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VARIATION IN THE RELATIONSHIP BETWEEN CORN YIELD AND CLIMATE IN A SAMPLE OF COUNTIES IN ILLINOIS 1951-1980

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ABSTRACT

Building off an earlier study, the relationship between corn yield and weather variables in ten counties in Illinois from 1951 to 1980 is studied. First differences in corn yield were computed and used to identify a change in the pattern of yield variability occurring after 1965-66. For each county, the time series of average per acre yield of corn was regressed in a stepwise fashion against weather variables using an additive model. From the regression results, a coefficient of variation was calculated showing the amount variation in the corn yield explained by the weather variables. In comparison to similar coefficients derived from an earlier study, the results of the present study indicate a marked increase in the amount of yield variability attributed to weather. Consequently, farmers are dealing with greater weather induced yield variability in corn than previously.

INTRODUCTION

Farmers operate in an uncertain world in which the impact of their managerial decisions on net farm income is affected by many factors beyond their control. Such factors include changes in commodity prices, input costs, and crop yield. In this study, we take up an investigation initially reported by Changnon and Neill in 1967. In that study they used estimates of the relationship between corn yield and weather variables to delineate regions of Illinois with similar weather dependent, corn yield variability. The significance of such research derives from the possibility of farmers adopting managerial strategies to lessen the adverse impacts of climatically induced yield variability as well as the needs of actuaries working for crop insurance programs to develop estimates of spatial yield variability.

Since the completion of the earlier study by Changnon and Neill, evidence has accumulated indicating change in corn yield variability. The corn yields in Illinois during the 1951-80 period seem to show great year to year variability, especially since 1965 (fig. 1). This variability is further highlighted when the first differences in the yearly yields are plotted (fig. 2). (A first difference is the difference in the observations for year i and year i - 1 in a time series. [Tintner 1940; Carter and Dean, 1960]). Additionally, a number of investigators have hypothesized that the nature of the variability of key climatic parameters has changed as well (e.g. Dyer 1978; Skaggs, 1978 and Thompson, 1975). The question that arises from these observations is, 'Is the increased yield variability in Illinois during the period 1951 through 1980 weather induced?'

If crop yield variability has increased in response to increased climatic variability, then application of the same crop climate model to two different time periods should show that weather variables for the period increased climatic variability account for a larger share in the explanation of yield variability. To test this hypothesis we repeated a portion of the Changnon and Neill study using a time series of yield and climatic data partially overlapping the data of the earlier study, i.e., 1951 through 1980 vs. 1930 through 1963. County data for one sample county from each of the Crop Reporting Districts of Illinois were used. Due to local interest, Jackson County was also included.

MATERIALS AND METHOD

Data on the average per acre yield of corn and weather variables were collected from ten counties throughout Illinois. The data on yields were collected from the Illinois Cooperative Crop Reporting Service. The data on the climatic variables were collected from U.S. Weather Stations located in the respective counties and adjacent to them. The map in fig. 3 indicates the counties studies as well as the weather stations from which data were obtained. The weather variables used in the analysis paralleled those used by Changnon and Neill: mean temperatures for the months of May, June, July and August; total rainfall for June, July and August and preseason precipitation (September through May).

In their study Changnon and Neill used two sets of dummy numbers following Thompson, 1966; one set representing the general trend of technology in the 1930-57 period and the second set expressing an accelerated technology effect since 1958. Instead of using two sets, in this study one set of dummy variables was used with a uniform rate of change till 1960 and an accelerated rate of change in the later years; both rates follow the trend in fertilizer use for Illinois.

Changnon and Neill used all the 102 counties in their study. In the present study, one sample county was chosen from each Crop Reporting District; the choice was based on availability of climatic data for the period of study. The counties included in the study and their corresponding Crop Reporting Districts in parenthesis are: McHenry (Northeast), Bureau (Northwest), McDonough (West), McLean (Central), Vermillion (East), Sangamon (West Southwest), Shelby (East Southeast), Wayne (Southeast) and St. Clair and Jackson (Southwest).

For each county, the time series of average per acre yield was regressed in a stepwise fashion against the weather variables using an additive model. The exact functional forms used in the earlier study were unreported and unavailable from the authors. For each regression model, relevant statistics were calculated using programs contained in Statistical Package for the Social Sciences (SPSS), e.g., R^2, $\bar{R}^2$, Durbin-Watson, standard errors of the estimated coefficients. In addition, we calculated the coefficient of variation used by Changnon and Neill to identify regions of the state with different degrees of weather dependent yield variability. The coefficient of variation is calculated as follows:

$$\text{Coefficient of Variation} = \frac{\sqrt{\text{Regression Mean Square}}}{\text{Mean Yield}}$$

As this coefficient of variation increases, it implies that more and more of the variation in the yield is explained by the variables included in the regression equation, in this case weather. The results from out analysis were then compared to the results of the earlier study using this coefficient of variation.

RESULTS AND DISCUSSION

Yield per acre was regressed on the eight weather variables previously used in the Changnon and Neill study. The results obtained from the present study are contained in table 1. The table indicates a number of interesting results, first across the counties studied there is a large amount of variation in the $\bar{R}^2$s and the $\bar{R}^2$s. The range in R^2 is from 0.26 for McDonough County in the West Crop Reporting District to 0.61 for St. Clair County in the Southwestern Crop Reporting District. The small R^2s indicate a need to reduce the number of independent variables. This has been done in subsequent analyses. This need for a reduction in the number of independent variables is also indicated by the limited number of independent variables that have statistically significant estimated coefficients. The Durbin-Watson statistics indicate a potential problem with serial autocorrelation, in most cases the statistic falls into the indecisive range for the test. This indicates the need to look at a new functional form, e.g., log linear or some other curvilinear form, or the use of generalized least squares. Across the estimated models in table 1, we see that there is extensive variation in the size of the estimated coefficients for the same variable across counties as well as variation in sign.

For example, the sign of July temperature (JLT) is negative across all the sites indicating that as average July temperature increases, all else held constant, that corn yields decline. However, the actual size of the estimated coefficient ranges from a low of −0.29 for McHenry County in the the Northeastern Crop Reporting District to a high of −6.79 in McLean County in the Central Crop Reporting District. Similarly for June temperature (JT) we find that the sign of the estimated coefficients is negative for all the sites except for McHenry County where it is positive and significant at the 10% level. Perhaps this is due to the fact that among the counties studied this county is located in the northernmost part of the state.

August precipitation (AP) is another example of variability in the estimated coefficients across the study counties. August precipitation is significant in Wayne, McHenry, Vermillion, St. Clair and Jackson Counties. Across the counties, August precipitation is positively related to yield except in McDonough County. In six of the sites we find that the positive effect of August precipitation is balanced by the negative effect of August temperature. Indeed, out next step is the development of a new variable capturing the joint effects of such variables.

Comparing the coefficients of variations from this study and the earlier one by Changnon and Neill (table 2), we find that for all the counties studied, there has been a significant increase in the amount of variability in corn yields attributed to the weather variables. Only for the case of Shelby County do we find that the new coefficient of variations is contained in the bounds reported by Changnon and Neill. For the other counties, there has been a marked increase, indicating the increased influence of weather variability on year to year yield variability. This can be taken as an indication of increased weather variability.

The weather events during the last 10-12 years suggest increased year to year variability compared to the years before. The Southern Leaf Blight during 1970, the early freeze during 1974 and the dry summer of 1980 caused large yield reductions. The 1960's, on the other hand, were generally favorable years for corn. Consequently, we can conclude that farmers in these areas are finding an increased portion of the variability in corn yields attributed to weather variation.

In the Changnon and Neill study additional regressions of both technology and weather factors with corn yields produced correlation coefficients above 0.88 in all counties. Table 3 shows the R^2s, $\bar{R}^2$s and Durbin Watson statisitics obtained in our updated study. The R^2s range from 0.77 for Wayne County (SE) to 0.91 for McHenry County (NE). The technology variable is significant for all the counties. July temperature is the most significant weather variable with the level of significance ranging between 1% and 10%. July precipitation is the next significant weather variable followed by August temperature and August precipitation. Six counties showed significant, estimated coefficient for July precipitation. Most of these counties are in the southern part of the state, e.g., Wayne (SE), St. Clair (SW), Shelby (ESE), Jackson (SW). The counties not in the southern part and showing a significant, estimated coefficient for July precipitation are McDonough (W) and McHenry (NE).

Similar observation can be made about August temperature. The counties with significant, estimated coefficients are Sangamon (WSW), Shelby (ESE), Jackson (SW) and Wayne (SE). The pattern agrees with the areas of high and low correlation found by Changnon and Neill. August precipitation does not show such regional differences; the counties with significant, estimated coefficients are

McHenry (NE), McDonough (W) and Wayne (SE). June temperatures show a significant effect on yield only in McHenry County whereas June precipitation shows significance for Wayne County (ESE) only. May temperature shows a significant positive relationship with yields at Sangamon (WSW) and Shelby (ESE) Counties. Although preseason precipitation shows a significant effect in McHenry (NE) and St. Clair (SW) Counties, the signs for the coefficients are opposite.

SUMMARY

Our analysis indicated that during the last thirty years there has been an increase in corn yield variability attributed to weather. This increase needs to be further verified by using other appropriate functional forms in the regression analysis. In addition, an effort must be made to move away from the use of monthly data and begin specifying weather variables that more closely approximating weather factors influencing yield throughout the growing season, i.e., a drought index, wet days and dry days, etc. Even given these limitations, the data indicate that farmers throughout Illinois have experienced greater variation in the yield of corn from weather factors than previously. This increase in variability influences the decisions farmers make with repect to crop management, marketing strategies, and on-farm investment. Consequently, farmers require strategies to help them minimize the negative effects of increased weather-dependent variability in corn yields.

LITERATURE CITED

Carter, H.O. and G.W. Dean, 1960. "Income, Price and Yield Variability for Principal California Crops and Cropping Systems." *Hilgardia* 30:175-218.

Changnon, Stanley A. and James C. Neill, 1967. "Variations in Corn-Weather Relations in Illinois." *Transactions Illinois Academy of Sciences* 60:221-230.

Jones, P.D., P.M.L. Wigley, and P.M. Kelley, 1982. "Areal Variation in Surface Air Temperature: Part I - Northern Hemisphere, 1881-1980." *Monthly Weather Review* 111(2):59-70.

Skaggs, Richard H. 1978. "Climatic Changes and Persistence in Western Kansas." *Annals of Association of American Geographers.* 68(1):73-80.

Thompson, Louis M., 1975. "Weather Variability, Climate Change, and Grain Production." *Science* 188 (4188):535-541.

Tintner, Gerhard, 1940. *The Variate Difference Method.* Bloomington, Ind.:Principia Press.

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Table 1. Results of Regressing Corn Yield Against Weather Variables for Ten Illinois Counties: 1951-1980.

	Independent Variables, Estimated Coefficients & Standard Errors									Regression Statistics		
Area & County	Intercept	MT	JT	JLT	AT	JNP	JLP	AP	SNP	R^2	$\bar{R}^2$	DW
Bureau NW	450.73	−0.23 (3.37)	−1.21 (1.55)	−2.67 (2.11)	−0.83 (1.60)	−1.45 (2.35)	−1.38 (3.37)	1.28 (1.48)	0.37 (0.92)	0.28	−0.00	1.17
McHenry NE	−76.75	0.74 (0.99)	1.81 (1.27)*	−0.29 (1.59)	—	2.82 (1.74)*	−1.53 (2.43)	3.01 (1.76)*	−0.20 (0.60)	0.29	0.06	0.66
McDonough W	455.63	0.36 (1.54)	−1.59 (1.84)	−2.02 (2.28)	−1.73 (2.40)	−1.03 (2.66)	0.88 (3.06)	−1.64 (2.63)	0.55 (0.87)	0.26	−0.02	0.69
McLean C	754.75	−0.56 (1.50)	−1.00 (1.78)	−6.79 (2.59)***	−0.33 (2.47)	−2.16 (2.32)	−3.82 (3.29)	0.42 (2.98)	0.42 (0.85)	0.34	0.09	0.91
Vermillion E	574.15	−1.12 (1.37)	−0.88 (1.72)	−4.27 (2.36)*	−0.51 (2.38)	−2.71 (2.40)	0.34 (2.24)	5.21 (2.25)**	—	0.35	0.14	0.97
Sangamon WSW	249.78	1.98 (1.46)*	−0.96 (2.00)	−0.88 (2.85)	2.54 (2.55)	−3.97 (2.60)*	0.87 (3.43)	—	2.33 (1.40)*	0.29	0.06	0.84
Shelby ESE	318.10	2.23 (1.69)*	−1.37 (1.92)	−0.81 (2.58)	−3.52 (2.77)	−3.11 (1.96)*	6.37 (3.16)**	1.53 (3.57)	1.08 (1.07)	0.40	0.17	0.74
St. Clair SW	444.80	0.41 (1.09)	−0.16 (1.27)	−2.10 (1.40)*	−3.63 (1.62)**	−2.05 (1.45)	4.36 (1.61)***	3.96 (2.58)*	0.96 (0.57)*	0.61	0.46	1.16
Wayne SE	512.49	−1.14 (1.24)	−0.45 (1.55)	−2.16 (2.05)	−2.78 (2.16)	−0.44 (2.19)	0.85 (1.87)	4.54 (2.22)*	0.36 (0.77)	0.41	0.19	0.94
Jackson SW	638.66	−1.21 (0.91)*	NS	−1.28 (1.72)	−5.27 (1.71)**	−1.99 (1.94)	1.41 (1.21)	2.49 (1.46)*	−0.13 (0.45)	0.57	0.44	1.24

Numbers in parenthesis are standard errors.
*10% level of significance.
**5% level of significance.
***1% level of significance.

Table 2. A Comparison of Coefficients of Variation in Two Studies for Two Different Time Periods.

Area	CV 1	CV 2
Bureau County (Northwest)	8-14	21
McHenry County (Northeast)	15-19	25
McDonough (West)	15-19	42
Vermillion (East)	15-19	32
Sangamon (West Southwest)	20-24	32
Shelby (East Southeast)	29-38	37
St. Clair (Southwest)	29-38	46
Wayne (Southeast)	29-38	45

CV 1: 1931-1963, from Changnon and Neill, 1967.
CV 2: 1951-1980, from present study.

Fig. 1. Yield of Corn in Bushels Over Time for Three Selected Counties in Illinois, 1951-1980

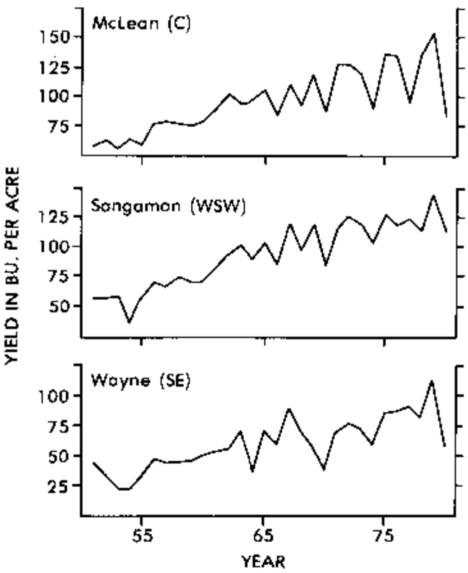
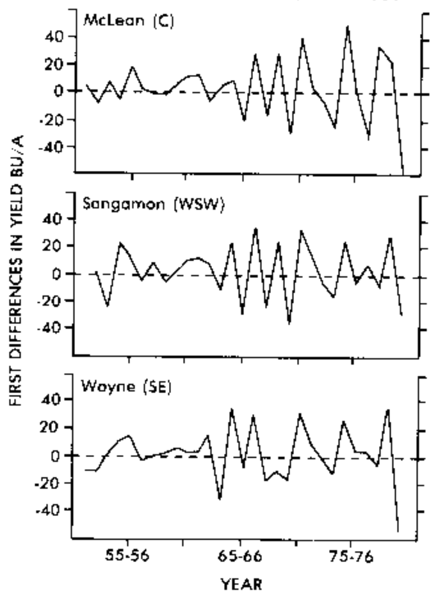


Fig. 2. First-Differences in Corn Yield Over Time for Three Selected Counties in Illinois, 1951-1980



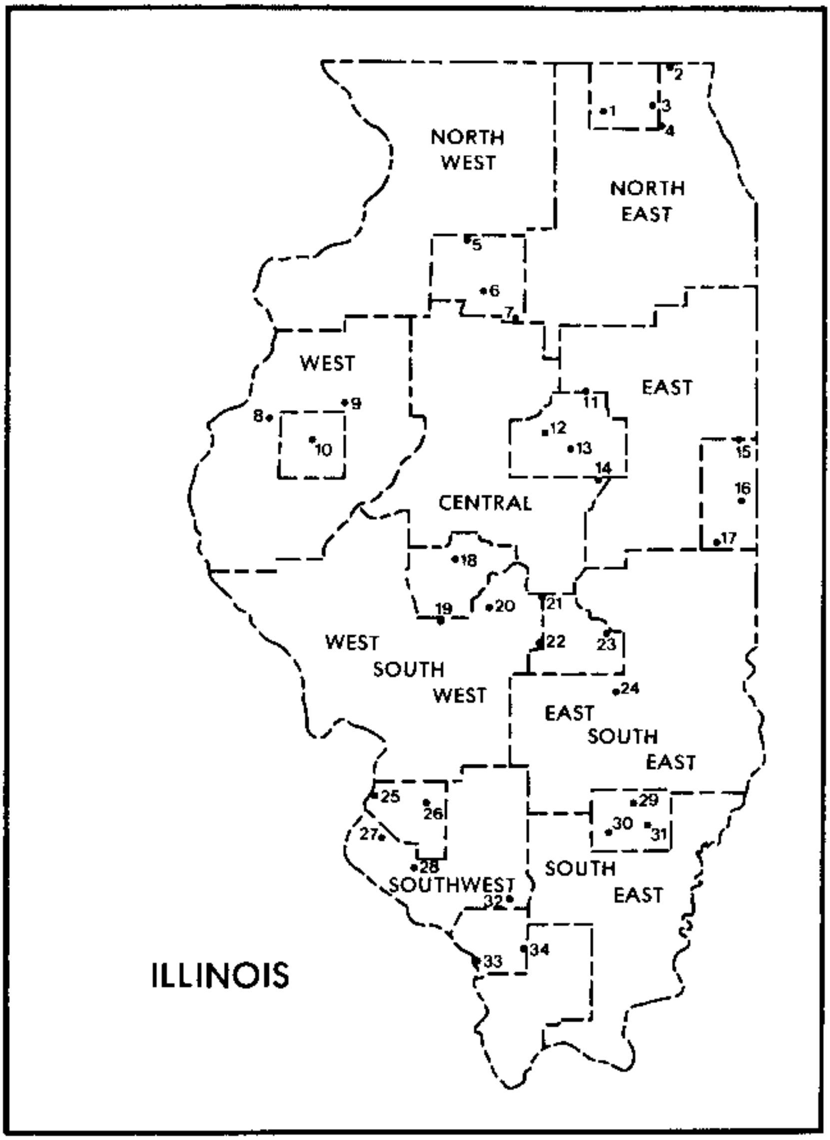


Fig. 3. Location of Study Counties in Illinois and Weather Stations Used For Data on Weather Variables

Key to Figure 3

Map Number	Names of Weather Stations
1	Marengo
2	Antioch 2 NW
3	McHenry Lock & Dam
4	Barrington
5	Walnut
6	Tiskilwa 2 SE
7	Hennepin Power Plant
8	LaHarpe
9	Macomb
10	Avon 5 NE
11	Chenna
12	Bloomington Water Works
13	Downs 2 NE
14	Farmer City
15	Hoopeston 1 SE
16	Danville
17	Sidell
18	Springfield WSO AP
19	Virden 1 N
20	Kinkaid
21	Mowengna
22	Pana
23	Windsor
24	Effingham
25	Cahokia
26	Belleville So. Ill. Univ.
27	Waterloo
28	Sparta
29	Cisne 2 ESE
30	Wayne City 1 N
31	Fairfield Radio WFIW
32	DuQuoin 4 SE
33	Grand Tower 2 N
34	Carbondale Sewage Plant

Table 3. Results of Regressing Corn Yield Against Technology and Weather Variables for Ten Illinois Counties: 1951-1980

	Independent Variables, Estimated Coefficients & Standard Errors										Regression Statistics		
Area & County	Constant	Tec	MT	JT	JLT	AT	JNP	JLP	AP	SNP	R^2	$\bar{R}^2$	DW
Bureau NW	100.81	1.32 (0.17)***	—	0.36 (0.82)	−1.45 (1.08)*	0.39 (0.82)	−1.14 (1.19)	−0.61 (1.69)	0.62 (0.75)	−0.17 (0.47)	0.81	0.74	3.03
McHenry NE	−4.50	1.29 (11.73)***	0.08 (0.22)	1.18 (2.51)**	−1.22 (2.07)*	0.51 (0.91)	0.67 (1.02)	1.58 (1.70)*	1.52 (2.30)**	−0.66 (3.00)***	0.91	0.87	1.97
McDonough W	−24.62	1.59 (0.17)***	0.52 (0.69)	0.55 (0.86)	−1.70 (1.03)*	1.47 (1.14)	−0.39 (1.20)	1.86 (1.38)*	−2.55 (1.19)**	0.09 (0.40)	0.86	0.79	2.02
McClean C	343.40	1.58 (0.19)***	—	0.21 (0.85)	−4.12 (1.27)***	−0.19 (1.06)	−0.82 (1.05)	1.13 (1.69)	−0.97 (1.27)	—	0.84	0.79	2.41
Vermillion E	323.69	1.61 (0.16)***	−0.48 (0.60)	0.45 (0.75)	−3.60 (1.05)***	−0.33 (1.03)	−0.58 (1.06)	1.09 (0.97)	0.97 (1.06)	−0.49 (0.38)	0.89	0.84	2.48
Sangamon WSW	197.59	1.95 (0.17)***	1.04 (0.57)*	—	−1.89 (1.04)*	−1.47 (0.98)*	−0.19 (1.00)	1.57 (1.28)	−0.18 (1.07)	−0.09 (0.56)	0.90	0.86	2.33
Shelby ESE	226.71	1.68 (0.17)***	1.43 (0.17)**	−0.14 (0.81)	−1.99 (1.08)**	−2.13 (1.16)**	−1.14 (0.84)*	3.33 (1.35)**	0.95 (1.48)	0.21 (0.45)	0.90	0.86	2.64
St. Clair SW	202.85	1.09 (0.18)***	0.66 (0.67)	0.53 (0.78)	−2.47 (0.86)***	−1.38 (1.06)	−0.91 (0.91)	3.55 (0.99)***	1.69 (1.62)	0.75 (0.35)**	0.86	0.80	1.64
Wayne SE	273.86	1.11 (0.20)***	−0.34 (0.81)	0.37 (0.81)	−1.80 (1.32)*	−1.88 (1.40)*	−1.59 (1.43)	1.97 (1.22)*	2.44 (1.48)*	−0.09 (0.50)	0.77	0.66	1.76
Jackson SW	419.69	0.86 (0.20)***	−0.60 (0.70)	0.71 (0.94)	−1.81 (1.31)*	−3.55 (1.35)***	−0.94 (1.51)	1.49 (0.93)*	1.02 (1.23)	−0.10 (0.34)	0.78	0.68	1.76

All values in parenthesis are standard errors.
* 10% level of significance.
** 5% level of significance.
*** 1% level of significance.