Yield Trends and Shifts in the U.S. Corn Belt

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1. Introduction

Recent research highlights a north and westward spatial shift in the Corn Belt (Laingen 2012; Hart and Lindberg 2014; Laingen 2017). For example, Laingen (2017) showed that the center of the Corn Belt has shifted roughly 150 miles northwest from near Benville in west-central Illinois (Brown County, IL) to near Sigourney in eastern Iowa (Keokuk County, IA) between 1950 and 2012. While the spatial expansion to the northwest in the Corn Belt is evident, it is not clear if there has also been a corresponding shift in the highest yielding areas over time.

During the 2012 flash drought that affected almost all of the traditional United States Corn Belt, there seemed to be media consensus that the highest yields will eventually be in states like Minnesota and South Dakota. Therefore, we extended previous work to determine whether such a hypothesis about the northward shift in the highest yielding districts has been concurrent with the spatial expansion of the Corn Belt. We found that northward shift in the highest yields is consistent with the overall shift in the Corn Belt, but what may have gone unnoticed is the equally significant westward shift in the highest yields. This short report quantifies some of the changes that have been observed over the Corn Belt since the early 1960’s.

Within this report we are only describing the trends in annual average yield for a crop reporting district and not the true total production (i.e., total bushels produced) for a crop reporting district. Additionally, our work does not account for changes in acres planted to corn. As shown by recent research (e.g., Johnston, 2014, Lark et al. 2015) there has been a significant increase in the number of acres planted to corn in some sections of the Corn Belt. This increase in acres planted to corn has been most significant in the Dakotas but most other areas have seen increases in corn acreage as well. Other researchers (Lin et al. 2016; Laingen 2017; Wimberly et al. 2017) have also shown that many of these acres in the Dakotas now planted to corn are acres that have been converted from grasslands or small grains (e.g., wheat, barley).

This report also does not account for any crop reporting district corn yield intra-variability as we are only using the final yield for the entire district. In some cases, this variability could be significant. What this report shows is the annual average yield for an agricultural district compared with other agricultural districts in the Corn Belt using an annual ranking. This ranking is then used to illustrate the spatial shift of in the region with the best rankings over time.
2. Methodology

Data were collected from the United States Department of Agriculture’s (USDA) National Agricultural Statistics Service (NASS) for 60 crop reporting districts (CRD’s) in the period 1961 to 2016. This report is primarily focused on rainfed (i.e., non-irrigated) corn, but in cases where Nebraska irrigated CRD’s are considered, Nebraska CRD’s are counted twice for a total of 66 CRD’s. This was done because the yields of irrigated corn in Nebraska have generally far exceeded those of rainfed corn and thus they should truly be considered independent and separate districts. Figure 1 (below) shows the map of the CRD’s and each CRD’s corresponding number. The districts chosen for this report are those with significant portions of them being designated as a major or minor corn area by the USDA. We fully realize that there are other areas in the United States that grow corn in significant quantities (both irrigated and rainfed) but for this initial study, we wanted to concentrate our focus on the contiguous Corn Belt in the Midwest. Districts that were excluded in the Midwest states either don’t generally have enough corn production to be considered viable or are geographically separate from other CRD’s in the same state (e.g., irrigated corn in the Missouri Bootheel).

Figure 1. Assigned numbers for each CRD in the twelve-state study area. Nebraska numbers reflect the number assignment for irrigated corn. The assigned number for the Nebraska rainfed CRD’s are as follows: Central (41), East (42), Northeast (43), South (44), Southeast (45), Southwest (46).

Decadal rankings were determined as follows: The average corn yield in bushels/acre (bu/ac) for a CRD was given an annual ranking of 1-60 (or 66), with 1 being assigned to the CRD with the highest corn yield for a given year in a decade, 60 (66) being assigned to the CRD with the lowest corn yield, and everything in between receiving the numeric value corresponding to its ranking. For example, in 2016 the CRD with the highest yield was Central Illinois (218.6 bu/ac) and the CRD with the lowest yield was (rainfed) Southwest Nebraska (97.7 bu/ac). Those CRD’s
received 1 and 60 (66) “points” respectively. The points a CRD received were accumulated over a decade and the CRD with the fewest points over a decade was considered the winner. Please note that the last decade referred to in this report is only covering the six-year period from 2011-2016. While it is possible that the current rankings will be unchanged after the 2020 growing season, we are not necessarily projecting that to be true.

Several 30-year trend-lines were calculated for this study, but the most prominent in this work is the 56-year trend line encompassing the entire period (1961-2016). While a 30-year trend line (or even a 15-year trend line) may well be more appropriate for other studies, we felt the long-term trend line most accurately depicted the gradual spatial shift in the highest yielding districts. The “Baseline” period in Table 3 refers to the numeric value of the intercept on the y-axis of the long-term linear trend-line for each district (i.e., the ‘b’ in y = mx+b, where ‘m’ is the slope).

3. Results

This section is broken up into a quick report on Nebraska irrigated corn and then a longer report on the rainfed corn over the entire Corn Belt.

a. Nebraska irrigated

Irrigated corn in Nebraska has been and continues to be the most consistent and highest yielding corn in the Corn Belt. All six Nebraska CRD’s analyzed in this study have a slope of greater than 2.00 bu/ac over the long-term and four of the six districts (East, Northeast, South, and Southeast) have 30-year (1987-2016) slopes equal to or exceeding 2.50 bu/ac per year. Each district in the state has had the number 1 overall ranking at least once (the Northeast CRD finally got their first number 1 ranking in 2013) and four of the six districts (East, South, Southeast, Southwest) have been either number 1 or number 2 overall (out of 66 districts) ten times or more. The South CRD has been the overall winner 16 times and in the top two a total of 26 times. Both are tops in the Corn Belt. Table 1 shows more detailed results of the irrigated CRD winners over the study period, including the first and last time a CRD finished in the top two.

Table 1. Number of Top 2 finishes by decade for districts that had at least one occurrence between 1961-2016. District abbreviations: C- Central, E- East, NE-Northeast, S-South, SE-Southeast, SW-Southwest. Irrigated corn only.
It should be noted that the Southwest CRD has not been in the top two overall since 2006, whereas every other district has been in the top two at least twice since then. Also, the 30-year slope of 2.07 bu/ac per year is not only lower than any other irrigated CRD in the state (and lower than the rainfed Northeast CRD), it is also the only irrigated CRD where the value of the slope in the long-term trendline (2.10 bu/ac per year) exceeds that of the 30-year slope.

b. Rainfed corn

As shown in Figure 1, the Corn Belt extends laterally from western Nebraska east to central Ohio and vertically from the southern portion of Illinois to East Central North Dakota. This “definition” of the Corn Belt compares favorably with the spatial delineations presented in Hart and Lindberg (2014) and Laingen (2017). We did not break the Corn Belt into separate geographic regions (e.g., Eastern) for analysis in this study and will be referring primarily to states or individual CRD’s within a state in this section.

There has been a northward and westward shift in the CRD’s with the highest yields since the beginning of the study period. As shown in Figure 2a, the highest baseline yields (please refer to section 2 for definition) were in Eastern Illinois (CRD 2) and the top 10 were split almost equally between the states of Illinois, Indiana, and Iowa. Table 2 shows that Illinois had the highest average rankings in the baseline followed by Indiana, Iowa, and Wisconsin. The bottom four were Minnesota, Nebraska, North Dakota, and South Dakota respectively.

![Baseline CRD Rankings](image)

Figure 2a. Baseline corn yield rankings by CRD.
Table 2. Statewide average rankings of all crop reporting districts in study area (rainfed only) by decade. The baseline column represents the ranking as determined by the intercept on the y-axis from the long-term slope equation.

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Today the story is quite different in some ways (Figure 2b). Indiana, which was the second highest yielding state in the baseline, and remained third behind some combination of Iowa and Illinois through the 1980’s, is now essentially an average yielding state. Conversely, Minnesota has gone from a low average yielding state in the baseline (even trailing the combined CRD’s of northeast Kansas and northern Missouri), to an average yielding state in the 1980’s, to a top yielding state in the current decade. When comparing Figures 2a and Figure 2b, it should be noted that every single CRD in Indiana has fallen in ranking and in most cases, the ranking has fallen by double digits. Indiana has seen the most drastic fall in rankings as a state, but it is also worth noting that there has been an almost equally impressive drop in rankings in the eastern and southern parts of Illinois. This decline also extends westward into north central and northeast Missouri, but in that case, the CRD rankings have gone from merely below the median to some of the worst performing CRD’s in the Corn Belt.
Further evidence for this exists in Table 3, which shows the number of years that a particular CRD has finished in the top 2 (out of 60). Central Illinois (CRD 1) is the clear “winner” and has had three top two finishes in the six years of this decade. The CRD to the immediate east (Eastern Illinois) has had 11 top two finishes, good for third place among all 60 rainfed CRD’s. For many years, Eastern Illinois kept pace with Central Illinois for most top two finishes. However, its last appearance in the Top 2 was way back in 1985 and it has rarely even cracked the top 10 in the past ten years. Other Top 2 “droughts” in Illinois include East Southeast Illinois (1987) and West Southwest Illinois (2000). The news is different in the northern third of Illinois. Northwest Illinois (CRD 1) is the top yielding CRD overall thus far in the current decade, Central and Northeast Illinois (CRD 4) are in the top 5, and Western Illinois (CRD 8) has remained a solid yielding district, including a recent top two appearance (2014).
Table 3. Number of Top 2 finishes by decade for districts that had at least one occurrence between 1961-2016. District abbreviations: C- Central, E- East, W- West, EC- East Central, NC- North Central, NE- Northeast, NW- Northwest, WC- West Central, ESE- East Southeast, WSW- West Southwest.

If corn yield rankings are viewed as a zero-sum game and Indiana and parts of Illinois are declining in ranking, then it is Minnesota and surrounding CRD’s in Iowa, South Dakota, and even northeast Nebraska that are gaining the most. The most impressive gain in yield rankings between the early 1960’s and the present is indeed the tri-state region of northwest Iowa, southwest Minnesota, and eastern South Dakota. In the baseline period, the Northwest Iowa and Southwest Minnesota CRD’s had corn yield rankings of 31st and 45th. They are now ranked 2nd and 12th respectively. Other impressive gains in corn yield rankings were found to the west in South Dakota, the Northeast Nebraska CRD, and a bit further east in Southeast Minnesota and Northeast Iowa.

The mathematical reason for this northwestward shift in higher rankings can be shown by the differences in the long-term slopes in Figure 3. The CRD’s with the biggest gain in rankings all have long-term slopes that are in excess of 2.00 bu/ac per year, some considerably above (e.g., western Minnesota and South Dakota districts). The CRD’s that have fallen off in rankings have slopes that are generally between 1.40 and 1.60 bu/ac per year (e.g., eastern Illinois and Indiana CRD’s).
Figure 3. Long-term slope of corn yields across the Corn Belt.

It should be noted that in no CRD’s are the slopes negative. So corn yields are indeed increasing everywhere and in most locations, the rate of yield gain has been increasing over time. However, the rate of gain in corn yield has not been equitable across the Corn Belt. This mathematical inequality has led to the northwestward shift of the highest corn yields being centered over downstate Illinois and western Indiana to a center that now spans the northern third of Iowa, northern Illinois, and southern Minnesota. It also means that the worst overall corn yields have shifted from the far northern Corn Belt to the southern and western fringes of the Corn Belt. In addition, those areas with the highest slopes generally also have the highest coefficient of determination ($R^2$), as shown in Figure 4. The main exception is southern Michigan, which has lower slopes but strong year-to-year consistency.
Figure 4. Coefficient of determination ($R^2$) from the long-term trendline for each CRD.

Figure 5 offers another visual of the overall change. The CRD’s in the gray shading are those that were only in the Top 10 in the baseline period (i.e., the early 1960’s). These are all CRD’s that have lower overall slopes and have gradually fallen off in the rankings over the past 50 years. Those in the light blue shading were generally in the bottom half of the Top 10 in the baseline but have had high enough yield gains to maintain status as a high yielding (i.e., Top 10) CRD. The Northeast Iowa and Northeast Illinois CRD’s in dark blue were not in the Top 10 in the baseline but are in the top 10 for corn yield thus far in this decade. Going further west and north, the Northwest Iowa, South Central Minnesota, and Southeast Minnesota CRD’s (medium green) are in the top 10 for corn yield thus far in this decade and have a long-term slope ranking in the top 10. Last but not least, the districts in light green shading are in the top 10 for long-term slope.
Figure 5. Comparison of the top 10 CRD’s in the baseline, current top 10 highest yielding CRD’s, and CRD’s with the top 10 long-term slopes. Legend: Gray CRD’s: Top 10 in baseline only. Light Blue CRD’s: Top 10 in both baseline and in the current decade. Dark Blue CRD’s: Top 10 in current decade only. Medium Green CRD’s: Top 10 yield in current decade and Top 10 long-term slope. Light Green CRD’s: Top 10 slope only. White shading: No applicable ranking. Note that 11 were included in the baseline since East Southeast Illinois was essentially tied for number 10 with East Central Iowa.

Figures 6 shows the final example of the changes in the Corn Belt, which in large part is a depiction of the slow move toward corn yield convergence across much of the Corn Belt. During the baseline period, the CRD’s with the highest percentages above the Corn Belt average* stretched from central Iowa and east-southeast into central Indiana. As with the change in rankings, there is a divide between those CRD’s with large decreases in the percent above Corn Belt average and those with lesser decreases or increases in the percent above Corn Belt average. That divide also is essentially in the central part of Illinois, with districts including CRD 1 (Central Illinois) and to the northwest and west having smaller declines or increases (significant increases once you get to Minnesota and the Dakotas) and those to the south and east generally either have larger declines in the percent above average or have fallen further below the Corn Belt average. It should be noted that the average does include irrigated Nebraska corn but we did not consider those districts in this analysis.
Figure 6. Percent above or below the Corn Belt average for all districts that were or are in the top 10 in either the Baseline (B), Current decade (C), or for slope (S). CRD’s that are top 10 in multiple categories have two letters designating that status.

The final figure (Fig. 7) is essentially a combination of Figures 5 and 6. It shows that the Corn Belt, as a whole, has been slowly headed toward convergence of corn yields since the early 1960’s. Only 6 CRD’s were above the Corn Belt average in the baseline and have shifted rightward (i.e., toward a higher percentage above the Corn Belt average) and only 10 CRD’s were below the Corn Belt average and shifted leftward (i.e., toward a greater percentage below the Corn Belt average). The former CRD’s are all located in northern and western Iowa and southern Minnesota. The latter CRD’s are generally located in the southern fringes of the Corn Belt (e.g., southern Illinois and Indiana) or in CRD’s that have consistently poorer soils and/or nighttime temperatures in the summer that exceed 70F.
Figure 7. More sophisticated grouping of the CRD’s. Legend is as follows:

**Gray**- Above Corn Belt average for baseline period but gap is narrowing.
**Blue**- Above Corn Belt average for baseline period but gap is narrowing. Currently a top 10 district.
**Light Blue**- Above Corn Belt average for baseline period but gap is narrowing. Former top 10 district.
**Green**- Above Corn Belt average for baseline period and gap is widening. Some of these are also current top 10 districts. Likely to be best performers in the next 20 years.
**Light Green**- Below Corn Belt average for baseline period but gap is narrowing. Some could be top performers in the next 20 years.
**Red**- Below Corn Belt for baseline period and gap is widening. These are marginal districts that are falling further behind.

Looking at it another way, this has meant a shift of the highest yields occurring in the region roughly bounded by I-70 and I-80 in Illinois and Indiana to the highest yields occurring in the region roughly bounded by I-80 in Illinois and Iowa to a bit north of I-90 in Minnesota. The highest overall slopes, which could indicate where the highest yields will be in the future, are in the I-29 corridor in South Dakota, Northwest Iowa, and neighboring districts in Minnesota and Nebraska. It should be noted the corn yields in places like eastern South Dakota, while increasing rapidly, are still well behind those CRD’s in Illinois, Iowa, and Minnesota that are currently the highest yielding. Thus, we don’t intend to imply that all of the CRD’s with the highest slopes will be the highest yielding corn districts within a year or two.
4. Conclusions and Future Work

The Corn Belt has gradually shifted toward the northwest since the early 1960’s, both in terms of its pure spatial extent and its highest yielding areas. This shift has not occurred because of absolute declines in yield in places like Eastern Illinois and Indiana, but rather the spatial inequity of higher corn yield gains per year in the northern and western portions of the Corn Belt compared to the eastern and southern sections of the Corn Belt. Reasons for this are likely multi-factored and complex and we are not prepared to attribute this spatial shift to one or multiple factors at this time.

However, we are reasonably certain some combination of the following factors below are the primary drivers. The first and perhaps the most obvious factor is climate. For example, one hypothesis we plan to test is to determine if the increased growing season length has disproportionately benefitted the northern portion of the Corn Belt compared to the southern Corn Belt. Other factors include genetics, soil fertility, management practices, and air pollution. In the coming months we will be working with a team of inter-disciplinary scientists from multiple sectors to try and determine the contribution from these factors, starting first with climate change.

5. References


