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Weather and corn production

Louis M. Thompson

Iowa State University

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Weather and Corn Production

CAEA Report 12

CENTER FOR AGRICULTURAL AND ECONOMIC ADJUSTMENT

IOWA STATE UNIVERSITY of Science and Technology

Ames, Iowa 1962
WEATHER AND CORN PRODUCTION

by

Louis M. Thompson

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and Professor of Agronomy

The Center for Agricultural and Economic Adjustment

College of Agriculture

Iowa State University
of Science and Technology

Ames, Iowa

1962
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Iowa Agricultural and Home Economics Experiment Station Project 1449
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FOREWORD

This publication contains a summary of studies of wheat, soybeans and grain sorghums, and a more detailed summary of a technical bulletin published by the Center For Agricultural and Economic Adjustment entitled "An Evaluation of Weather Factors in the Production of Corn," by Dr. Louis M. Thompson. The latter study is designated as CAEA 12T.

These studies are very timely because of the effect they might have on development of agricultural policy. They represent an exploratory effort to determine the significance of weather in the build-up of the feed grain surplus. Another important feature of these studies is the application of modern statistical techniques along with principles well known to physical and biological scientists in solving problems of great importance to the nation's agricultural economy. These studies point up the kind of contribution that can be made by combining the resources and techniques of the physical, biological and social sciences.

Given the magnitude of production control programs and foreign surplus disposal during the period, Dr. Thompson interprets the contribution of weather to the surplus build-up from 1957 through 1961. Studies of this nature are needed, along with those relating to food use in international development, to determine the sustained capacity of U.S. Agriculture and the likely demands on it in the decade ahead. Only then can we determine the extent of surplus capacity and the policies best adapted to it. For example, that portion of surplus build-up due to favorable weather might be best handled through storage programs; that due to other forces, by entirely different programs. Studies such as the one reported here provide an important foundation for selecting among relevant policy elements.

Earl O. Heady, Executive Director
Center for Agricultural and Economic Adjustment
The author has just completed four statistical studies dealing with the relation of weather to trends in yields of corn, grain sorghums, soybeans and wheat for the period, 1935-1961. The four studies embraced the eleven state area known as the Great Plains and the Prairie regions. The latter is also known as the Corn Belt. These eleven states, from North Dakota to Texas, and Iowa, Missouri, Illinois, Indiana and Ohio, produce a high proportion of each of the four crops named above.

The Great Plains and Prairie regions experienced a drouth period in the early fifties. The drouth period was followed by improved weather in 1956 and 1957. Then 1958 turned out to have the highest "crop-season" rainfall in recent history of these regions. The three-year period, 1959-61, also proved to be quite favorable for corn, grain sorghums and soybeans. The summer rainfall and temperature of 1961 were more favorable to corn and soybeans than in any other year from 1935 to 1961. The weather for wheat was relatively unfavorable in 1959 and better than average in 1960 throughout the Great Plains. The 1961 weather was relatively unfavorable to the spring wheat states of North Dakota and South Dakota, but was better than average for the winter wheat states in the Great Plains from Nebraska on south in the Great Plains.

The outcome of a drouth cycle followed by a favorable weather cycle has created a 10-year trend of increasing surpluses of wheat and feed grains, and a threat of a surplus of soybeans. The serious mistake being made is that of projecting yields several years into the future from the yield trends of the last 10 years. If one were to ignore weather and use a simple straight-line projection to measure the influence of improved technology, he would conclude that the average rate of increase in yields due to such improved technology during the period 1950-1961 was nearly twice that shown in this present study. But to ignore weather in this period would be serious.
years (1953, 1954 and 1955) in the Corn Belt that were followed by improved weather. To extend into the future a simple trend line drawn through yield data from 1950 to 1961 one would have to assume that weather will continue to improve at the same rate as it did from the early fifties to the late fifties. Such a view is very unrealistic.

The better than average weather of the Great Plains and Prairie regions since 1957 has caused the production of enough additional corn and grain sorghums to account for that which was added to storage after 1957.

Favorable weather in the Great Plains caused more than half the increase in stored wheat in the United States after 1957. It should be recognized that the United States uses only about half the wheat produced in this country, so the amount exported each year is a factor even more important than variation in yield caused by weather.

The feed grain production in the United States is almost in balance with domestic needs and foreign commitments. The recent studies of the author indicate that weather conditions have been a major factor in the build-up of the feed grain surplus. This is highly significant because the present feed grain surplus of about 75 million tons represents only half as much as we use in the United States in one year. This amount of surplus could disappear rapidly in another drought cycle.
INTRODUCTION

This statistical study was made to evaluate the relative effects of weather and modern farming practices in producing high yields of corn in the Corn Belt states of Iowa, Illinois, Indiana, Ohio and Missouri in recent years. These states produce about half the corn grown in the United States. Significantly, corn accounts for about 70 percent of the feed grains produced in the United States and about a fourth of all the cultivated crop land in the country.

The years 1935 to 1961 were selected for study since corn yields started climbing at a significant rate in 1935. Farmers began growing hybrid corn in that year and by 1945 nearly all corn planted in the Corn Belt was from hybrid varieties. In fact, most of the yield increase from 1935 to 1945 can be attributed to hybrid corn varieties. The year 1945 marked the beginning of a rapid increase in the use of nitrogen fertilizers in corn production. Thus most of the increase in yield since 1945 due to improved technology can be attributed to fertilizers, especially after 1950. Improved cultural practices, especially timely operations in the spring, have contributed significantly to increased yields throughout the period of study. They were particularly influential from 1945 to 1950.

A statistical method known as multiple regression was used to differentiate between the variables selected for study. All of the factors of improved technology were found to be effective over a period of years in giving a fairly steady increase in yield per acre. Therefore, "time" (shown as years) was used in the regression equation to represent technology. It was found that with the passage of time yields increased approximately in a straight line or linear fashion.
The weather variables selected for the initial study were June rainfall, June temperature, July rainfall, July temperature, August rainfall and August temperature. The analysis, therefore, was that of the relative effects of time and the weather variables on the yield of corn in each of the five states.

The five states were analyzed separately for two reasons: (a) This method permitted comparison of results from state to state. Thus, if the studies of each of the five states gave similar results, one could have greater confidence in the general conclusions drawn from the overall research project. (b) It was expected that the influence of weather on corn yields might vary from state to state because of the range in climate from western Iowa to eastern Ohio and from northern Iowa to southern Missouri.

RESULTS OF THE INITIAL STUDY

Table 1 shows the regression coefficients for each of the seven variables for each state. These coefficients are useful in comparing the effects of the various weather factors on corn yields. The coefficients are particularly interesting in that they indicate the rate at which improved technology has been adopted over a 27-year period in each state. Each coefficient is an expression of the effect of the variable in bushels of corn per acre. For example, under the column labelled "time" for Illinois, .77 means an average annual increase of 77 hundredths of a bushel of corn per acre. The 2.65 under "July rainfall" means that one inch of rainfall above average in July increased the yield by 2.65 bushels per acre. The -.87 under "July temperature" means that one degree of temperature above average in July caused a reduction of .87 bushels of corn per acre.
Table 1. Regression Coefficients for Time (for technology) and the Weather Variables.

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<tbody>
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<td>Illinois</td>
<td>.77</td>
<td>-.93</td>
<td>.18</td>
<td>2.65</td>
<td>-.87</td>
<td>.41</td>
<td>-.68</td>
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<tr>
<td>Indiana</td>
<td>.68</td>
<td>.33</td>
<td>.11</td>
<td>1.78</td>
<td>-.53</td>
<td>-1.41</td>
<td>-.79</td>
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<tr>
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<td>.63</td>
<td>-.50</td>
<td>.84</td>
<td>2.55</td>
<td>-.32</td>
<td>.33</td>
<td>-.61</td>
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<td>Missouri</td>
<td>.72</td>
<td>-.125</td>
<td>-.30</td>
<td>1.72</td>
<td>-.91</td>
<td>-1.32</td>
<td>-1.46</td>
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<tr>
<td>Ohio</td>
<td>.91</td>
<td>-.13</td>
<td>.21</td>
<td>2.27</td>
<td>-.26</td>
<td>-.33</td>
<td>-.53</td>
</tr>
</tbody>
</table>

The best summer weather for growing corn in Iowa and Illinois appears to include warmer than average June temperature but cooler than average July and August temperature. Higher than average July and August rainfall seems to increase yields of corn, but higher than average June rainfall appears to depress such yields.

Corn in Indiana appears to be favorably affected by higher than average June rainfall, June temperature and July rainfall. It is unfavorably affected by higher than average temperature in July and August, and also by higher than average rainfall in August.

Corn in Missouri is favorably affected by higher than average rainfall in July. It is unfavorably affected by higher than average rainfall in June or August and by higher than average temperatures in any summer month.

In contrast with Missouri, Ohio corn is favorably affected by higher than average temperature in June and July. Best weather for corn in Ohio appears to include higher than average July rainfall and lower than average August temperature.
THE SIGNIFICANT WEATHER VARIABLES

Table 1 indicates that July rainfall stands out as the most important weather variable in all five states. The results of this study are consistent with the findings from other studies published over a period of many years--i.e., that July rainfall is the most critical factor in corn production in the Corn Belt states. Figure 1 shows that July and early August are the periods when rainfall is generally deficient for high yields of corn in the five states studied. The figure shows that more rainfall generally occurs in June than can be fully utilized in that month. If the extra moisture in June drains down into the subsoil, it may help tide the crop over the deficit period in July. The problem, however, is that rainfall may occur in excessive amounts over a short time in June and thus not contribute substantially to the supply of subsoil moisture. It is recognized that if more than average rainfall occurs in early August, it is about as beneficial as more than average rainfall in July. This study does not demonstrate this fact, however, since all of the August rainfall is averaged together for each state.

There are two critical periods in the production of corn insofar as high yields are concerned. One is silking time, which occurs around the last week in July or first week in August. The other is the "grain filling" stage, occurring around the last of August. A moisture deficiency at silking time is much more damaging than one occurring before or after silking. High temperatures are quite damaging in late August, when the ears are "filling out."

This study indicates that the weather variables that are most important, and stand out for all states of the Corn Belt, are July rainfall and August temperature. July temperature appears to be an important variable in Iowa, Illinois and Missouri. June temperature is lower in Iowa than in other states of the Corn Belt. In other words, higher than average June temperature is
FIGURE 1. WATER REQUIREMENT CURVE FOR CORN IN RELATION TO SUMMER RAINFALL IN 5 CORN BELT STATES
desirable in Iowa; cooler than average July temperature is desirable in Iowa, Illinois and Missouri; cooler than average August temperature is desirable in all states of the Corn Belt. June and August rainfall is of little significance in explaining yield variation of corn in the Corn Belt states.

Early studies of weather factors in corn yields beginning around 1910 assumed straight line relationships—that each additional inch of rain above average in July, for instance, would increase yields as much as the first inch of rain in that month. But this assumption is not correct. Statistical studies assuming such a straight line relationship are useful only in explaining what might happen with a small deviation from average, such as shown in Table 1.

Thus an additional study was made using a more complex statistical method known as multiple curvilinear regression. When corn yields were plotted on graph paper against either rainfall or temperature data by this method a more meaningful picture of the situation was obtained—i.e., curves with smoothly rounded peaks indicating the optimum average rainfall or optimum average temperature for any month for any state.

These curves show the optimum average monthly temperatures for corn are 73° F. in June, 75° F. in July, and 72° F. in August. Six inches of rainfall in July appears to be optimum for Ohio and Indiana, but somewhat more than six inches would be optimum in the western part of the Corn Belt.

The summer weather of 1961 was more nearly optimum for corn than in any other year from 1935 to 1961. The rainfall in July of 1961 and the temperature in August of 1961 were nearly ideal for corn in all states of the Corn Belt. The odds for another year in the near future like 1961 are extremely small.
THE RELATION OF RECENT WEATHER CONDITIONS TO
THE BUILD-UP OF FEED GRAIN SURPLUS

The rapid introduction of improved technology from 1950 to 1956 (primarily the increase in use of nitrogen fertilizers) was associated with favorable prices of corn. Even though 1953 was a dry year, fertilizer consumption in 1954 was high because of the publicity given to the advantage of fertilizers in the dry year of 1953. The year 1954 turned out to be a drought year, particularly in the western part of the Corn Belt, and fertilizers were less effective than in 1953 because of dry subsoils at the beginning of the growing season. The year 1955 was also unfavorable. During the 1953-55 period, when weather was relatively unfavorable, the rate of utilization of feed grains as livestock feed was somewhat retarded because of the high prices for corn (around $1.50 per bushel) in relation to prices of livestock products. After the support price on corn was reduced after 1955, there was a marked increase in the rate of utilization of feed grains, but the weather conditions continued to improve. The outcome was a relatively small addition each year to an already large carry-over. Figure 2 shows this relationship.

The years 1958, 1959 and 1960 were very favorable for the growth of corn in all of the five states in this study. The actual yields after 1957 were generally higher for all five states than the upward trend in yields projected on the basis of improved technology alone. The weather of 1958 was almost as good as in 1961. July rainfall totalled 7.55 inches in Iowa in 1958 and even more than this in the four other Corn Belt states. There was little deviation from average summer rainfall and temperature in 1959 and 1960. The pre-season moisture was generally quite favorable, however, and the rainfall was generally well distributed over time throughout the Corn Belt. There were no large areas of the Corn Belt with moisture stress during the critical part of the growing season. The outcome was a combination of desirable growing conditions. The
FEED GRAIN PRODUCTION
AND ITS UTILIZATION
1938-1960

SHADED AREA WAS SURPLUS

EXPORT

FEED FOR LIVESTOCK

USED FOR SEED, FOOD AND IN INDUSTRY

FIGURE 2. DATA FROM 1962 U.S.D.A. OUTLOOK CHARTS
BASED ON CROPS HARVESTED FOR GRAIN
difference between trend-line yields and actual yields resulted in a production of about 7.2 percent more corn due to favorable weather from 1958 to 1960 inclusive. This was more than the amount added to the surplus from these Corn Belt states in the three-year period.

This phase of the study indicates that weather factors were partially responsible for the build-up of feed grain surplus during the period 1958-60. This concept is in contrast with the belief that an "explosion of technology" occurred during the decade of the 1950's. If one were to ignore weather and use a simple straight-line projection to measure the influence of improved technology, he would conclude that the average rate of increase in yields due to such improved technology during the period 1950-1961 was nearly twice that shown in this present study. But to ignore weather in this period would be serious. There were three drought years (1953, 1954 and 1955) in the Corn Belt that were followed by improved weather. To extend into the future a simple trend line drawn through yield data from 1950 to 1961 one would have to assume that weather will continue to improve at the same rate as it did from the early fifties to the late fifties. Such a view is very unrealistic.
DIFFERENCES IN WEATHER BETWEEN
1960 AND 1961

The 1961 growing season was extremely favorable for corn. The deviations from averages were generally favorable. The difference between July rainfall in 1960 and 1961 was the most important factor in causing higher yields in 1961 than in 1960. Table 2 has been included to show the differences in summer rainfall and temperature between 1960 and 1961. The differences in July rainfall were 1.16, 1.28, 2.48, 2.76 and 2.82 inches for Indiana, Ohio, Missouri, Iowa and Illinois respectively. This study has shown that in the range from three to six inches of rainfall in July, an additional inch of rainfall in July would increase yields about 2.5 bushels on the average in the Corn Belt. Of course, if the inch of rain occurs late in July, it boosts corn yields most-- about five bushels of corn for each additional inch of rain.

The second most important difference between weather conditions of 1960 and 1961 was the cooler August temperatures. The August temperatures were cooler in all five of the states in 1961 than in 1960.

Table 2. Averages of Monthly Rainfall (inches) and Monthly Temperatures (degrees F.) for the Period 1935-61 Compared to the Corresponding Data for 1960 and 1961

<table>
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<td>Illinois</td>
<td>1935-61</td>
<td>4.46</td>
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<td>3.58</td>
<td>76.5</td>
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<td>1960</td>
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<td>73.9</td>
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<td>1960</td>
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<td></td>
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<td>4.66</td>
<td>73.8</td>
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<td>1935-61</td>
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<td>74.9</td>
<td>3.81</td>
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<td></td>
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<td>3.91</td>
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<td></td>
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<td>5.07</td>
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Table 3 shows the differences due to the weather variables compared with differences due to other variables between 1960 and 1961. These differences were calculated from multiple curvilinear regression equations. While the average rate of introduction of technology has been causing an increase of nearly a bushel per acre per year in the Corn Belt states in the period 1935-60, Table 3 indicates an increase from 1960 to 1961 of two to three times the average rate. This is not at all unrealistic for 1961 in view of the fact that the Feed Grain Program was started in 1961. It is generally recognized that farmers attempted to increase their yields in 1961 in view of a promised increase in price of corn compared to 1960; that is, if they reduced acreage. Some increased their rates of planting. Those accustomed to using fertilizers increased their rates of application on the acreage planted. These two factors were undoubtedly important in 1961. With smaller acreages farmers could select their better land for corn and take care of farming on the reduced acreage on a more timely basis.

By weighting the yield increases from Table 3 by the acreages of corn grown in each state, it was calculated that 66 percent of the increase in yield in the five Corn Belt states from 1960 to 1961 was caused by improved weather conditions in 1961 as compared with 1960.