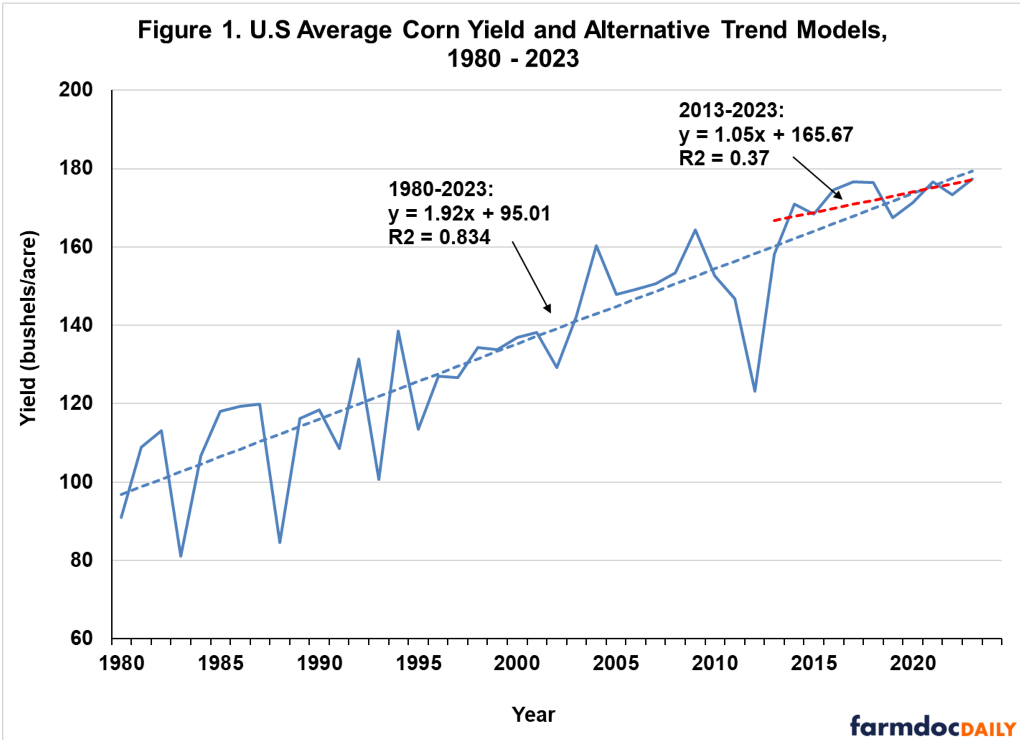
Projecting the size of the U.S. corn crop depends on two components—harvested acreage and yield per acre. The USDA Prospective Planting report released near the end of March provides a starting point in making this important projection. The report showed that U.S. farmers intend to plant 90 million acres of corn during the 2024 planting season. Combined with an estimate of the difference between planted and harvested acreage, this can be used to project harvested acreage. Yield is then the only remaining component needed to project crop size. Given the difficulty of forecasting summer weather conditions so far in advance, a simple "trend" projection is typically used at this point in the season. Despite the seeming simplicity of making a trend projection, there is always debate about the best way of going about it. Currently, there is more than the usual amount of debate because U.S. average corn yields have moved in a fairly narrow range for more than a decade. Some argue that the growth of trend corn yield in the U.S. has slowed considerably since 2013 (Boussios, 2024), while others caution about projecting trend yields from a small sample of years (*farmdoc daily*, April 16, 2024). The purpose of this article is to use a crop weather model of the U.S. average yield of corn to formally test whether the trend rate of growth in the U.S. average corn yield has slowed in recent years.

Analysis

We begin by reviewing the history of U.S. corn yields over 1980 through 2023 in Figure 1. The dashed blue line is the estimated trend line using all the observations over this time period. The trend coefficient is 1.92, which indicates that, on average, the U.S. average corn yield trnds to increase slightly less than two bushels per year. The red dashed line uses only the observations for 2013 through 2023 to estimate trend, and the slope of this line is much flatter, around one bushel per year. Projecting the lines forward a year in the future results in trend yield estimates for 2024 of 181.3 bushels per acre using the entire 1980 through 2023 sample and 178.2 bushels using the smaller 2013 through 2023 sample. The 3.1-bushel difference in trend yield projections is not large, but one can easily see that it would not take very many more years for the difference to become pronounced.



There is not enough information in Figure 1 to determine which of the two lines to use in projecting trend yield for 2024. The reason is that weather is not considered, and variation in weather is the dominant factor driving corn yields from year-to-year (*farmdoc daily*, October 9, 2023). For example, it is possible that what appears to be a slowing of the rate of growth in the U.S. average corn yield since 2013 is in fact simply a run of less than stellar growing season weather. This issue is not new and has been debated and analyzed for many years (e.g., Thompson, 1975; Tannura, Irwin, and Good, 2008).

To disentangle trend changes from weather impacts, a model is needed that considers both factors simultaneously. Fortunately, this type of crop weather model was developed and presented in several recent *farmdoc daily* articles (October 9, 2023; April 8, 2024; April 29, 2024). The "Thompson-style" regression model used in these articles relates the U.S. average corn yield to a time trend, the percentage of the crop planted late, and an array of weather variables. The updated version of the model estimated here uses data from 1980 through 2023 and includes the following explanatory variables: i) a linear time trend variable to represent technological change, ii) the percentage of the corn crop planted late, iii) linear functions of preseason (September-March) and April precipitation, iv) quadratic functions of June, July, and August precipitation, and v) linear functions of April, May, June, July, and August temperatures. The late planting variable is defined as the percentage of U.S. corn acreage planted after May 30th from 1980 through 1985 and after May 20th from 1986 onwards. While there are certainly other specifications that could be considered, the model explains 98 percent of the variability in the U.S. average yield of corn, and therefore captures the most important factors that drive yield at this level of aggregation. Complete details on the model specification can be found in the October 9th article.

The monthly weather data are collected for 10 key corn-producing states (Iowa, Illinois, Indiana, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin). These 10 states typically accounted for about 75-80 percent of total U.S harvested acreage of corn during the sample period. An aggregate measure for the 10 states was constructed using harvested corn acres to weight state-specific observations. The weighted-average monthly weather variables are used to represent weather observations for the entire U.S. corn crop. Precipitation data are monthly totals and temperature data are monthly averages. The National Weather Service is the source for the weather data via the Midwest Regional Climate Center.

Table 1 presents the regression estimates for the crop weather model for 1980 through 2023. The model has a high explanatory power, with an R2 of 98 percent. The signs of the coefficient estimates are as expected. The time trend coefficient indicates that the trend rate of growth in the U.S. average corn yield is slightly less than two bushels per year, very close to the unconditional trend coefficient presented in Figure 1. Each percentage of the U.S. corn crop planted late is estimated to reduce corn yield by 0.35 bushels per acre. The crop weather variables are statistically significant at the ten percent level or better except for pre-season precipitation and April-June temperature.

Table 1. Regression Estimates for U.S. Corn Crop Weather Model, 1980-2023

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	237.47	48.42	4.90	0.00
Time Trend	1.95	0.06	31.76	0.00
Late Planting	-0.35	0.09	-4.01	0.00
September-March Precipitation	0.40	0.35	1.13	0.27
April Precipitation	2.51	1.08	2.32	0.03
June Precipitation	7.42	4.22	1.76	0.09
June Precipitation Squared	-0.83	0.44	-1.88	0.07
July Precipitation	30.99	4.46	6.95	0.00
July Precipitation Squared	-3.32	0.49	-6.82	0.00
August Precipitation	2.54	0.83	3.07	0.00
April Temperature	0.10	0.30	0.33	0.74
May Temperature	0.32	0.31	1.04	0.31
June Temperature	-0.37	0.42	-0.89	0.38
July Temperature	-2.23	0.41	-5.43	0.00
August Temperature	-1.06	0.41	-2.61	0.01
R-squared	0.98			
Adjusted R-squared	0.97			
S.E. of regression	4.51			
Sum squared resid	588.60			
F-statistic	107.95			
Prob(F-statistic)	0			

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The next step is to formally test if the trend estimated via the crop weather model changes in a similar manner to that shown in Figure 1. More specifically, we want to test whether the intercept increased, and the trend coefficient declined after 2013. This can be accomplished by specifying a “dummy” variable that takes on a value of zero before 2013 and one thereafter. This variable is inserted into the crop weather model as a “shifter” variable for the intercept and as an “interaction” term for the trend coefficient. A statistical test can be then performed to determine if the coefficients on these two new variables are significant. After re-estimating the crop weather regression model, the dummy variable coefficients are found to be statistically insignificant both individually and jointly. Additional tests are conducted with the trend break assumed to be 2014 or 2015. The results are unaffected. Conditional on the crop weather model used here, there is no evidence of a statistically significant change in the trend of the U.S. average corn yield in recent years. Stated differently, the relative narrow range of U.S. average corn yields over 2013 through 2023 is likely a reflection of poorer than average growing season weather rather than a slowdown in the technology of corn production.

Before concluding, it is fascinating to consider previous examples of similar debates about changing rates of growth in the trend for U.S. corn yields. For example, corn yields were excellent in the 1960s and early 1970s, and there was considerable discussion whether the rate of growth in trend yields had increased. Thompson (1975, p. 535) observed: “There has been more than usual attention in the press to weather and climatic change since mid-1974. The United States had so little variability in weather and grain production in the past two decades (until 1974) that an attitude of complacency had developed. There was frequent reference in the early 1970’s to the fact that technology had increased to such a level that weather was no longer a significant factor in grain production.” Unfavorable weather for corn yields followed, especially in 1980, 1983, and 1988. This further identified the 1960s through the early 1970s as a favorable period for corn yields. Thompson (1990, p. 89) later stated: “The trend was very steep from 1960 to 1972 because the favorable weather each year resulted in excellent response to increasing technology.”

A more recent example is provided by the relatively high corn yields in the U.S. that occurred in the decade after 1995. Many crop experts and seed companies credited new genetically modified traits for the excellent corn yields and argued that the rate of growth in trend yields had turn up sharply. Irwin, Tannura, and Good (2008) used crop weather models like the one used in this article to test whether the trend had changed, concluding there was no statistically significant evidence that the rate of growth in trend yields had increased since the mid-1990s. The authors argued that observers had failed to recognize the impact of relatively favorable weather since the mid-1990s, and thereby, mistakenly attributed weather-driven corn yield increases to accelerating technology. A shockingly low U.S. average corn yield followed in 2012, due to a severe drought, and this added further credence to the argument that rate of growth in corn trend yields had not changed (*farmdoc daily*, April 17, 2013).

Implications

Trend yield projections are foundational to supply and demand analysis for corn before the growing season begins. The most appropriate model to use in projecting trend yield has been the subject of considerable debate for many years. At the present time, the question being debated is whether the rate of trend growth in the U.S. average corn yield has slowed. We use a crop weather model to disentangle potential trend changes from weather impacts and find no evidence of a statistically significant change in trend for the U.S. average corn yield starting in 2013. The relatively narrow range of U.S. average corn yields since 2013 is likely a reflection of poorer than average growing season weather instead of a slowdown in the technology of corn production. It is fascinating to observe the similarity of the present debate to previous controversies. After excellent corn yields, first in the 1960s through the early 1970s and then again in the decade after the mid-1990s, it was widely argued that corn trend yields had accelerated. Subsequent research revealed that observers had failed to recognize the impact of relatively favorable weather, and thereby, mistakenly attributed weather-driven yield increases to accelerating technology. It appears that observers in recent years have made just the opposite error, mistakenly attributing the impact of relatively unfavorable weather to decelerating technology. At the present time, the evidence suggests that the crop weather model used in this article provides a reasonable estimate of the trend for the U.S. average corn yield. The trend yield estimate for 2024 using the model is 182.1 bushels per acre. This estimate will soon need to be modified by the actual observation for late planting, which will be available after May 20th. It will be interesting to compare the crop weather model trend estimate to the first corn yield projection for 2024 in the upcoming May WASDE report to be released this Friday.

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