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PERSPECTIVE

A perspective on changes across the U.S. Corn Belt

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1. Introduction

Corn (*Zea mays L.*) has long been a staple crop of the Corn Belt of the U.S., which today extends latitudinally from central Nebraska to central Ohio and longitudinally from northeast Kansas to the eastern Dakotas and western Minnesota. However, the production of corn in the Corn Belt has been transformed in both magnitude and spatial extent since the 1960s. Previous research has shown that there has been an overall increase in the number of acres planted to corn across the Corn Belt (e.g. Johnston 2014, Lark *et al* 2015), with a pronounced increase in the eastern Dakotas and modest increases across the historical Corn Belt, which includes most of the states of Illinois, Indiana, and Iowa (i.e. the 'I' states). Much of the intensification across the Dakotas can be attributed to the conversion of grasslands and small grains croplands (e.g. wheat and barley; Lin *et al* 2016; Laingen 2017, Wimberly *et al* 2017) for corn and soybean (*Glycine max L.*). Some of this change can be attributed to government programs (Laingen 2011) and to the substantial increase for corn ethanol in areas with traditionally lower corn yields (Murphy *et al* 2011). Recent research also highlights a north and westward spatial shift in the Corn Belt (Hart and Lindberg 2014; Laingen 2017, Auch *et al* 2018) such that the geographic mean of the Corn Belt has shifted over 200 km northwest since the 1950s (Laingen 2017).

In this paper, we build on these previous studies by presenting evidence of two key points: 1) The relative dominance of corn production of the traditional Corn Belt has been diminished, and 2) The crop reporting districts with the highest corn production have also started to shift spatially, partly from increased acreage outside the traditional Corn Belt and partly from spatial shifts in the districts with the highest corn yield trends.

2. Methodology

Yield and production data were collected from the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) for 60 crop reporting districts (CRDs) across 12 states over the period from 1961 to 2018. Our analysis is broken into three separate periods: 1961–1978 (first period), 1979–1998 (second period), and 1999–2018 (third period). The first half of this paper is focused on the total accumulated corn production (in millions of metric tons) for an aforementioned period for each CRD. In the next section, the CRD totals are scaled up to the state level to demonstrate changes in production at the state level.

The second half of the paper is focused on yield trends across CRDs for each period. While management practices have changed over time and still vary across the region, the only practice that can be reasonably isolated in the NASS dataset is irrigation. Thus, for the sake of consistent comparisons across the Corn Belt region, we limited the trend analysis to rainfed (i.e. non-irrigated) corn only. A table of yield trends (i.e. slope of a line) for each CRD and period that also includes irrigated corn in Nebraska is available in the supplemental material. Yield trends (metric tons per hectare, MT/ha) were calculated via linear regression for each of the three periods for all 60 CRD's and were then broken into quartiles for analysis.

3. Corn production by state

The Corn Belt 'I' states historically have had the highest total corn production and have the strongest negative price-yield correlations. While the 'I' states are still essential for corn production, the comparative advantage has declined in recent years (table 1).

Table 1. Total percent of corn in the U.S. produced in the Corn Belt over the periods of 1961–1978, 1979–1998, and 1999–2018. Note that for every state but the 'I' states, the state percentages include only the CRDs considered part of the Corn Belt in this analysis (figure 1) (available online at stacks.iop.org/ERL/15/071001/mmedia). A map indicating the state boundaries is available in the supplemental material.

State	1961–1978	1979–1998	1999–2018
'I' States	49.2	44.3	41.6
Illinois	*19.4*	*16.7*	*16.1*
Indiana	*9.5*	*8.6*	*7.3*
Iowa	*20.3*	*19.0*	*18.2*
Great Lakes	9.0	9.1	7.5
Michigan	*1.8*	*2.0*	*1.6*
Ohio	*4.9*	*4.6*	*3.7*
Wisconsin	*2.3*	*2.5*	*2.2*
Nebraska	7.9	10.5	10.7
Rainfed	*3.0*	*2.7*	*3.5*
Irrigated	*4.9*	*7.8*	*7.2*
Minnesota	7.8	8.4	9.8
Kansas/Missouri	2.6	1.8	2.3
Northeast Kansas	*0.4*	*0.3*	*0.6*
Northern Missouri	*2.2*	*1.5*	*1.7*
Dakotas	2.0	2.6	4.4
North Dakota	*0.2*	*0.4*	*1.3*
South Dakota	*1.9*	*2.2*	*3.1*
Non-Corn Belt	21.6	23.3	23.7

In the first period almost half (49.2%) of U.S. corn production was in the 'I' states and in many years in the 1960s, the 'I' states produced over 50% of U.S. corn. The 'I' states still easily produce the most corn. However, the relative dominance of corn production from the 'I' states has declined over time, producing 44.3 and 41.6 of U.S. corn production in the second period and third periods respectively. Declines in the production percentage have been roughly equivalent among the three states.

An increase in the irrigated corn acreage in the central and south central CRDs of Nebraska in the late 1960s and 1970s. (Hiller *et al*, 2009; Kucharik and Ramankutty 2005) helped increase the relative contribution of U.S. corn production in Nebraska from 7.9% in the first period to 10.5% in the second period. While this percentage was well short of the combined percent contribution from the 'I' states (10.5 vs. 44.3), the CRDs of Nebraska did surpass the state of Indiana during the second period. The percentage of corn production from Minnesota also increased (7.8 to 8.4%) in the second period, putting it slightly behind Indiana.

In the third period, an increase in rainfed corn production helped maintain Nebraska's ranking and slightly increased its percentage of U.S. corn production from 10.5 to 10.7%. Minnesota continued to narrow the gap, with an increase from 8.4 to 9.8%. The only larger increase in the percent production of U.S. corn was found in the Dakotas. In the five CRDs that make up the Dakotas, the percentage of U.S. production increased from 2.6 to 4.4% between periods two and three. The ranking list in the third period was rounded out by the Great Lakes, the Dakotas, and Kansas/Missouri.

4. District analysis of corn yield and production

Two important points are noted in figure 1. First, corn yield trends are positive across the Corn Belt and the magnitude of the trends has become increasingly positive over the last twenty years. Second, total corn production has increased significantly, with tenfold increases in parts of the Dakotas and doubling of production across the historically most productive districts.

Corn yield trends are increasingly positive across the Corn Belt. After nearly identical median trends of 0.088 MT ha^{-1} yr^{-1} and 0.089 MT ha^{-1} yr^{-1} respectively in the first and second periods across the 60 CRD's of the Corn Belt, the median yield trend increased significantly to 0.143 MT ha^{-1} yr^{-1}in the third period. For a sense of the magnitude of recent change, consider the following. The north central Iowa CRD was in the bottom quartile in the third period with a trend of 0.120 MT ha^{-1} yr^{-1} but the south central Nebraska CRD was in the top quartile with a trend of 0.108 MT ha^{-1} yr^{-1} in the second period. Thus, even though a CRD like north central Iowa had a trend that increased by more than 0.05 MT ha^{-1} yr^{-1}, the gain was not enough to move them out of the bottom quartile.

In the first period, the overwhelming majority of the top quartile yield trends (as depicted in green) were in the 'I' states and southern Minnesota. The bottom quartile trends were primarily confined to the western Corn Belt. Conversely in the second and third periods, the majority of the top quartile corn trends were outside the 'I' states and a majority of the bottom quartile trends were in the eastern Corn Belt. In the third period, no CRDs in Indiana or Iowa had a top quartile trend and only three CRDs in Illinois (northwest, northeast, and central) had a top quartile trend.

The median total corn production for a CRD increased from 23.6 million metric tons (MMT) in the first period to 43.4 MMT in the second period to 63.1 MMT in the third period. For perspective, there were only six CRDs in the third period with total production less than the median of the first period and there were only six CRDs in the first period with total production greater than the median of the third period.

Even though the strongest yield trends in the second and third periods were concentrated in Nebraska, South Dakota, and Minnesota, the CRDs with the highest production have remained concentrated in Iowa and Illinois. However, there are a few spatial shifts to note. Between the first and third period, eastern Nebraska and southern Minnesota both gained a district in the top quartile while Illinois and Indiana lost a top quartile district. The bottom quartile of

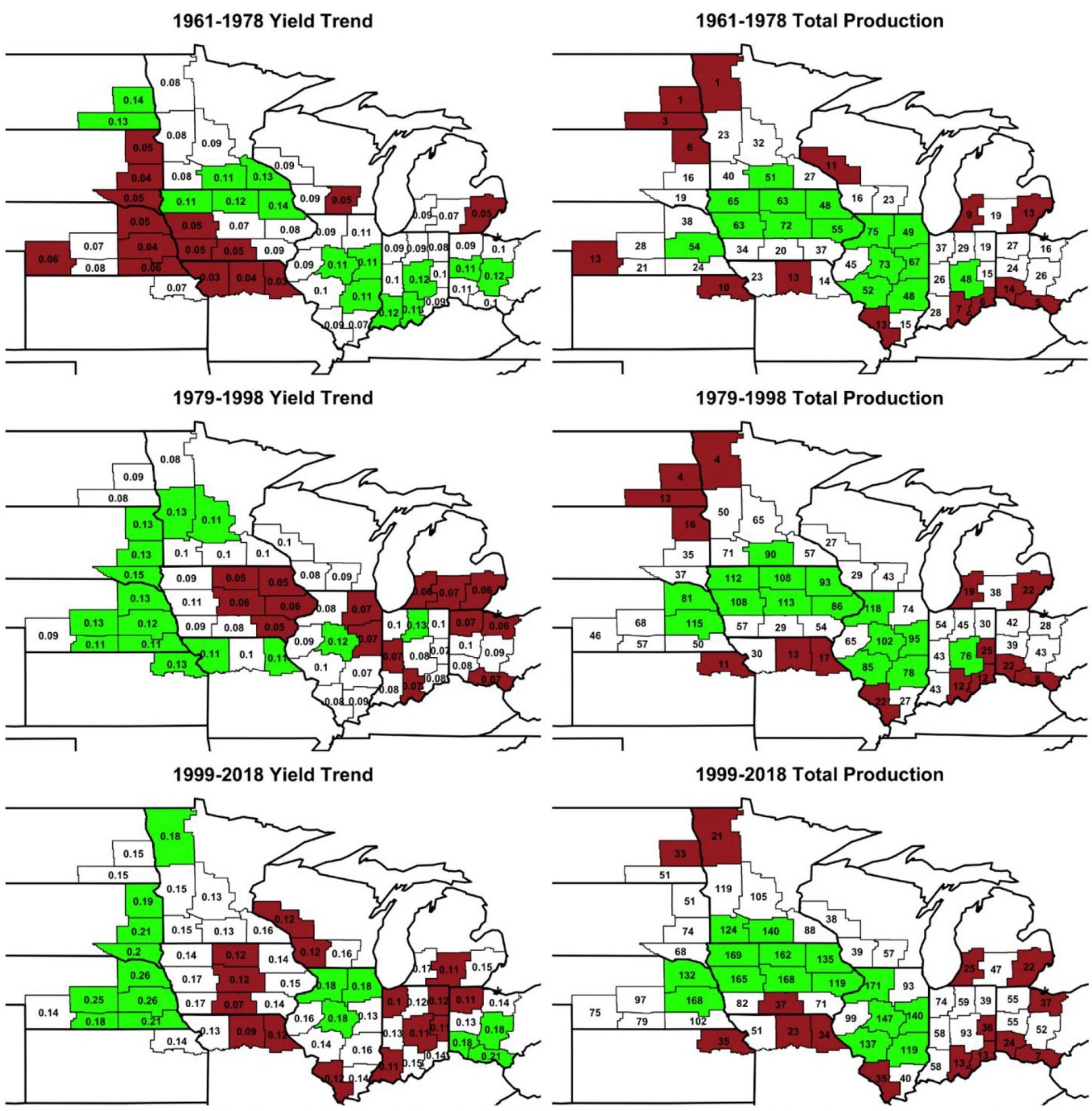

Figure 1. On the left half from top to bottom are the corn yield trends (MT/ha) over the periods spanning 1961–1978, 1979–1998, and 1999–2018 for each crop reporting district (CRD). The top (bottom) quartiles for trend for each period are shown in green (brown). On the right half from top to bottom are the total production of corn (millions of metric tons) over the three periods. The top (bottom) quartile for total corn production are shown in green (brown).

CRDs have shifted a bit more, with CRDs in northeast South Dakota and southeast North Dakota moving out of the bottom quartile and more marginal CRDs in northern Missouri, southern Iowa, and Ohio moving into the bottom quartile. As expected, the largest changes in accumulated corn production were found in the Dakotas, with roughly a tenfold increase in production between the first and third periods.

5. Summary and closing thoughts

Corn production in the Corn Belt has become even more robust over recent decades, driven in part by significant changes in the yield trend and partly by a significant increase in acreage in areas once considered marginal for corn. This increase in acreage has been driven by changes to conservation programs and demand for corn ethanol, to name a few reasons. The most positive yield trends are currently in eastern Nebraska and South Dakota where large scale corn production is more recent, though the CRDs with the highest production in Illinois also have highly positive trends. These changes have diminished the relative importance of the 'I' states for corn production, but the comparative advantage is still quite large and likely to remain that way into the coming decades.

While we did not attribute any causes to the large increases in yield trend over the past twenty years, a variety and combination of factors are likely responsible. First, climatic trends have mostly been favorable for corn production in recent decades (Takle and Gutowski 2020), though an increasingly warm and volatile climate may eventually start offsetting these current positive trends. The strong increase in corn yield trend in period 3 corresponds to several cultural changes. First, over the last 15–20 years, most Corn

Belt farmers have adopted genetically engineered corn seed (Ortiz-Bobea and Tack 2018), including drought tolerant varieties in places like Nebraska. Second, farmers have increased adoption of soil conservation measures, such as no-till and cover crops (Basche *et al* 2016) and increased plant population density and optimized row spacing (Assefa *et al* 2018, Licht *et al* 2019). Finally, investments in larger machinery has decreased the time needed for planting, which is advantageous in years with wet springs. All of these factors are important but we also recommend that additional research be conducted to determine the relative importance of each factor for improved projections of corn trends in the coming decades.

6. Data availability

The data that support the findings of this study are openly available through the USDA website (https://quickstats.nass.usda.gov)

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