ERS-72

Measuring the Effects of WEATHER on Agricultural Output

PROCEDURES FOR CONSTRUCTING WEATHER INDEXES

Farm Economics Division
Economic Research Service
U. S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENT

The weather is of professional interest to many researchers dealing with agricultural problems. The authors wish to thank, in addition to their many colleagues in the Farm Economics Division who provided help and advice, the agronomists and meteorologists who assisted in this study.

Glen T. Barton, Farm Economics Division, Economic Research Service, gave invaluable assistance to the authors at all stages of the study. L. A. Tatum, Crop Research Division, Agricultural Research Service, and research workers in his branch, and C. D. Hutchcroft and R. H. Shaw, Iowa State University, gave assistance as to sources of data.

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Washington, D. C. October 1962

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SUMMARY

How much of the dynamic increase in agricultural output in recent years is due to weather and how much to technology? Researchers and policymakers in agriculture have long struggled to analyze these forces separately, but year-to-year variation in yields due to weather obscures the changes due to improvements in technology. This study presents a procedure for separating the effects of these two factors in a changing agricultural output.

When we talk about weather in agriculture, we are interested in the net influence of all meteorological and closely associated factors on output. Weather and technology, therefore, are defined in their broadest sense. Weather is those conditions of the crop-growing environment that are beyond the control of farmers; technology is the sum total of controllable resources and how they are used.

Weather indexes for corn yields and production in Iowa from 1929 to 1960 were constructed using a plot data approach. State indexes were developed by aggregating weather indexes for individual Crop Reporting districts. The weather indexes were used in adjusting for the influence of weather the State and district actual yields per harvested acre and total production of corn. Variation in the adjusted yield series is an estimate of the effect of changes in technology.

The series of adjusted corn yields for Iowa, 1929-60, indicates that improved technology increased yields in two steps. Yields from 1929 to 1935 were relatively stable. Beginning around 1935, corn yields increased rapidly until the early 1940's. This was the period marked by the rapid acceptance of hybrid seed corn. Less than 1 percent of the corn acreage in 1933 was planted with hybrid seed; the percentage increased to nearly 99 by 1942. Corn yields remained at the new level throughout the 1940's and early 1950's. Then about 1954 a second period of yield increase began. This second increase does not appear to be due to any single factor but to a combination of improved practices such as increased use of fertilizer and higher planting rates.

Indexes were constructed for only one crop and one State in this study. However, the procedures can be used to construct weather indexes suitable as deflators for single and aggregate measures of crop production now published for farm production regions and the United States.

Although the purpose of constructing weather indexes in this study is to separate the effects of weather and technology in aggregate agricultural output measures, the indexes per se are valuable research tools. They provide a measure of the "what" of weather which can be used in investigating the "why," the cause-and-effect relationships between individual meteorological factors and crop production. The indexes may also be used to study climate. They provide a measure of variability in agricultural output due to the influence of weather. Another use of weather indexes is in measuring the yield effect of a changing weather-technology interaction. With technological advances of the last generation, man is now able to control a greater portion of his crop-growing environment than he could in 1930. In Iowa it appears that improved technology has reduced the effects of bad weather on corn yields but has not yet capitalized on good weather.

MEASURING THE EFFECTS OF WEATHER ON AGRICULTURAL OUTPUT
Procedures for Constructing Weather Indexes

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BACKGROUND

From the beginning of civilization the weather has caused men to prosper, fail, and be puzzled. The ancient Egyptians were plagued with hail and droughts, and great famines have decimated populations. Though these major calamities are no longer commonplace, weather is still of first order in agricultural problems.

For about a century the cause-and-effect relationships between crop production and weather have been the subject of much research. Agronomists have sought to understand the ways in which plants react to the environment and our knowledge has been greatly expanded in this area. Economists and statisticians have also delved into these relationships using correlation techniques. All these efforts have been directed at making the farmer better able to deal with his environment.

In recent times, there has been another interest in the influence of weather on crop production. With Keynes, aggregate economic analysis evolved. This aggregate perspective now plays an important role in the study of the economics of agriculture. Today, the U. S. Department of Agriculture regularly publishes aggregate measures of farm outputs and inputs to aid in understanding the changing agricultural picture. It is only with this total picture in mind, the net result of the actions of many individuals, that proper policy decisions in agriculture can be made. But here too weather is of major concern.

In annual economic data there are two elements of variation -- random and nonrandom. Economists are usually interested in studying the nonrandom elements of variation, those elements which show changing structural relationships over time. It is assumed that the random variation is distributed normally and will average out to zero in the long run. Years in which the random variation has been especially great are generally excluded from analysis. War years, for example, are often excluded. In agricultural studies, the major drought years, 1934 and 1936, are often excluded for the same reasons.

Weather is one of the causes of random variation. In most industrial economic studies, it does not influence the data enough to obscure the effects of the nonrandom elements. In agricultural studies, however, the random variation in the data is frequently greater than the nonrandom variation. Structural changes are covered up by the year-to-year fluctuations caused by the weather.

Many measures have been developed for studying the nonrandom elements of variation when the random variation is small. When the random variation is far from small, these measures are not as easily used. The logical step in trying to get around this problem is to somehow remove variation due to weather before studying the other factors causing variation. The most frequently used method has been to present data in the form of moving averages. A moving average will smooth out much of this random variation.

Unfortunately, moving averages long enough to smooth weather variation also smooth variation due to nonrandom factors. In the past we have had to compromise, analyzing only broad sweeps but being able to remove part of the random variation due to weather.

With the advent of massive multiple correlation studies in the 1950's came another way to account for the weather variation. In these studies, a weather variable is introduced to explain that variation which is left unexplained by the other variables. This weather variable is usually a rainfall measure, or perhaps a measure of temperature and rainfall at a critical period. The difficulty here is that the researcher attempts to explain the variation due to weather by a limited number of factors which go to make up the weather.

Still more recently, J. L. Stallings in his thesis research developed indexes of the influence of weather using a plot data approach. 1/ The method, which was used earlier by G. L. Johnson (3) and D. E. Hathaway (2), is essentially this: From experiments where practices have been controlled, year-to-year variation in yield data is due primarily to weather. 2/ A trend is fitted to the data to describe the yield effect due to changes in factors which were not held constant, such as soil conditions or changes in farming practices. The influence of weather is then measured in each year as that year's actual yield as a percentage of the computed trend yield. 3/ For example, if for 1930 the trend yield is 40 bushels per acre and the actual yield 50 bushels, the weather effect would be measured as 125. In other words, yields in 1930 were 25 percent higher because of favorable weather. This percentage can be expressed over time as an index. A weather index value of 100 would indicate a year where the trend yield and actual yield are identical. This corresponds to "normal" or expected weather, a long-term average of weather conditions.

1/ Indexes of the Influence of Weather on Agricultural Output. Unpublished Ph. D. thesis, Michigan State University, 1958.

2/ Underscored numbers in parentheses refer to items in the Literature Cited, p.30.

3/ This concept is by no means revolutionary. H. A. Wallace computed least-squares trends for State yields of corn in the Corn Belt and then took the percentage deviation of actual yields from trend yields to measure the influence of weather on corn yields. Wallace's purpose was to correlate meteorological factors with yields, and this percentage deviation was used as the yield measure. See page 439, Monthly Weather Review (6).

In this study, the feasibility of constructing weather indexes on a comprehensive scale using a modification of Stallings' approach is investigated. For an empirical appraisal of the methodology of measuring yield variation due to weather, a pilot study of limited scope was undertaken. Eventually, it is hoped that weather indexes for yields and production of individual crops and of all crops can be developed. The indexes would be most useful if developed and kept up to date for farm production regions and the United States.

If such indexes could be computed for these aggregate measures of crop production, a major advance in the analysis of agricultural output would be made. The indexes, if properly constructed, could be used to adjust for the influence of weather. We would then be able to adjust output series for weather in the same way that current dollar series are now deflated for changes in price. Thus, we could compute adjusted output series which would show the effects of changing technology. For example, in 1960 we can speculate on whether recent yield increases, especially in feed grains, are due to a rapidly advancing technology or just to good weather. The policy implications of answering this question are direct and decisions seeking adjustments in agriculture could be made with much more surety.

Projections of aggregate measures of yields and production is another area of analysis where weather indexes would be useful. Past projections of yields have been severely handicapped by the influence of weather. Projections based on least-squares trends can be particularly misleading if the trend is computed for a period which has poorer than average weather at one end and better than average weather at the other.

In addition to these uses in improving aggregate economic analysis, there would be many byproducts of the construction of weather indexes on a comprehensive scale, uses which would aid weather researchers generally. If a measure of the influence of weather on crop yields and production were available, then researchers could have a better base to work with in investigating the "why" of weather, the cause and effect relationships of the individual meteorological factors, the knowledge of which would help farmers to better adapt to the environment. A second byproduct is the use of weather indexes to compare weather over time and over locations. Such questions as, "Does climate cause cotton production to vary more in the Delta than in the Southeast?" could be answered more precisely if weather indexes were available. A third byproduct, which was developed in the study reported here, is a procedure for measuring the effect that technology has had on yield variation due to weather.

MEASURING THE INFLUENCE OF WEATHER

Weather is a most ambiguous word. A dictionary defines weather as "the state of the air or atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness, or any other meteorological phenomena."4/ Weather covers a multitude of things.

Many people make a distinction between climate and weather. Climate refers to the average conditions of the air or atmosphere over a period of years, while weather refers to individual year-to-year or day-to-day variation in these conditions. The distinction, though rather artificial, is a useful one. Weather then refers to the conditions of the atmosphere in relation to what one would expect on the average.

4/ Webster's New Collegiate Dictionary, 1957, p. 969.

Because of the many components of weather a standard of measurement, a common denominator, is needed. We could convert individual factors to inches of rain or create a new unit of our own. But when we talk about weather in agriculture we are really interested in the net influence of weather on output. We do not care about inches of rain or degrees of temperature or velocity of wind but rather whether these factors combine to hurt or help potential agricultural output. An appropriate standard of measurement, then, is the effect which weather has on crop yields and production.

Rainfall and temperature have been used synonymously with weather, partly because they are the dominant meteorological influences on yields, and partly because the data are readily available. But there are many other factors that go to make up weather. Light intensity is one factor which affects growth, and wind, which affects evaporation and transpiration rates, is another. A comprehensive weather measure should include these factors.

There are also many factors affecting yields which, though not conditions of the atmosphere, are so closely associated with weather that it is impossible to separate their effects. Insect infestations and disease epidemics often occur only in certain meteorological conditions. Grasshoppers, for example, are rampant when it is hot and dry, and certain varieties of rust which affect small grains cause damage only in cool, moist weather.

What then would an ideal indicator of the influence of weather measure? It would measure the effect on yields and production of the many meteorological and other factors closely associated with them. In a sense, it would be an indicator of the yield effect of the uncontrolled elements which farmers have to face. In addition, an ideal indicator would allow for adjusting actual yields or production for annual deviations in weather.

Weather is only relevant to the level of technology that exists at each point in time. As man makes technological advances, he is able to bring more and more of the environment under his control. For example, in 1930, a 20-percent downward deviation from average rainfall may have cut yields 50 percent. In 1960, the same deviation may only cut yields by 25 percent because of improved varieties, methods of cultivation, and so on, used generally by farmers. In other words, the environmental conditions beyond the control of the farmer are different in 1960 from what they were in 1930.

In measuring weather there are two other important considerations. First, weather is relevant to a specific crop. We know, for example, that the meteorological conditions which are good for cotton are not good for oats. Second, weather is relevant to a specific area. Weather varies considerably from location to location, even within a State and certainly between States. Extremely good weather at location A may offset some bad weather at location B, so that the average for locations A and B might be good. Geographical compensation then is a particularly important facet of the development of a weather index. Thus, individual weather measures or weather indexes must be developed for single crops grown at single locations. These indexes then become building blocks for indexes which will represent combinations of crops or locations.

How then can an indicator of weather influence be developed? A method that has great appeal to some is one that generates a weather measure from a function containing all meteorological and closely associated factors. In this case, parameters would differ by crops and locations. However, in using component weather factors we have been handicapped by our limited knowledge of the cause-and-effect relationships and by the difficulty of identifying all the factors. To avoid these complicated problems, a plot data approach seems to be an appropriate alternative. It measures the net effect of weather on yields without specifying the component weather factors. It has the additional advantage that the methodology used for one crop and location is applicable to all crops and locations.

Let us look more closely at how a weather index using plot data would be constructed for one crop at one location. For the location we would have basic yield data for the crop in question. These data would be continuous over a period of years. The technological level of the farming used to grow the crop in each year would approximate the average level of the area to be represented. A secular trend may be used to measure the yield effect of changes in this technological level. To derive the weather index, the actual yield in any year would be divided by the trend yield. The ratio would be the measure of weather for that year. A ratio of 110 says that yields were 10 percent higher than expected in that year because of favorable weather. Thus over time we would have a series of values indicating the percentage effect on yields of the crop which weather caused at that location.

We would ideally want such a weather index for every location where the crop is grown. Obviously this is not realistic and the index from one location would be used to represent a larger area. The Crop Reporting districts are convenient areas. 5/ For each district, then, a weather index would be constructed. These weather indexes would be weighted and combined into weather indexes for aggregates of districts (States, farm production regions, United States, or other regions, depending on the eventual use). The appropriate weights are volumes of production of the crop in question. Because actual production in any year is a function of the weather in that year, these production weights would have to be adjusted for weather. 6/

5/ In 1928, each State was divided into Crop Reporting districts. These districts, which are used by the Department of Agriculture in statistical reporting, are divisions used generally in agriculture. The Weather Bureau, for example, uses almost identical divisions.

6/ The following numerical example shows how this bias enters in the weighting system. Assume that in a given year the weather index for location A is 100 and that for location B is 200. Production weights are used to combine the two indexes. The production potential of both locations is 50 million bushels. Because weather in location B is favorable, actual production for location B is 100.

Location	Weather index	Potential production	Actual production
A	100	50	50
B	200	50	100

The weighted index using actual production weights would be 167. If weighted by potential production (that is, with weather neutral), the resultant index would be 150.

Similar indexes could be developed for other crops. Combining the weather indexes for several crops requires a system of weights (one cannot add wheat and apples directly). Indexes which would indicate the influence of weather on groups of crops would be feasible only for farm production regions or larger areas.

Now that we have gone through the procedure for constructing weather indexes for aggregate crop production measures, let us look back at what would be required for the development of these indexes on a large scale. First, appropriate yield data for major crops and for many areas over the country are needed. Second, production and weights are needed to combine the indexes for individual crops at individual locations.

It does not appear as difficult to meet these two requirements as one might think. Taking the second one first, the raw data for the weighting system are already available from the Department of Agriculture (the Statistical Reporting Service, and the Farm Economics Division of the Economic Research Service). As for the first requirement, a preliminary investigation on our part has indicated the availability of a vast store of appropriate data. These data come secondhand from the many experiments conducted by the State Experiment Stations and the U. S. Department of Agriculture. The compilation of these data is a major task in developing a comprehensive set of indexes of the influence of weather on crop production.

METHODOLOGY USED TO CONSTRUCT INDEXES OF THE INFLUENCE OF WEATHER ON CORN YIELDS AND PRODUCTION IN IOWA

In order to appraise the methodology used to construct our weather index and its practical application, a pilot study of limited scope was undertaken. In this pilot study, indexes of the influence of weather on corn yields and production in Iowa, 1929-1960, were constructed.

Admittedly Iowa does not have the most heterogeneous climate in the United States. Nor are all the problems of collecting data for the construction of weather indexes likely to be encountered in Iowa. Because this is a study in methodology, it was felt that using corn in Iowa would present most of the general problems which would have to be faced without offering some of the cases, which, considering the country as a whole, would be extremes. As in all studies of wide geographical scope, particular problems will be faced in particular areas, either because of the inapplicability of a general technique or because of data limitations.

The techniques used here represent the practical application of the theoretical constructs set up in the preceding section. One never attains an ideal but rather approximates it. This pilot study shows how such an index would actually be constructed. Similar indexes could be constructed for other crops. Combining indexes for several crops is not a major problem, as the same weighting system currently used for the farm output series is applicable.7/ The methods used to build up a State weather index are the same as those which would be used to build up regional or national indexes.

7/ The farm output series is published annually in Changes in Farm Production and Efficiency, U.S. Dept. Agr. Statis. Bul. 233.

The first requirement in constructing a weather index by the plot data approach is a set of yield data for the crop in question. The available data vary between two extremes. These extremes are:

A. Yields from check plots where all practices have been held constant. Here the same variety of the same crop was grown using the same methods over time. Yield changes are due to (1) weather, and (2) changes in soil conditions due to the particular treatment.

B. Crop Reporting Board data on actual yields. Here everything is free to vary over time. Yield changes are due to (1) weather; (2) changes in soil conditions; (3) changing acreage; (4) changes in farming practices and in varieties; (5) changing Government programs and economic conditions; and (6) changes in reporting accuracy.

In the first extreme it can be assumed that the yield variation due to changes in the soil is gradual and can be removed by a trend. Changes in yield due to weather can then be measured as deviation from trend yield values. Weather thus measured is relevant only to the level of technology of the experiment. Thus, the result is a weather measure which has no real meaning by itself. Such a weather measure could not be used as a deflator because it would overdeflate as technology made it possible to control more elements of the environment.

Geographical coverage is another drawback in using check plot data. These data, normally from fertilizer or rotation experiments, usually represent only one location within the State.

In the second extreme the weather which is being measured is relevant to the current level of technology and is therefore a meaningful indicator of the uncontrollable elements in the environment. The problem in dealing with this extreme is the removal of the effect of other factors. It cannot be assumed that yield variation due to these other factors is gradual. An abrupt increase may be due to a sudden rise in the use of a yield-increasing input. Such abrupt increases would show in the index as weather variation. Changing acreage patterns may be a particularly important source of yield change (1). Perhaps this effect could be removed by a trend; if not, it would be ascribed to weather.

Important also in using actual yield estimates would be the fact that it is the trend, derived by crude means, which is really being described rather than weather (weather effect would only be deviation from trend). Using experimental plot data we have more assurance that a trend can be removed by simple techniques. Here there is enough control of the experiment to prevent most of the possible abrupt changes in yields. Also because we are dealing with one resource base, a simple trend is more appropriate. When many resource bases are combined, as they would be in Crop Reporting Board (CRB) data, the appropriate average trend may be more complex and less adaptable to simple techniques of trend removal.

The one outstanding advantage of using actual yield estimates is geographical coverage. These data are available for the Crop Reporting districts and afford almost ideal representation of important weather and crop areas.

A compromise between these two extremes would be the use of data from variety yield tests. The tests are, for the most part, conducted under actual farming conditions. The cooperating farmers prepare the plots and cultivate them in the same way that they treat the rest of their fields. Planting and harvesting are done by research workers. Plots are chosen to represent soil types in the area and a continuity in management is approximated. Yield variation is thus due to two broad factors: Weather, and changes in technology (varieties, tillage methods, fertilizer application, changing soil conditions, and management).

If changes in technology on the cooperator's farm are assumed to be gradual, the influence of weather can be measured as deviation from trend. Weather so measured would be approximately relevant to the current level of technology.

If the cooperators happened to be better-than-average farmers, weather in each year would be relevant to a technology level which would be attained generally a few years hence. The weather measure would have a slight predictive element when used to deflate CRB estimates of actual yields. If meteorological weather in the 1960-70 decade is similar to what it was in the 1950-60 decade, by extrapolating the 1950-60 trend to 1970 we are likely to have an estimate of yields with compensation for any change in the weather-technology interaction. 8/ The weather index would be, of course, less accurately a description of weather effect in the current year.

The important question is whether a trend can describe the variation in yield due to changes in technology. In the yield tests there is relative constancy of soil type and management. As harvesting and planting are done by hand, there are five factors which would vary from year to year: (1) Varieties used; (2) cultivation techniques; (3) fertilizer application; (4) other technology on the cooperator's farm or in the experimental design; and (5) soil conditions. Each of these factors is discussed below.

(1) Using the mean yield of all varieties tested, we can assume that the effect on yields of a changing group of varieties is gradual and may be removed by trend.

(2) Changes in cultivation (particularly the trend to limited cultivation) may occur and affect yields. However, since these changes affect soil moisture and moisture reserves, they are likely to have a gradual effect on yields and one that can be removed by a trend.

(3) The effect of changes in fertilizer application by better-than-average farmers may be assumed to occur in a gradual rather than abrupt fashion.

(4) Other changes in farm practice are possible. An increased plant population is an example of such a change and one which can have a pronounced yield effect.

8/ The concept of a weather-technology interaction is discussed on page 25 .

When such changes are identifiable, adjustments in the data should be made. The nature of these adjustments would depend on the nature of the changes in farm practice.

(5) Changes in soil conditions may occur from particular soil-improving rotations or from soil-deteriorating use. These changes and their effects may be assumed to be gradual.

The variety tests are also a compromise in terms of geographical coverage. They are conducted at many locations within a State and within a region. Because the object of the tests is to find the best commercial variety of a crop for a particular area, this geographical coverage is a built-in feature.

When the advantages of geographical coverage, the possibility of removing the effect of other yield-influencing factors with a trend, and measuring weather effect relevant to the current level of technology are considered, the most suitable source of basic yield data is the variety yield trials. Admittedly there are many places where error can result.

For Iowa, the Corn Yield Test is the major variety yield trial. Yield data from other trials were available but the yield test data more closely approximated the ideal. 9/ The purpose of these tests is to compare the performance of corn seed used in Iowa. In the Iowa Corn Yield Test, varieties of hybrid corn have been tested annually since 1926 in 12 areas of Iowa. Each area, an Iowa Corn Yield Test district, was considered an individual location, and a separte weather index was developed for each district. The district numbers are not identical with those published currently in the Iowa Corn Yield Test reports. Adjustments which are discussed below were made in order to have each district represent approximately the same geographic area over the 1929-60 period.

The varieties tested were not grown on the same land throughout the 1926-60 period. Changes have occurred in district composition, cooperators, and location of plots on the cooperators' farms. When the cooperator changed, the yield data were considered to represent the same location if the new cooperator's farm was in the same CR district. When the cooperator's farm changed to another district it was considered a separate location. 10/ No adjustment is necessary for changing plot locations. The plots are chosen by research workers who consider previous soil management and physical location in order to select plot locations in each district.

Once the basic yield data were chosen, weather indexes were constructed for the individual locations. There are several general considerations in developing weather indexes for individual locations. What adjustments are necessary in the basic yield data? Two kinds were required in using the Iowa Corn Yield Test data.

9/ For a more detailed explanation see appendix, "Selection of the Basic Yield Data."

10/ One exception to this was in ICYT district 6. In 3 years, 1940, 1947, and 1948, the test was conducted out of Crop Reporting district 3, but in adjacent counties. In these years, the yields from the test were used to represent district 3.

First, an adjustment was required because of change in the planting rate. 11/ Second, there were gaps in the data because of abandonment.

Abandonment occurred in two ways and the following adjustments were made: The published yields in the Iowa Corn Yield Test are the average yields from approximately six replications. Occasionally, replications were abandoned because of water damage, severe insect infestations, or other local problems.

If hail or some other catastrophe occurred at a location, some plots were not harvested and no yield was published. In this second type of abandonment an adjustmen was made on the basis of the proportional change in CRB estimates of actual yields per harvested acre in the same district. Because of these adjustments, the yield of corn in the ICYT is a yield per harvested acre. When neither type of abandonment occurred, the yield per harvested acre equals the yield per planted acre.

Abandonment, of course, is not a significant factor in Iowa corn production. For other crops in other regions (for example, wheat in the Great Plains) abandonment greatly affects production.

Another general consideration is the selection of a proper trend to remove yield variation due to changes in technology. Ideally we would like to have data with no trend, and to measure weather effect as departure from an average of yields in the period. This ideal does not exist, and the weather effect in any year is measured as percentage deviation from the computed trend value for that year.

Given that a trend must be removed, several questions arise.

What kind of trend should be removed? Stallings (see footnote 1) assumed that a linear least-squares regression would adequately describe the increases or decreases in soil fertility which he believed to be responsible for the trend. When data which represent changes in technology are used, other factors enter and perhaps a linear trend is not as applicable as it may be with changes in levels of fertility.

In view of the difficulties associated with the linear trend technique, other techniques of trend removal were investigated. First, it seems advisable to remove years of extreme weather from the trend-fitting process. Since the time period under consideration is relatively short, if extreme years are not removed, part of the weather effect could easily be removed as trend. For example, if bad weather lowered yields at the beginning of the period and good weather raised them at the end of the period, a straight-line trend fitted to the yields would have an excessively high upward slope.

Deviation from a long moving average of yields appears to be a criterion for deciding which years are extremes. Once extremes are removed there are several possibilities for fitting the trend:

(1) One or several linear trends fitted to the data.
(2) Nonlinear trends.
(3) Long moving averages.

11/ For details of the adjustment see appendix, "Basic Yield Data: Source and Adjustments."

Rather than fit an arbitrary function to the data, a series of straight-line trends between groups of yields obtained with reasonably average weather conditions were first used. 12/ In such a way, the data themselves describe the trend to be fitted.

Weather cycles, should they exist, might possibly introduce error into this trend procedure. If the weather cycle influences the moving average used to elimanate extreme years, part of this cyclical behavior would enter into the trend and would not show up in the final weather index. For two reasons this error is minimal. First, the length of the moving average is sufficient to prevent cycles from affecting the selection of "normal" weather yields. Second, we found no evidence of cyclical behavior in corn yields in Iowa.

In detail, the following steps were taken to develop a weather index for each location. (A numerical example is shown in the appendix.)

(1) A 9-year moving average of the yields of hybrid corn, 1926-60, was computed. The moving average is a first approximation of the trend in yields due to factors which were not held constant. A period of 9 years is somewhat arbitrary; however, we considered it appropriate after testing other moving averages of 5, 7, and 11 years. The period needs to be long enough to average out the effect of extreme years, but not so long that it obscures changes in technology.

The yield data at each location represent the average yield in bushels per acre of all hybrids tested at the location. The group of varieties changes over time, but it is assumed that the yield variation due to this change may be taken out by a trend.

An analysis of variance showed no significant difference between the variation in yields of hybrid and open-pollinated corn. 13/ Hybrid yield variation was used throughout even though open-pollinated corn was the predominant type grown in Iowa at the beginning of the period.

(2) The moving average was extrapolated forward and backward to the terminal years. The method of extrapolation backward is as follows: The change between 1930 and 1931 was averaged with the change between 1931 and 1932. This average change was applied to the average yield in 1930-32 for as many years as necessary to estimate a first approximation of the trend value for all years. The same principle was used in extrapolating forward.

(3) Actual yields for each year were divided by the corresponding moving average yield. Any year in which this percentage ranged from 85 to 115 was considered an average-weather year for the purpose of making a second approximation of the trend in yields.

(4) Yields in average-weather years were used to compute the trend. By using yields only for these years, the years of extreme weather do not affect the trend. A series of straight line trends between mean yields of groups of average-weather years was used to approximate the true trend yields for the intervening years in

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12/ See appendix, "A Test for Weather Cycles," for details.

13/ For the details of this analysis, see appendix, "Yield Variation in Open-Pollinated and Hybrid Corn."

which actual weather was not average. If the terminal years were ones of abnormal weather, the change between the nearest two groups of average-weather years was used to extrapolate back to 1926 and forward to 1960.

(5) A 5-year moving average of yields in the average-weather years in step 4 was computed and used as the final measure of the trend in yields at the location. The moving average was extrapolated forward by the same technique used in step 2. 14/ By using a moving average, yields in step 4 were smoothed. Errors due to changing cooperators and fluctuations because of the relatively wide range (85 to 115 percent of the 9-year moving average of actual yields) which is used to select average-weather years were thus reduced.

Figure 1 shows the actual yields and the computed trend yields for the 12 districts.

(6) The weather index for the location is the percentage that actual experimental yields are of trend experimental yields. For each year from 1929 to 1960, the actual yield was divided by the trend yield. 15/

The weather indexes for the 12 locations in Iowa were combined into a weather index for the State. 16/ Because areas in the State account for differential shares of the total production in the State, weather indexes should be differentially weighted to get a State weather index. For example, if an area which represents a small part of total production has a drought which substantially cuts yields, the effect on total production is much less than if the drought had occurred in a major production area.

The following procedure was used to combine the 12 indexes.

The weather indexes for individual locations within a Crop Reporting district were averaged. In other words, the weight for the CR district was divided equally among locations in the district. The resultant weather indexes for the nine Crop Reporting districts (table 1) are charted with the appropriate district yield per harvested acre in figure 2. The areas they represent are indicated on the map in figure 3.

The district indexes were then combined. The estimate for yield per harvested acre in district i (Yha_i) 17/ was divided by the average weather index for that district (WI_i). The resultant yield is a yield per harvested acre, adjusted for weather [$Yha\ (adj)_i$].

$$\frac{Yha_i}{WI_i} = Yha\ (adj)_i$$

14/ Because of this extrapolation and also the extrapolation of the 9-year moving average used to select average weather yields, the weather indexes for the last few years are preliminary. With regular reporting of the indexes, revisions could be incorporated at 5-year intervals.

15/ See appendix table 13 for a detailed numerical example.

16/ The individual weather indexes are in appendix table 16.

17/ Actual yields, acreage, and production used in weighting are in appendix tables 18-22.

Table 1.-Yield weather indexes, by Crop Reporting districts, corn in Iowa, 1929-60 1/

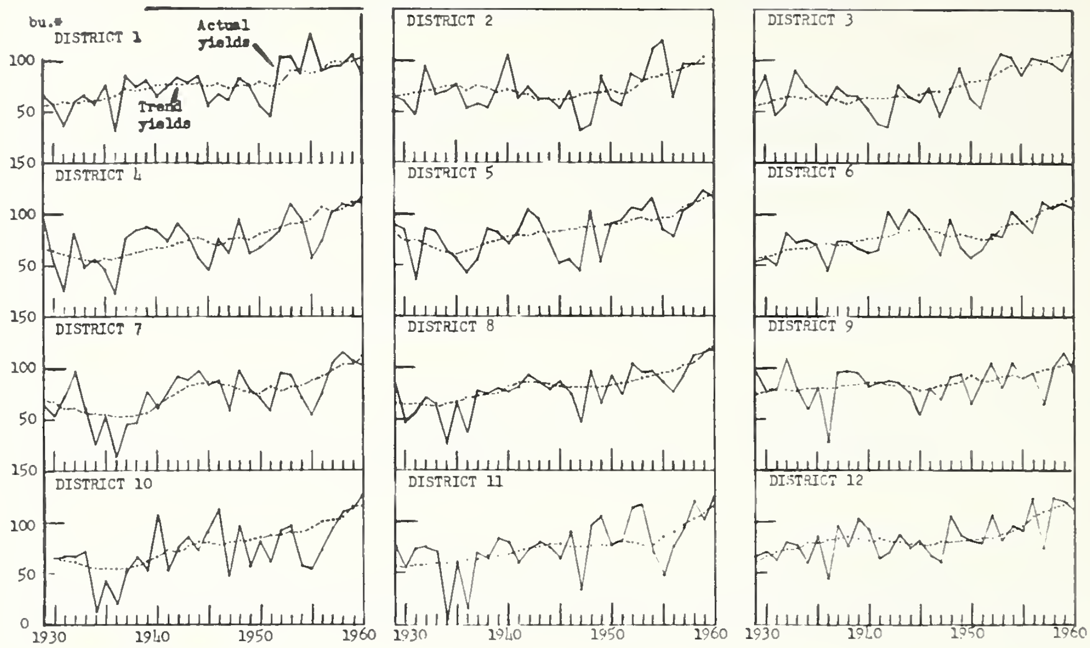
Year	District 2/									
	1	2	3	4	5	6	7	8	9	State 3/
1929	120	102	102	90	125	129	123	136	108	112
1930	82	98	114	75	71	98	100	100	104	88
1931	52	62	82	114	88	101	107	128	89	86
1932	118	130	108	155	108	141	109	127	108	122
1933	99	108	122	98	102	100	122	109	102	104
1934	98	98	113	48	44	77	20	6	76	67
1935	103	97	98	99	100	100	74	100	104	97
1936	42	71	75	23	53	36	40	24	53	45
1937	120	82	113	88	108	116	94	113	118	104
1938	122	104	106	88	101	117	112	98	93	103
1939	125	108	96	137	106	115	85	124	122	112
1940	108	119	83	96	94	96	163	115	111	105
1941	100	98	76	107	97	101	73	82	78	92
1942	117	124	94	120	112	106	105	100	89	110
1943	104	110	113	110	100	103	111	107	110	107
1944	92	95	112	120	95	92	93	97	97	99
1945	70	73	100	97	106	70	116	82	105	87
1946	102	90	100	106	93	100	144	118	89	101
1947	88	50	70	73	60	85	60	44	79	67
1948	120	88	108	124	118	107	118	126	133	114
1949	92	91	104	102	83	107	69	137	108	94
1950	79	94	78	93	108	73	98	101	97	90
1951	76	94	74	72	87	100	70	99	95	83
1952	114	118	103	120	117	112	101	140	130	115
1953	116	105	102	108	107	90	104	147	93	106
1954	100	125	113	88	106	114	64	92	104	101
1955	98	112	94	58	92	99	56	56	96	83
1956	86	76	94	83	81	100	73	84	117	86
1957	97	100	106	106	89	64	91	97	68	89
1958	99	100	96	113	103	99	101	117	108	103
1959	102	101	94	102	105	109	99	94	102	102
1960	93	74	97	98	103	91	107	105	91	94

1/ A yield weather index is the percentage actual yields are of trend yields.

2/ Indexes for the 12 Iowa Corn Yield Test districts were combined into indexes for Crop Reporting districts by simple averaging.

3/ The State index is an average of Crop Reporting district indexes, weighted by adjusted production.

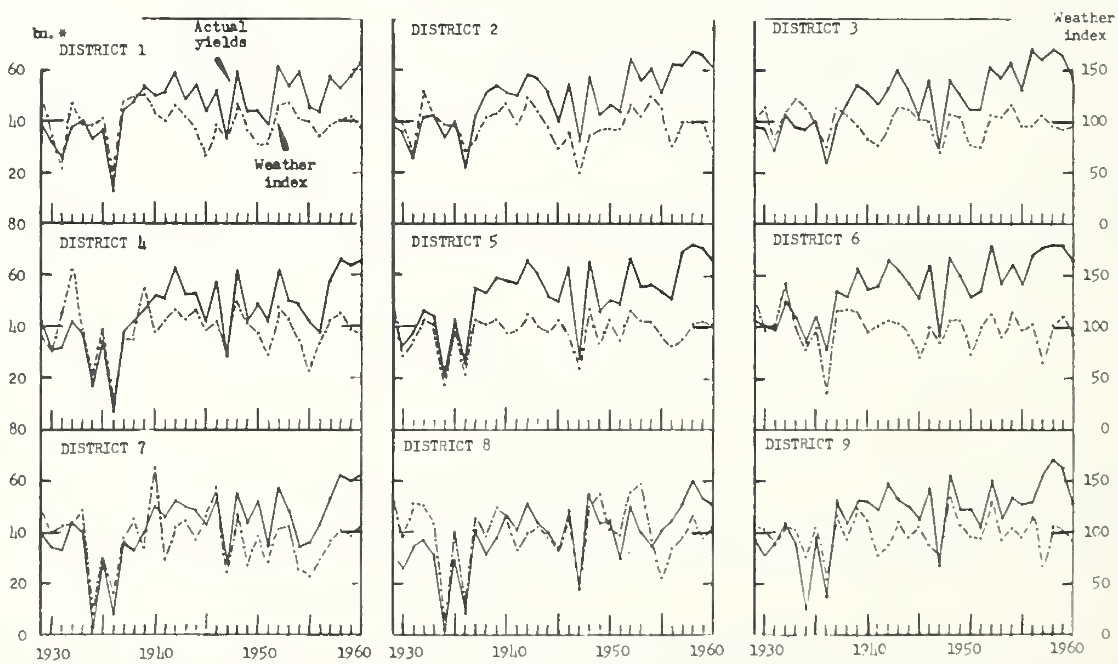
ACTUAL AND TREND YIELDS
Iowa Corn Yield Test Districts



* per harvested acre

Figure 1

ACTUAL CORN YIELDS AND YIELD WEATHER INDEX
Iowa Crop Reporting Districts



* per harvested acre

Figure 2

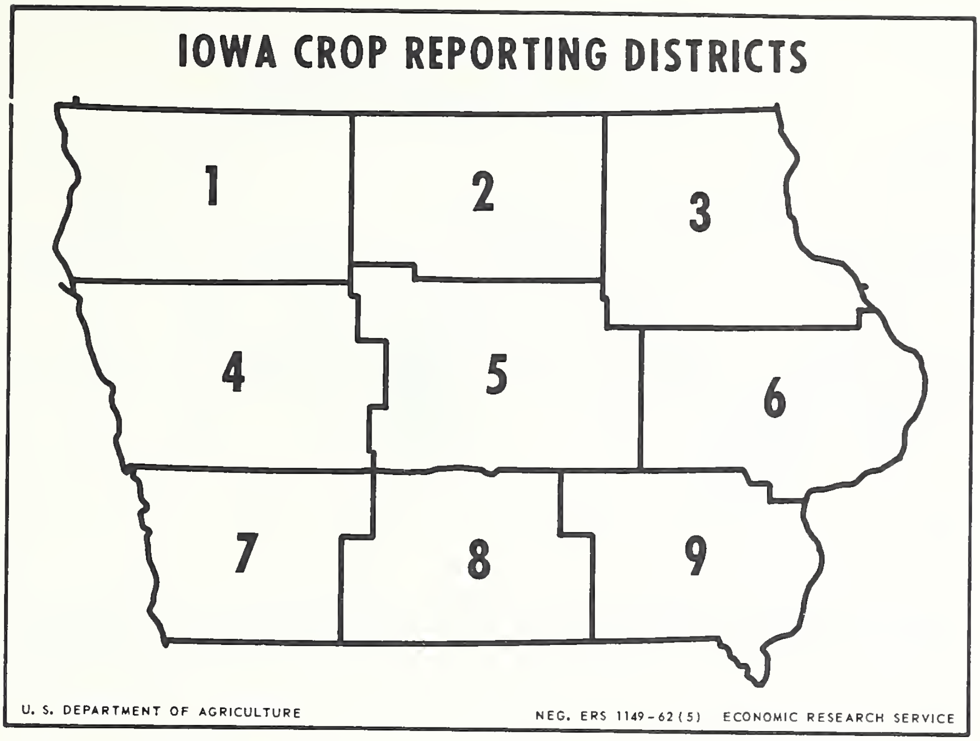


Figure 3

In computing this adjusted district yield it was assumed that the weather factors which caused, for example, a 10-percent increase in experimental corn yields caused a 10-percent increase in actual corn yields.

The adjusted yield per harvested acre was then multiplied by harvested acres (HA) in that district to obtain an estimate of production, adjusted for weather $[P(adj)_i]$.

$$Yha\ (adj)_i \cdot HA_i = P(adj)_i$$

Adjusted production estimates for the nine CR districts were summed. Actual production (P) was divided by adjusted production to obtain an implicitly weighted State yield weather index (WI). 18/ (See fig. 4 and table 1.)

$$\frac{P}{P(adj)} = WI$$

The weather index so derived is a suitable index of the influence of weather on yields per harvested acre. Essentially the same weighting system was used in computing a production weather index. 19/ Planted acres were used instead of harvested acres in order to adjust production for abandonment. Abandonment is assumed to be due to weather and the potential yield on abandoned acres is assumed to be equal to the yield per harvested acre (appendix table 17).

The two weather indexes are very similar. In areas other than Iowa, where abandonment is considerable, there will be a significant difference.

18/ For details and rationale of the weighting system, see appendix, "Aggregating District Weather Indexes."

19/ For details see appendix, "Aggregating District Weather Indexes."

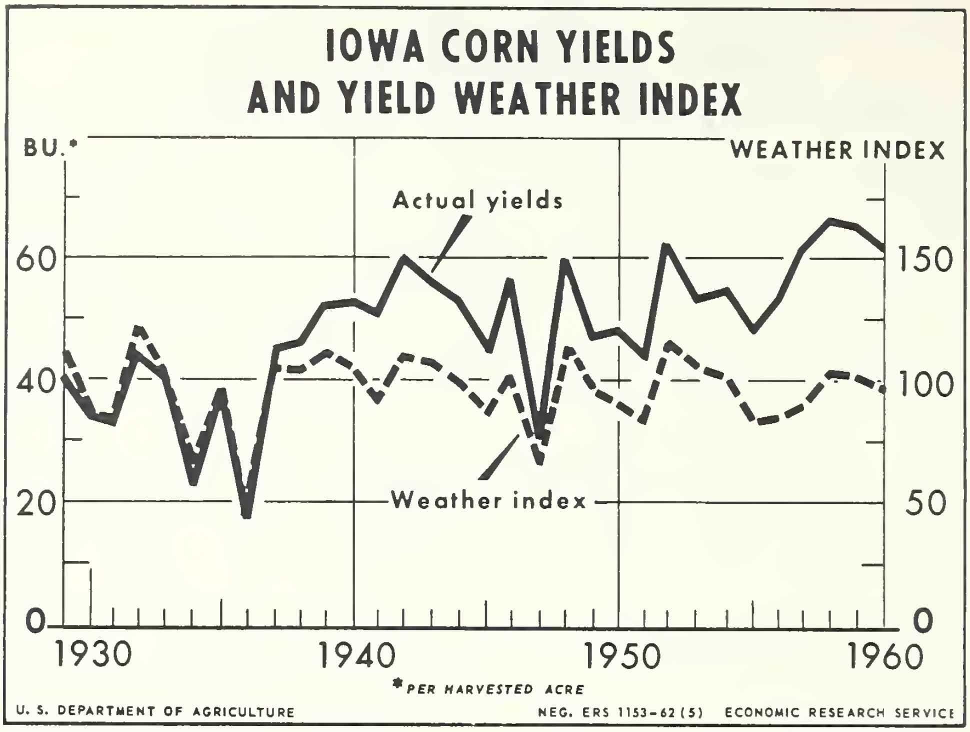


Figure 4

ADJUSTMENT FOR THE INFLUENCE OF WEATHER ON CORN YIELDS AND PRODUCTION IN IOWA, 1929-60

The weather indexes developed to measure the effect which weather has had on output of corn in Iowa may be used to remove the influence of weather from actual yields and production. Variation in the resultant measures of adjusted yields and adjusted production, therefore, should be due to technology.

A major purpose of this study is to investigate the possibility of developing such measures of adjusted yields and production. Researchers have worked hard and long in trying to understand the underlying factors in a changing output of agricultural products. With the influence of weather obscuring the influence of technology, the data have not revealed basic truths. One researcher, depending on how he interprets the effect which weather has had on production, finds a relationship which another researcher, because of his different interpretation of the weather effect, may refute.

The removal, by objective and rational means, of the influence of weather from output data would aid immeasurably in production response analysis. The Iowa study provides a good example of what useful tools weather indexes can be in economic analysis.

Yields and production of corn in Iowa were adjusted for the influence of weather. The appropriate measure as reported by the Crop Reporting Board was divided by the corresponding weather index value in each year. The adjustment is analogous to price deflation and the development of series of constant dollar value.

Figure 5 shows actual and adjusted yields per harvested acre of corn in 1929-60. 20/ Variation in adjusted yields of corn represents the effect of a changing technology. There is a certain amount of unexplained variation in the adjusted yield measure. Examples of years when the yields are irregular are 1947 and 1957. Intuitively, it appears that the weather index underadjusted in 1947 and overadjusted in 1957 for the influence of weather. Such over or underdeflation should be randomly distributed and compensated for at higher levels of aggregation. If a national weather index were developed, subindexes or regional indexes would probably be aggregated at greater than State levels. However, the adjusted yield measure does indicate the technological changes in yields.

Technological changes in corn yield in Iowa seemed to have come in two steps. Yields from 1929 to 1935 were relatively stable and slightly under 40 bushels per acre. Beginning around 1935, yield-affecting factors came into play raising the yield to slightly above 50 bushels per acre. Yields remained at this new level throughout the 1940's and early 1950's. Beginning around 1954 a second period of rapid increase in yields began.

Let us explore the rational basis for these increases. The first yield increase can be ascribed chiefly to the adoption of hybrid seed. Table 2 shows percentages of hybrid and open-pollinated seed used in 1933-42. By 1941, over 95 percent of the corn acreage was planted with hybrid seed and future adoption was not likely to result in much increase in yield. 21/

The second yield increase does not appear to be due to any one technological adoption but rather to a combination of factors, which together cause a significant yield increase. Greater use of fertilizer is one of the major factors. Table 3 shows the application of plant nutrients has increased. Since the middle forties there has been a marked increase in use of fertilizer, particularly nitrogen, in Iowa.

20/ Yields per planted acre may be deflated by the production weather index. The production weather index is used instead of the yield weather index because yield per planted acre is affected by weather in two ways: Level of yield and abandoned acres. The production weather index accounts for both these effects while the yield weather index only deflates for the influence of weather on yield level. The resultant adjusted yields per planted acre are identical to adjusted yields per harvested acre.

21/ B. T. Shaw analyzed Iowa corn yields from 1870 to 1950, and by a rather simple method made a similar interpretation of the technological effect on yields in 1930-50. His method was to assume that the effect of technology on yields is indicated by new highs in yields. Weather was assumed to be equally better than average in these years. (The Role of Research in Meeting Future Agricultural Requirements, paper presented before the American Society of Agronomy, November 18, 1952.)

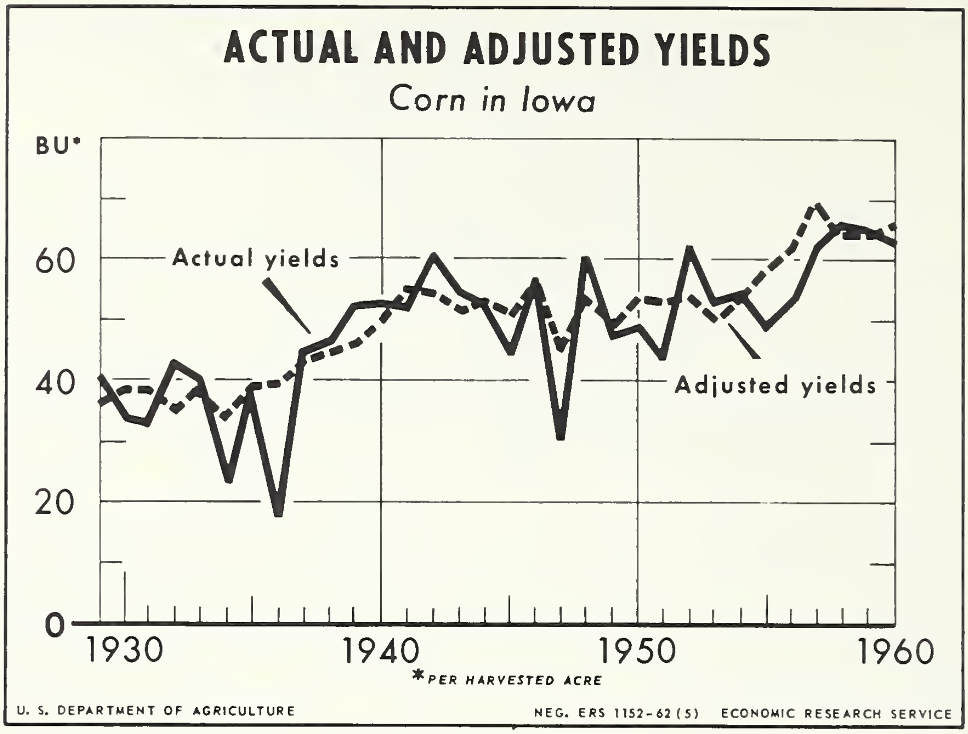


Figure 5

Table 2.-Proportions of corn acreage planted with hybrid and open-pollinated seed, Iowa, 1933-42

Year	Hybrid seed	Open-pollinated seed
	Percent	Percent
1933	0.7	99.3
1934	2.1	97.9
1935	6.0	94.0
1936	14.4	85.6
1937	30.7	69.3
1938	51.9	48.1
1939	73.4	26.6
1940	90.3	9.7
1941	96.9	3.1
1942	98.9	1.1

Data from "Hybrid Corn--Total Corn Acreage, Percentage Planted With Hybrid Seed, Indicated Hybrid Corn Acreage, 1933-1945, By States," Bur. Agr. Econ., U. S. Dept. Agr., July 1947.

Table 3. --Pounds of fertilizer used per harvested acre of corn in Iowa, selected years

Year	N	P_2O_5	K_2O	All nutrients
	Pounds	Pounds	Pounds	Pounds
1947	1	8	5	14
1954	12	11	8	31
1959	15	16	10	41

Data obtained from D. B. Ibach, Farm Economics Division, Econ. Res. Serv., U. S. Dept. Agr. The 1959 and 1954 data are from the Census of Agriculture for those years. The 1947 data refer to the Corn Belt and Lake States rather than Iowa. In all years total pounds of nutrients used were divided by total harvested acres to obtain the rates.

The yield effect of this increased use of fertilizer is tempered by many other factors. New varieties, increased plant population per acre for the new fertility level, and better ways of cultivation are necessary to get the maximum benefit from increased fertilizer application. There is evidence that farmers are stepping up their planting rates. The Iowa Experiment Station recommends an average rate of 16,000 plants per acre. Past estimates of the actual rate indicate that it has been considerably below this. Limited cultivation and fall plowing are other practices which would combine with increased fertilizer application to get a substantial increase in corn yields.

Actual production also was adjusted for weather variation. Variation in the adjusted production series is due to two factors, changing total acreage and changing technology.

The indexes we have developed provide an objective method of adjustment for the influence of weather. The method is universal in application and would provide a basis for adjustment within the framework of current output statistics.

OTHER USES OF WEATHER INDEXES

Though the primary use of the weather indexes is to adjust yields and production for the influence of weather, there are many byproducts.

Changes in Corn Yields Due to Weather and Technology

One of the most obvious byproducts of the weather index is the ability to quantify actual yield changes due to weather and to technology. Changes in the adjusted yields (actual yields deflated by the weather index) measure the yield effect which is due to technology. Therefore, the contribution of weather to actual yield change is the difference between the actual yield change and the adjusted yield change.

Table 4 shows two empirical examples of how yield changes can be quantified. Actual corn yield in Iowa increased 18.5 bushels between 1930 and 1940, while the adjusted yield increased about 11 bushels. Therefore, weather was responsible for 7.2 bushels of the actual increase in yield (18.5 – 11.3 = 7.2). Looking at the individual

Table 4. --Changes in actual and adjusted yields of corn in Iowa for specified years

Item	Yield per harvested acre			Change from--	
	1930	1940	1950	1930 to 1940	1930 to 1950
	Bushels	Bushels	Bushels	Bushels	Bushels
Actual yield	34.0	52.5	48.5	18.5	14.5
Adjusted yield	38.5	49.8	54.2	11.3	15.7
Yield Difference	-4.5	2.7	-5.7	7.2	-1.2

years, poorer than average weather in 1930 reduced the actual yield by 4.5 bushels. But in 1940, better than average weather increased the expected yield over 2.5 bushels.

Weather reduced the actual yield change between 1930 and 1950. In both years weather was poorer than average. However, weather was less favorable in 1950 than it was 20 years earlier.

Corn Yields and Meteorological Factors

In the background section we mentioned briefly how the weather indexes could be used to investigate cause-and-effect relationships between yields and individual meteorological factors. Although it is not the purpose of this study to analyze these cause-and-effect relationships, an example seems apropos to illustrate this potential use of the weather indexes. It is the function of agronomists and meteorologists, who are intimately aware of the physiological mechanisms involved, to study these relationships. We present the example only as an illustration of how weather indexes could be of help in this research.

The U. S. Weather Bureau publishes data on mean monthly temperature and precipitation for the nine districts used in this study (the divisions in Iowa correspond with the CR districts, that is, Northwest Division = CR District 1; Northcentral Division = CR District 2, and so on). July data from Climatological Data - Iowa are in appendix tables 23 and 24. Scatter diagrams of the weather indexes and deviations in July temperature were made for each of the nine districts (fig. 6).

In the scatter diagrams the highest weather index values were associated with mean or near mean July temperatures. Similarly, the lowest weather index values were associated with extremes, either warmer than average or cooler than average July temperatures.

The following steps were taken to measure this relationship more carefully:

(1) All years (1929-60) in all districts were classified into the following weather index classes: 135 and above; 125-134, 115-124, 105-114, 95-104, 85-94, 75-84, 65-74, 64 and below.

(2) For each class the deviations in July temperature associated with the years involved were averaged. Deviations were treated separately by sign (table 5).

(3) The average deviations were charted against the midpoints of the weather index classes.

RELATION OF JULY TEMPERATURE TO YIELD WEATHER INDEX
Corn in Iowa

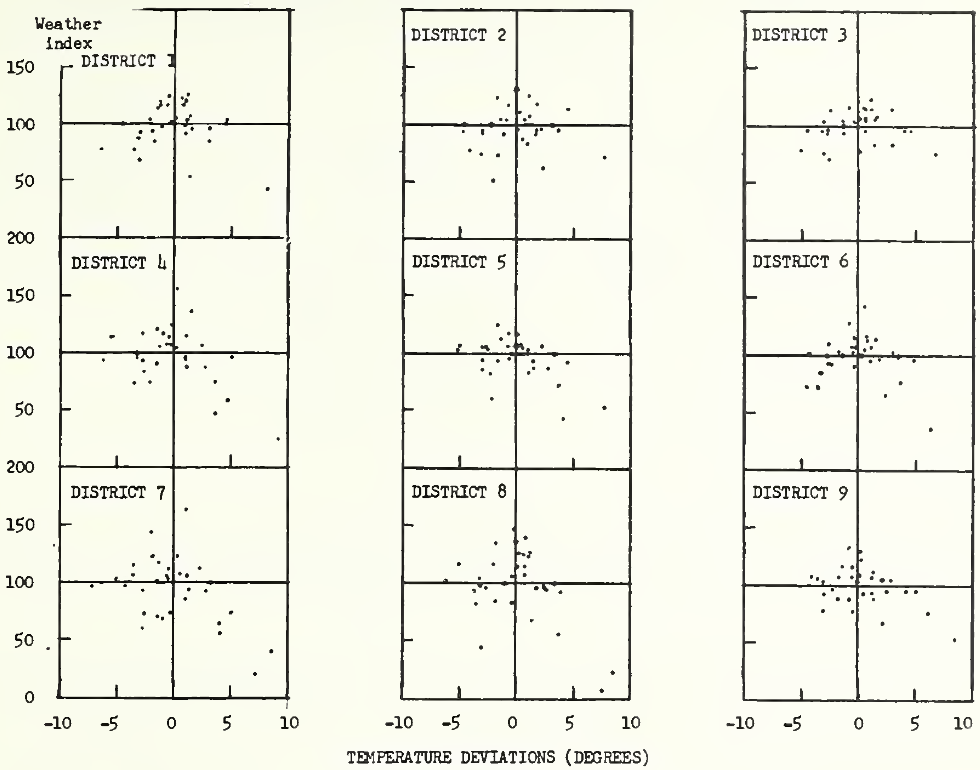


Figure 6

Table 5.-Average deviation in July temperature and precipitation by corn yield weather index class, Iowa, 1929-60 1/

Yield weather index 2/	Average temperature deviations: Less than average	Average temperature deviations: More than average	Average precipitation deviations: Less than average	Average precipitation deviations: More than average
	Degrees		Degrees	
140-------	-1.3	0.7	-0.88	0.89
130-------	-1.2	.7	-.43	1.18
120-------	-1.5	.8	-.63	1.55
110-------	-1.9	1.2	-1.05	1.54
100-------	-2.7	2.2	-1.05	1.57
90-------	-2.6	1.9	-1.03	1.03
80-------	-3.0	3.0	-1.78	1.87
70-------	-2.5	4.7	-1.67	1.42
60-------	-2.6	5.7	-2.15	.73

1/ Deviations from 1929-60 average.
2/ Midpoint of class interval.

The relationships between the weather indexes and deviations in July temperature (fig. 7) appear to be curvilinear with maximum values of the weather index associated with mean July temperature. The relation between the deviations in July precipitation and the weather indexes was curvilinear also (fig. 8). 22/

This brief example of the use of weather indexes to examine cause-and-effect relationships has its own byproduct. The relationships between deviations in individual meteorological factors and corn yields appear to be curvilinear rather than linear. Thus one should seriously question the validity of high coefficients of determination obtained in multiple linear correlation models where variation in yields is ascribed to individual meteorological factors, such as temperature and precipitation.

Annual Weather Variations for Corn Production in Iowa, 1929-1960

Another byproduct in the development of weather indexes is their use in comparing weather by location and over time.

A word about the accuracy of the weather indexes is appropriate here. Because the weather in only one or two locations is used to represent the weather for a Crop Reporting district, the accuracy of district weather indexes is limited. As the level of aggregation increases, and random errors are compensated for, the accuracy of the index increases.

Weighted indexes (for yield per harvested acre) were constructed for various regions of the State (table 6). 23/ A North-South division and an East-West division were made. In figure 9 these North-South regional indexes are compared.

The chart shows how weather varies over the State. Of course, weather refers only to the influence of weather on corn production. Figure 9 indicates that southern Iowa experiences the most year-to-year variation in weather. Northern Iowa experiences more variation than central Iowa, but the variation is frequently quite different from the variation in southern Iowa. There also appears to be a significant difference in the weather as one moves from east to west in Iowa.

22/ Wallace (6), in his study of the relationship between corn yields and meteorological factors, found a similar relationship.

23/ Regions are combinations of Crop Reporting districts. The weather indexes for the appropriate districts were weighted together using given year adjusted production weights. The following key defines the composition of the regions used in this study.

	Crop Reporting Districts
North-South Division	
Northern Iowa	1, 2, 3.
Central Iowa	4, 5, 6.
Southern Iowa	7, 8, 9.
East-West Division	
Western Iowa	1, 4, 7.
Central Iowa	2, 5, 8.
Eastern Iowa	3, 6, 9.

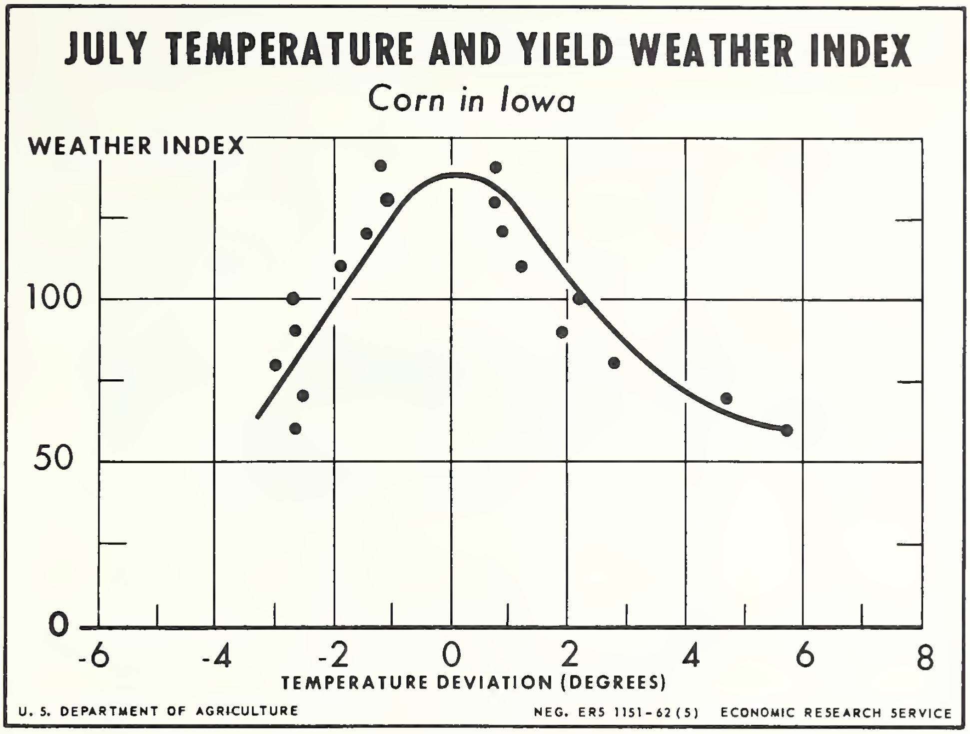


Figure 7

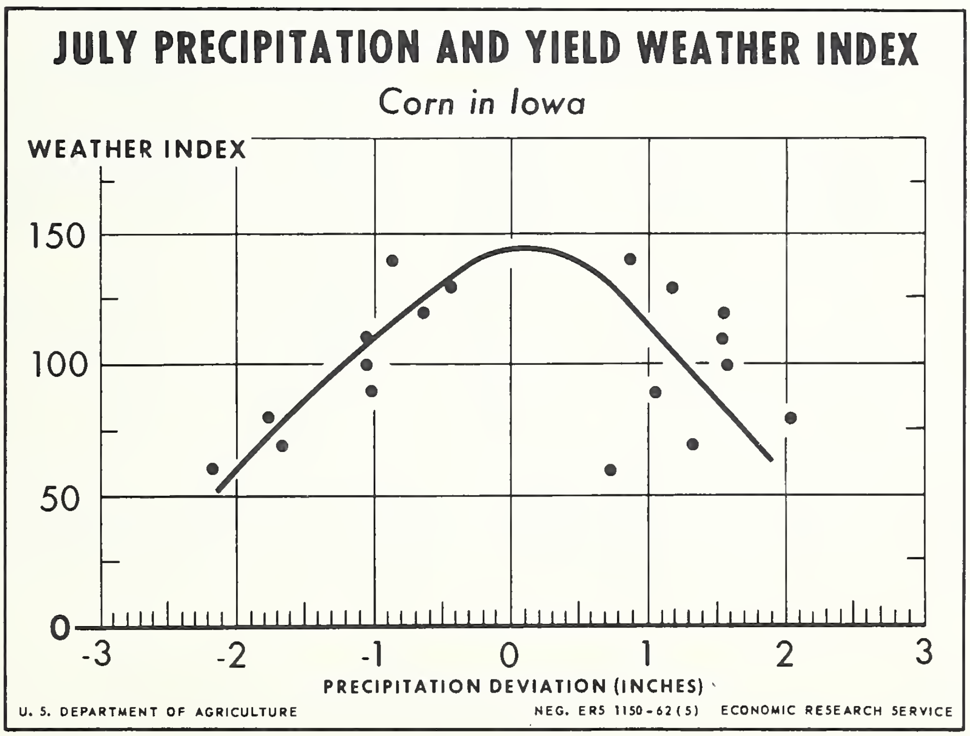


Figure 8

Table 6. --Regional yield weather indexes, corn in Iowa, 1929-60 1/

Year	North-South division			East-West division		
	Northern	Central	Southern	Eastern	Central	Western
1929------	109	109	121	113	118	106
1930------	94	78	101	105	84	83
1931------	62	99	106	91	85	82
1932------	119	130	113	119	118	127
1933------	107	98	113	103	105	104
1934------	102	53	26	90	55	64
1935------	99	100	89	100	99	94
1936------	59	39	38	47	53	30
1937------	102	103	107	119	99	100
1938------	108	100	101	106	99	105
1939------	111	118	104	109	109	118
1940------	106	95	131	95	105	108
1941------	93	101	77	86	95	94
1942------	113	113	98	97	113	115
1943------	109	104	110	108	105	108
1944------	97	103	95	99	95	102
1945------	77	91	103	85	89	87
1946------	97	99	115	97	95	111
1947------	66	71	61	78	53	75
1948------	104	117	125	114	106	123
1949------	95	95	92	106	93	88
1950------	84	91	98	80	101	89
1951------	80	84	84	88	90	73
1952------	112	117	118	113	120	113
1953------	108	104	107	95	110	110
1954------	111	102	84	111	111	89
1955------	102	80	67	96	90	69
1956------	84	88	87	101	78	81
1957------	101	83	82	75	94	99
1958------	99	105	107	100	103	105
1959------	99	105	99	102	102	101
1960------	86	98	101	93	89	98

1/ Regions are combinations of Crop Reporting districts. The appropriate district indexes were weighted together using given year adjusted production weights.

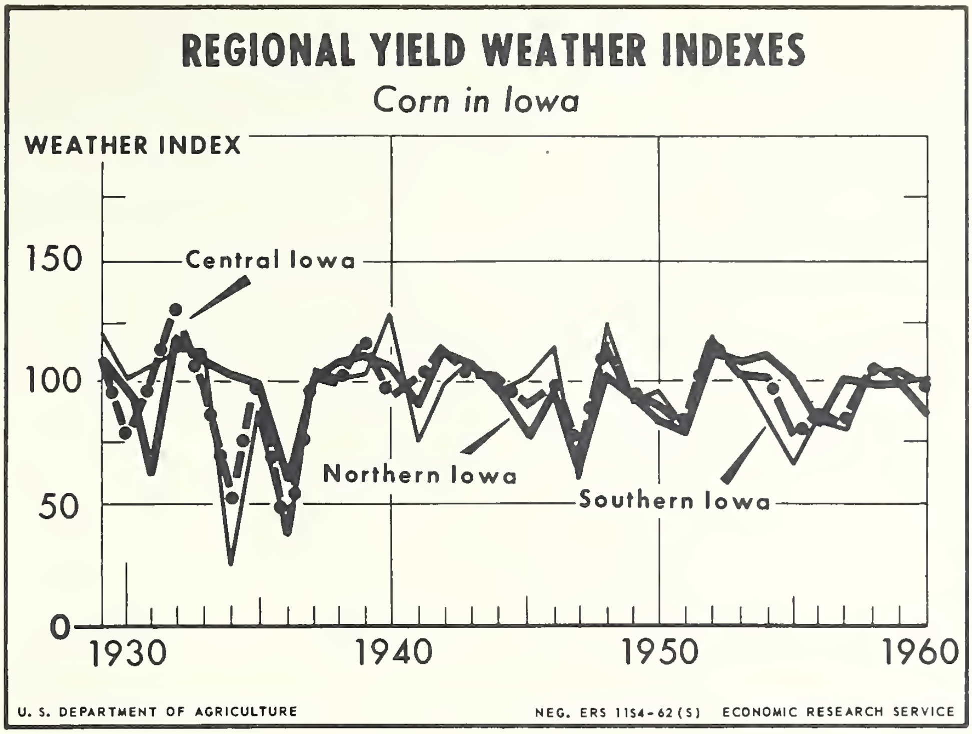


Figure 9

Climatic differences as well as differences in weather may be analyzed with the weather indexes. Climate here refers to averages of the weather indexes for a period of years. This definition of climate, as opposed to more meteorological definitions, depends on the average level of technology in the time period. The average decade weather indexes for the various indexes developed in this study are given in tables 7 and 8. Average weather or climate for corn production can vary by decades. For example, climate in southern Iowa appears to have been much more favorable for corn in the 1940's than it was in the 1930's or the 1950's. For the State as a whole, the climate seemed to remain stable over time.

The Yield Effect of a Changing Weather-Technology Interaction

Man may not yet be able to create his own environment, but it seems reasonable that with improvements in technology farmers may be better able to adjust to year-to-year fluctuations. It is possible, for example, that the farmer may now be able to make good weather work for him and prevent bad weather from working against him. In other words, the farmer with new varieties, better machinery, and better tillage methods may be able to raise yields much higher in good weather years than he could in average weather years. Similarly, he may be able to prevent bad weather from reducing yields.

Although yields are affected by two broad factors, weather and technology, it is doubtful that the two factors are independent. We hypothesize that a weather-technology interaction exists. Changes in this weather-technology interaction would indicate man's progress in attempts to control the farming environment.

Table 7. --Yield and production weather indexes for corn in Iowa, by districts and specified periods, 1929-60

Period	Crop Reporting district									State
	1	2	3	4	5	6	7	8	9	
	Average yield weather indexes 1/									
1929-39	98	96	103	92	91	103	90	97	98	94
1940-49	99	94	96	106	96	97	105	101	100	98
1950-60	96	100	96	95	100	96	88	103	100	96
1929-60	98	97	98	97	96	98	94	100	99	96
	Average production weather indexes 2/									
1929-39	97	96	102	92	91	102	89	96	97	94
1940-49	98	93	95	104	95	96	102	101	99	97
1950-60	94	98	94	93	98	95	87	101	99	94
1929-60	96	96	97	96	95	98	92	99	98	95

1/ Yield weather index is the percentage actual yields are of trend yields.
2/ Production weather index is the yield weather index adjusted for abandoned acres.

Table 8. --Average regional yield weather indexes for corn in Iowa, by regions and specified periods, 1929-60 1/

Period	North-South division			East-West division		
	Northern	Central	Southern	Eastern	Central	Western
1929-39	97	93	93	100	93	92
1940-49	96	99	101	96	95	101
1950-60	97	96	94	96	99	93
1929-60	97	96	96	98	96	95

1/ Regions are combinations of Crop Reporting districts.

From weather indexes developed using the experimental plot data approach, it is possible to derive a measure of this interaction. Two types of weather indexes may be developed for a particular location. The first, using yield data from check plots, measures variation in yield due to weather under constant technology. Weather-technology interaction also remains constant. The second type, using data from variety yield trials measures variation in yield due to weather under a technology which changes over time. Here weather-technology interaction may change. As the only conceptual difference between the two indexes is the weather-technology interaction (the yield effect of the difference in technologies is removed from the indexes in their construction), a comparison of the two indexes measures the effect that a changing weather-technology interaction has had on yields.

Let the following be an example:

Year	Index I	Index II	Ratio of Index II to I
1950	97	98	1.01
1951	115	120	1.04
1952	117	124	1.06
1953	83	85	1.02
1954	150	160	1.07
1955	98	100	1.02
		Average, 1950-55-----	1.037

Index I is a weather index constructed using check plot data relevant to the technology of 1930-35.

Index II is a weather index constructed using yield trial data relevant to technology in a given year.

Indexes I and II represent the same environmental conditions.

If there were no change in the weather-technology interaction, column three, the ratio, should approximate 1.00. If yields are higher because of changed weather-technology interaction, the ratio should be consistently greater than 1.00. Other possibilities may also be measured. If the changed weather-technology interaction raises yields in good weather but has no effect on yields in bad weather, the ratio should be greater than 1.00 for good-weather years (years with weather index I above 100) and should approximate 1.00 for bad-weather years (years with weather index I below 100).

In the example, weather-technology interaction has changed, and farmers have on the average 3.7 percent higher yields because of greater control of the environment in 1950-55 than in 1930-35. Farmers in 1955 can have larger yields in good and bad weather than they had with 1930-35 technology.

Empirical results of this test for corn grown at Ames, Iowa, 1929-59, are in table 9. Weather index I, assuming constant technology, was computed from check plot data, while weather index II, assuming a changing technology, is that for the ICYT district 8. Figure 10 shows the two weather indexes used.

Table 9.-Effect of changing weather-technology interaction, corn yields at Ames, Iowa, 1929-59

Year	Weather index I 1/	Weather index II 2/	Ratio of weather index I to weather index II		
			Years of "bad" weather 3/	Years of "good" weather 4/	All years
1929	107	125	---	1.17	1.17
1930	76	71	0.93	---	.93
1931	91	88	.97	---	.97
1932	113	108	---	.96	.96
1933	111	102	---	.92	.92
1934	53	44	.83	---	.83
1935	125	100	---	.80	.80
1936	57	53	.93	---	.93
1937	148	108	---	.73	.73
1938	96	101	1.05	---	1.05
1939	117	106	---	.91	.91
1940	92	94	1.02	---	1.02
1941	102	97	---	.95	.95
1942	106	112	---	1.06	1.06
1943	100	100	---	1.00	1.00
1944	95	95	1.00	---	1.00
1945	95	106	1.12	---	1.12
1946	80	93	1.16	---	1.16
1947	70	60	.86	---	.86
1948	143	118	---	.83	.83
1949	95	83	.87	---	.87
1950	105	108	---	1.03	1.03
1951	71	87	1.23	---	1.23
1952	92	117	1.27	---	1.27
1953	87	107	1.23	---	1.23
1954	110	106	---	.96	.96
1955	107	92	---	.86	.86
1956	44	81	1.84	---	1.84
1957	166	89	---	.54	.54
1958	96	103	1.07	---	1.07
1959	60	105	1.75	---	1.75
Average of:					
1929-59	---	---	1.12	.91	1.03
1929-45	---	---	.98	.94	.96
1946-59	---	---	1.25	.84	1.11
1930-39	---	---	.94	.86	.90
1940-49	---	---	1.01	.96	.99
1950-59	---	---	1.40	.85	1.18

1/ Computed from yield data representing a constant technology.
2/ Yield weather index for Iowa Corn Yield Test district 8.
3/ "Bad" weather refers to a weather index I value below 100.
4/ "Good" weather refers to a weather index I value above 100.

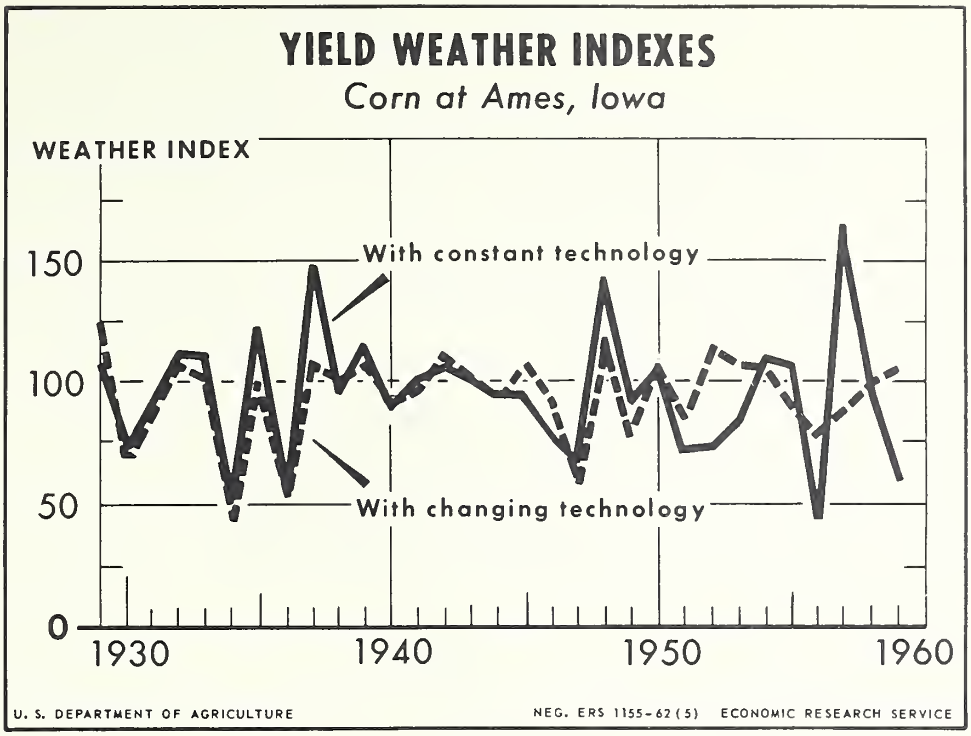


Figure 10

Looking at the results for all years we find that yields in the 1946-59 period are on the average 11 percent higher than they would have been if the weather-technology interaction had remained constant. Breaking the results into good-weather and bad-weather years (good = weather index I value above 100; bad = weather index I value below 100), we see that this 11 percent higher yield is the result of two factors, a relative lowering of yields in good weather and a relative raising of yields in bad weather. Thus it would appear that, in the case of corn, improved technology has not capitalized on good weather to the same extent that it has ameliorated the effects of bad weather.

A statistical analysis of the differences between the two weather indexes was made. Chi-square values were significantly different from what would be expected if variation were due only to chance. Following are the results of this test:

Period	All years	Bad years	Good years
1929-59	1/ 151.5*	87.7*	63.8*
1929-45	25.2	3.8	2/ 23.5*
1946-59	126.3*	83.9*	40.3*

1/ Starred chi-square values are significant.
2/ The degrees of freedom here are only 8.

Of course, it is impossible to generalize from this one example. Similar measures, though, could be developed for other crops and other areas.

This illustration affords another example of how weather indexes would be used in better analyzing changes in American agriculture.

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APPENDIX

Selection of the Basic Yield Data

Although the Corn Yield Test is the major variety yield trial in Iowa, other variety trials are conducted. USDA conducts comparative trials of varieties developed in corn breeding work. The double cross experiments, the last stage in testing, provide an additional source of basic yield data.

The experimental design is much the same as the design of the ICYT. In fact, both trials are often conducted side by side on the same cooperator's farm. There are several differences, however.

First, plants are thinned in the USDA trials. Second, locations are more likely to drop out and not be replaced in the following year. In the USDA trials there is not the same necessity of having all 12 districts represented in any 1 year. Third, the format of the experiments does not remain as comparable between years as the format of the ICYT.

For the following three reasons, it was decided that the ICYT provides a better source of data for our purposes than either the USDA trials or a combination of the ICYT and the USDA trials: (1) Data from the USDA trials are available only from 1939 to 1959. The ICYT data are for 1926-60. (2) Comparisons between the yields of two tests at the same location showed no significant difference either in yield level or variation in yield. (3) The yield data from the Iowa Corn Yield Test more closely approximate the ideal characteristics of basic yield data needed for the development of weather indexes.

In constructing indexes for other areas it is recognized that such fortunate sources may not always be available. In such cases less suitable data must be used.

Variety trials are conducted for major crops in the major producing areas of the country. The State Experiment Stations conduct trials in their breeding research. The USDA conducts similar trials. With the extensive research programs of both the State and Federal Governments there exist ample yield data which would be of great value in constructing weather indexes.

Basic Yield Data: Source and Adjustments

The Iowa Agricultural Experiment Station publishes annually the results of the Iowa Corn Yield Test. From 1926 to 1954 the mean yield of varieties tested at individual locations is published. Since 1955 only district mean yields, which are averages of two locations, are published. The individual location mean yields for 1955-60 were obtained from C. D. Hutchcroft of the Iowa Agricultural Experiment Station.

District composition varied over time. Because of this, the mean yields were associated with particular counties and the district yield thus represents the same location over time. District 10, for example, was called district 7 in the ICYT from 1933 to 1935. Similarly district 1 became district 1B for 1955 and 1956 and then district 1A for 1957-60. The plot, however, remained on the same cooperator's farm.

Abandonment Adjustment

Abandonment occurred in the yield trials and an adjustment was made on the basis of the yield estimated by the Crop Reporting Board for the same Crop Reporting district. Below is an example of one such adjustment. In district 1 the plot was not harvested in 1944 because of hail damage. The yields for the test in district 1 and in Crop Reporting district 1 in the 1942-46 period were

Year	CR district 1	ICYT district 1
	Bushels	Bushels
1942	59.5	81.7
1943	49.0	77.3
1944	55.5	---
1945	44.0	55.9
1946	52.3	88.7

The averages of the yields for 1942, 1943, 1945, and 1946 are 51.2 for CR district 1 and 75.9 for ICYT district 1. In 1944, the CR yield, 55.5, was 8.4 percent above the average. If the yield in district 1 of the ICYT were 8.4 percent above average it would be 82.3. This yield was used as an estimate of what the yield would have been had the plot been harvested.

In 1933-35 plots were not grown in districts 7, 9, and 11. Estimates were made for the yields in these districts by the same technique.

Planting Rate Adjustment

We have assumed in using the ICYT data that changes in farm practices occur gradually. The rate of planting has not remained constant over time. As this is a known abrupt change in practice an adjustment was made in order to minimize any error which it may cause.

Many factors influence the yield effect of a changed planting rate. Soil type (particularly the moisture potential of the soil), rate of fertilizer application, and tillage methods will temper the effect ofplanting more seed per acre. In making adjustments for planting rate changes, we have not made any arbitrary decision about what the yield effect may have been. Instead, we have tried to devise a technique which will adjust for the change, whatever the yield effect may have been in a particular location in a particular year.

Table 10 gives the planting rate history by district over time. Numbers refer to kernels per hill. A rate of 4 kernels per hill is approximately 16,000 kernels per acre.

Table 10. Planting rate in Iowa Corn Yield Test, 1926-60
(Number of kernels per hill) 1/

District	1926	1927-35	1936	1937-45	1946	1947-52	1953-60
1	4	4	3	3	4	3	4
2	4	4	4	3	4	3	4
3	4	4	4	3	4	3	4
4	3	3	3	3	4	3	4
5	4	3	3	3	4	3	4
6	3	3	3	3	4	3	4
7	3	3	3	3	3	3	4
8	3	3	3	3	3	3	4
9	4	3	3	3	3	3	4
10	3	3	3	3	3	3	4
11	3	3	3	3	3	3	4
12	3	3	3	3	3	3	4

1/ Rates of 3 kernels and 4 kernels per hill are equivalent to 12,000 and 16,000 plants per acre, respectively.

The following adjustments were made to account for the abrupt shifts in planting rate.

A. Change lasting over a period of years.--Two such changes occurred in the 1926-60 period. In 1936 in district 1 and in 1937 in districts 2 and 3, the rate changed from 4 kernels per hill to 3 kernels per hill. In 1953 the rate changed in all districts from 3 to 4 kernels per hill.

We attempted to remove by a trend the effect of a change in the planting rate on yield. In effect, the trend procedure averages out any abrupt change over a period of years, and thus error could be introduced in two steps of the construction of the weather index. First, the moving average yield value used to select average weather years is influence. Here, any error was reduced by weighting more heavily in the moving average the yields for years with the same planting rate as the year on which the moving average is centered. As the effect of the change in planting rates on the moving average varies over the period of the change, the weighting was varied. For example, in obtaining the 9-year moving average yield for 1952 the yields in 1948, 1949, 1950, 1951, and 1952 were weighted more heavily than the yields for 1953, 1954, 1955, and 1956.

The adjusted 9-year moving average was used to select average weather yields. Because of the interpolation between average weather yields and the 5-year moving average of these yields, an abrupt change is smoothed out in this step also, and a second adjustment is necessary. The ratio between the equally weighted 9-year moving average yield value and the unequally weighted 9-year moving average yield value was used to adjust the 5-year moving average yield value, our best estimate of trend, for the 2 years on each side of the change in the planting rate. The weather index was then taken as the actual yield as a percentage of the adjusted 5-year moving average yield.

In a theoretical example, this adjustment reduced by approximately 40 percent the errors in the resultant weather index caused by the planting rate change. The reduction of error was achieved in both the selection of average weather yields and in the estimate of a true trend value for any one year.

B. Change lasting only one year.--Two such changes occurred in 1926 for districts 5 and 9, and in 1946 for districts 1 through 6.

In 1946 an adjustment was made in the actual yield for the districts involved. Below are the average yields for districts 1-6 and 7-12 for selected years.

Districts	1944	1945	1946	1947	1948	1953	1954
(1) District 1-6----	73.4	61.7	90.4	51.2	80.9	98.2	104.0
(2) District 7-12---	81.7	79.8	85.3	60.9	98.2	93.6	89.4
(1)÷(2)-	89.8	77.3	106.0	84.1	82.3	104.9	116.3

On the average in the 1944-48 period, yields for districts 1 to 6 were 84.3 percent lower than yields for districts 7 to 12, given the planting rate of 3 kernels per hill. Therefore, if districts 1 to 6 had been planted at the 3 rate in 1946, we would have expected an average yield of 71.1 bushels (84 percent of the average yield for districts 7 to 12). The average yield was actually 90.4. This difference is assumed to be due to the planting rate, and the yields in districts 1 to 6 were reduced by the ratio 71.7/90.4. This adjustment makes several assumptions: First, that the yield effect of the higher planting rate does not vary over the six districts; second, that weather in districts 1 to 6 was not substantially different from weather in districts 7 to 12 in 1946. (If there were a marked difference between the two halves of the State in 1946, the expected ratio of the average yields would not be observed.) Although error could be introduced when the assumptions do not hold, the overall error of planting rate and assumptions is more likely to be less than that if no adjustment were made.

In 1926, districts 5 and 9 were planted at the rate of 4 kernels per hill. The 1926 yield was not used in this case to compute the 9-year moving average.

Yield Variation in Open-Pollinated and Hybrid Corn

In the 1926-40 period there were two divisions in the Iowa Corn Yield Test, open-pollinated varieties and hybrid varieties. Hybrids were entered in the yield tests beginning in 1923, but they were not in a separate division until 1926. Since 1941 all entries have been hybrids.

In each of the 12 yield test districts indexes of the average yields of hybrid and of open-pollinated corn were computed with the 1927-40 average equal to 100. The two indexes for each district were charted and visually compared. There appeared to be no significant pattern of deviation.

An analysis of variance showed that the variance of hybrid corn yields and the variance of open-pollinated corn yields are independent estimates of the same population variance (see table 11). Although the difference between the variances was not significant, the variance associated with hybrid corn yields was consistently lower than that of open-pollinated corn yields.

Table 11. - F test for comparing yield variation, open-pollinated and hybrid corn, Iowa, 1927-40

Iowa Corn Yield Test district	Degrees of freedom	Variance of open-pollinated corn yields	Variance of hybrid corn yields	F 1/	$F_{.95}$ 2/
1	13	784	738	1.06	2.57
2	12	878	735	1.19	2.69
3	12	352	342	1.03	2.69
4	12	966	892	1.08	2.69
5	13	736	609	1.21	2.57
6	13	357	309	1.16	2.57
7	9	949	691	1.37	3.18
8	12	800	597	1.34	2.69
9	10	1,274	1,132	1.13	2.97
10	13	1,310	1,177	1.11	2.57
11	9	1,506	1,251	1.20	3.18
12	13	548	491	1.12	2.57
All districts	152	841	725	1.16	1.32

1/ F is the ratio of the two variances. 2/ $F_{.95}$ is the 5 percent confidence limit for the ratio of independent estimates of the same population variance.

In order to make a test with more degrees of freedom, the yields of open-pollinated and hybrid corn for all districts were combined and variance computed. The difference was still not significant.

Aggregating District Weather Indexes

Production weights adjusted for given years were used in combining district weather indexes into an index for the State as a whole. As explained in footnote 6, actual production weights would be biased by the influence of weather in any given year. Thus the weights must be adjusted for weather.

The weather index was used to make the adjustment. Actual production for district "i" (P_i) was divided by the weather index for that district (WI_i) to estimate adjusted production [$P(adj)_i$].

(1)
$$\frac{P_i}{WI_i} = P(adj)_i$$

Adjusted production estimates were used to weight the district weather indexes into a State weather index (WI). Schematically, in any year the State weather index is equal to

(2)
$$\frac{\sum_{i=1}^{N} WI_i \cdot P(adj)_i}{\sum_{i=1}^{N} P(adj)_i}$$

Adjusted production is equal to the product of yield per harvested acre and harvested acres divided by the yield weather index. Substituting this definition in (2) the State yield weather index becomes

(3)
$$\frac{\sum_{i=1}^{N} WI_i \cdot \frac{Yha_i \cdot HA_i}{WI_i}}{\sum_{i=1}^{N} \frac{Yha_i \cdot HA_i}{WI_i}}$$

Simplifying, the weather index cancels out in the numerator

(4)
$$\frac{\sum_{i=1}^{N} Yha_i \cdot HA_i}{\sum_{i=1}^{N} \frac{Yha_i \cdot HA_i}{WI_i}}$$

Any error in the weather index, therefore, is not compounded by the weighting system.

In computing the production weather index we wished to make an additional adjustment for abandoned acres. Planted acres are substituted in the definition of adjusted production, and an abandonment factor introduced in order to make this adjustment. The production weather index is then equal to

(5)
$$\frac{\sum_{i=1}^{N} WI_i \cdot \frac{Yha_i \cdot PA_i}{WI_i} \cdot \frac{HA_i}{PA_i}}{\sum_{i=1}^{N} \frac{Yha_i \cdot PA_i}{WI_i}}$$

Simplifying, the index becomes

(6)
$$\frac{\sum_{i=1}^{N} Yha_i \cdot HA_i}{\sum_{i=1}^{N} \frac{Yha_i \cdot PA_i}{WI_i}}$$

The numerators in formulas (4) and (6) are both actual State production in bushels. The denominators are adjusted production in bushels. The adjustment for the yield weather index is for the influence of weather on yield level. The adjustment for the production weather index is for the influence of weather on yield level and on abandonment.

A Test for Weather Cycles

A nonparametric significance test for cyclical behavior in time series has been devised by Wallis and Moore (7). The test, which makes no assumptions about the fundamental distribution of the time series data, is a simple one.

The techniques of performing the test are these. In a series of N independent observations the expected number of completed runs 24/ of length d in the signs of the first differences is

$$\frac{2(d^2 + 3d + 1)\ (N-d-2)}{(d + 3)!}$$

Observed and expected number of runs may be compared by the usual method of summing the ratios of the squared deviations to the expectations. The sum is similar to X^2 for 2 degrees of freedom but is denoted by $X_p{}^2$ because its sampling distribution is somewhat different from that of X^2. The bulk of the distribution is covered by referring $6/7\ X_p{}^2$ to the usual X^2 tables for 2 degrees of freedom. The tail, i.e., $X_p{}^2 > 6.3$, is described by the X^2 distribution for 2 1/2 degrees of freedom.

24/ A run is a completed phase, the interval between a relative maximum and a relative minimum in the time series. A run can either be an expansion or a contration. Two consecutive runs form a cycle.

The results of this test for State yields per harvested acre, 1866-1960, showed no evidence of cyclical behavior (table 12).25/

Table 12.-Chi-square values for a test for weather cycles, Iowa corn yields, 1866-1960

Length of run in years 1/	X_p^2	X^2 2/
1	0.66	3/ 0.57
2	5.82	4.99
Over 2	1.60	1.37
Total	8.08	6.93

1/ A run is a completed phase, the interval between a relative maximum and a relative minimum in the time series.
2/ $X^2 = 6/7\, X^2_p$.
3/ All X^2 values are insignificant. The appropriate comparison value of X^2 is 10.27.

Statistical Series

Tables 13 to 24 give additional data and information which supplement that presented earlier.

25/ The nonparemetric characteristic of this test depends on the use of relative maximums and minimums to define runs. A relative minimum is defined as a point in the time series at which the series ceases to decline and starts to rise. A relative maximum is then a point where the series ceases to rise and starts to decline. The interval between these two points is called a run. The test has been misused by using deviations from a mean to define the relative maximums and minimums. In this case, the nonparametric quality of the test is lost. When there is a primary trend in the data the results will then show the presence of cycles, whether or not they actually exist.

Table 13.-Procedure for constructing yield weather index, Iowa Corn Yield Test district 1, 1929-60

Year	Actual yield (1)	9-year moving average yield 1/ (2)	Adjusted 9-year moving average yield 2/ (3)	Percentage col. (1) is of col. (2) (4)	"Average" weather yields 3/ (5)	5-year moving average of (5) 4/ (6)	Percentage col. (2) is of col. (3) (7)	Adjusted 5-year moving average 2/ (8)	Weather Index 5/ (9)
	Bushel	Bushel	Bushel	Percent	Bushel	Bushel	Percent	Bushel	
1926----:	81.2	73.2	73.2	110.9	81.2	---	---	---	---
1927----:	64.2	71.2	71.2	90.2	64.2	---	---	---	---
1928----:	95.7	69.1	69.1	138.5	66.3	---	---	---	---
1929----:	66.8	67.0	67.0	99.7	66.8	63.5	---	63.5	105
1930----:	53.4	64.3	64.3	83.0	61.3	61.8	---	61.8	86
1931----:	37.8	63.9	63.9	59.1	58.8	61.1	---	61.1	62
1932----:	55.9	60.1	57.7	96.9	55.9	59.2	---	59.2	94
1933----:	66.3	58.8	57.5	115.3	62.7	60.2	---	60.2	110
1934----:	57.3	59.6	58.0	98.8	57.3	62.0	102.8	60.3	95
1935----:	77.5	62.8	61.4	126.2	66.1	64.7	102.3	63.2	123
1936----:	30.4	65.7	66.1	46.0	67.8	66.9	99.4	67.3	45
1937----:	84.3	67.6	70.2	120.1	69.5	71.8	96.3	74.6	113
1938----:	73.9	69.4	70.3	105.1	73.9	71.4	---	71.4	104
1939----:	81.9	71.6	71.8	114.1	81.9	72.5	---	72.5	113
1940----:	63.7	72.1	72.1	88.3	63.7	75.0	---	75.0	85
1941----:	73.6	74.9	74.9	98.3	73.6	75.6	---	75.6	97
1942----:	81.7	73.3	73.3	111.5	81.7	75.7	---	75.7	108
1943----:	77.3	72.2	72.2	107.1	77.3	77.4	---	77.4	100
1944----:	82.3	72.1	72.1	114.1	82.3	76.6	---	76.6	107
1945----:	55.9	73.3	73.3	76.3	71.9	73.0	---	73.0	77
1946----:	69.8	71.4	71.4	97.8	69.8	71.6	---	71.7	97
1947----:	63.5	67.5	67.5	93.9	63.5	70.1	---	70.1	91
1948----:	81.2	70.2	70.2	115.7	71.0	71.2	---	71.2	114
1949----:	74.5	72.4	73.4	101.5	74.5	73.3	---	73.3	102
1950----:	56.5	76.0	74.7	75.6	77.2	77.3	---	77.3	73
1951----:	47.3	82.3	76.9	61.5	80.3	83.4	107.0	77.9	61
1952----:	100.9	85.2	80.5	125.3	83.4	86.3	105.8	81.6	124
1953----:	101.7	86.3	91.0	111.8	101.7	89.4	94.8	94.3	108
1954----:	88.8	88.6	91.8	96.7	88.8	91.3	96.5	94.6	94
1955 ---:	126.0	94.3	96.3	130.8	92.7	92.9	---	92.9	136
1956----:	90.1	98.9	97.4	92.5	90.1	91.5	---	91.5	98
1957----:	91.1	104.3	104.3	87.3	91.1	95.4	---	95.4	96
1958----:	95.0	109.5	109.5	86.7	95.0	98.5	---	98.5	96
1959----:	108.1	114.7	114.7	94.2	108.1	102.1	---	102.1	106
1960----:	88.4	119.9	119.9	73.7	108.2	105.6	---	105.6	84

1/ Moving average extrapolated at both ends as explained on page 11.
2/ Adjustment made to account for changes in the planting rate as explained on page 32.
3/ Actual yields for years where the percentage (column 4) is in the 85-115 range (underlined). Straight line interpolation between groups of these yields was used to estimate yields for intervening years.
4/ Moving average extrapolated for recent years.
5/ Percentage column (1) is of column (8).

Table 14.-Actual test yields, Iowa Corn Yield Test districts, 1929-60

Year	District 1	2	3	4	5	6	7	8	9	10	11	12
	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel
1929	66.8	66.8	66.5	92.7	85.2	52.0	64.8	84.2	99.6	81.5	76.8	68.4
1930	53.4	63.4	78.8	51.7	79.1	56.3	51.7	47.3	75.6	64.7	57.2	70.4
1931	37.8	49.3	49.1	26.0	39.4	50.0	72.5	57.9	78.8	67.6	74.6	63.5
1932	55.9	95.3	56.1	82.6	85.9	83.2	96.0	70.3	111.2	67.0	75.1	80.2
1933	66.3	69.1	94.1	49.3	79.6	67.2	57.7	65.8	80.1	73.2	65.5	78.4
1934	57.3	71.1	76.7	56.5	63.1	74.6	27.3	29.9	61.8	11.8	3.7	61.3
1935	77.5	78.6	66.4	46.0	57.3	70.5	53.1	68.7	80.6	41.6	61.6	86.1
1936	30.4	53.7	58.9	23.4	43.0	45.6	12.0	37.2	28.9	22.6	15.0	44.3
1937	84.3	59.7	74.6	76.1	55.1	74.7	45.2	79.5	94.0	53.4	72.3	98.8
1938	73.9	58.6	65.2	84.8	88.9	74.7	46.6	75.9	95.1	66.0	64.3	78.6
1939	81.9	78.3	63.1	87.9	77.9	66.9	78.0	81.7	95.0	52.6	84.0	102.8
1940	63.7	108.6	52.1	85.9	64.9	61.3	59.9	76.9	81.0	108.8	80.5	91.2
1941	73.6	62.2	39.9	72.5	84.7	67.8	75.7	80.8	85.5	52.4	59.7	65.0
1942	81.7	75.1	37.9	90.5	106.2	102.6	91.4	92.8	89.3	77.8	74.2	72.7
1943	77.3	62.4	78.9	80.0	97.4	86.5	88.2	84.7	86.6	84.6	81.2	87.8
1944	82.3	62.3	66.1	57.5	73.9	103.1	99.2	79.6	76.9	73.3	74.0	74.6
1945	55.9	51.9	60.0	45.1	51.5	94.2	81.6	86.7	55.9	92.1	63.1	82.7
1946	69.8	72.5	72.4	76.2	57.0	79.0	87.5	75.3	80.8	113.5	90.0	69.6
1947	63.5	31.7	45.4	61.3	45.1	60.8	59.7	49.0	71.1	48.6	33.8	63.8
1948	81.2	39.5	70.5	96.4	101.4	96.3	98.3	97.4	90.3	95.1	97.4	107.5
1949	74.5	83.6	93.5	61.9	52.9	69.3	79.5	67.9	91.9	56.5	106.9	89.0
1950	56.5	60.6	64.7	69.1	91.2	59.8	71.8	90.2	67.0	81.9	79.1	81.1
1951	47.3	59.1	53.1	75.2	93.4	64.0	59.7	74.4	89.3	61.1	81.0	80.1
1952	100.9	86.8	88.6	88.8	107.3	81.4	95.0	104.0	100.6	91.0	113.3	109.7
1953	101.7	82.7	109.1	113.9	104.7	77.0	88.4	96.2	82.9	96.4	115.8	82.1
1954	88.8	110.0	108.8	96.8	116.7	103.1	72.8	98.5	106.9	58.9	72.1	96.6
1955	126.0	120.7	86.4	56.8	84.4	91.7	52.3	87.3	91.8	54.1	48.4	92.8
1956	90.1	64.9	104.6	74.7	79.2	81.3	76.8	79.9	96.9	73.3	76.6	123.0
1957	91.1	95.6	100.6	101.2	101.4	113.9	105.0	91.4	64.7	94.6	94.9	75.2
1958	95.0	97.1	98.1	110.0	110.6	104.2	115.2	112.6	101.5	110.3	121.4	123.5
1959	108.1	96.9	90.1	109.5	120.7	110.6	107.1	118.4	114.2	111.9	103.1	120.8
1960	88.4	54.5	107.8	116.0	114.6	106.6	103.4	121.7	98.3	125.4	121.3	111.6

Table 15.-Trend yields, Iowa Corn Yield Test districts, 1929-60 1/

Year	District											
	1	2	3	4	5	6	7	8	9	10	11	12
	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel
1929	63.5	65.5	58.8	69.0	82.8	57.5	72.2	67.6	77.0	66.2	56.3	63.1
1930	61.8	66.7	59.8	66.3	78.7	59.4	69.0	66.8	77.5	64.6	57.2	67.5
1931	61.1	67.6	61.6	60.8	75.1	60.1	63.7	65.6	78.2	63.0	58.1	71.1
1932	59.2	68.5	63.7	58.3	70.7	64.6	61.8	64.8	78.7	61.4	59.0	73.9
1933	60.2	71.5	65.0	56.3	66.3	67.4	58.7	64.8	79.7	59.8	59.9	77.1
1934	60.3	71.9	64.8	55.4	64.2	69.4	56.8	67.2	80.1	58.2	60.8	81.0
1935	63.2	75.3	67.3	55.5	63.5	71.7	53.5	68.5	80.6	56.6	61.8	82.8
1936	67.3	71.4	67.2	57.9	64.1	73.2	51.3	70.5	80.9	56.2	62.6	82.9
1937	74.6	74.1	61.2	59.2	67.1	71.6	51.6	73.6	81.4	56.9	64.1	83.4
1938	71.4	72.6	59.3	61.1	70.6	72.7	52.9	75.3	81.5	58.8	65.8	84.4
1939	72.5	69.3	61.9	64.1	74.7	73.8	56.9	77.4	82.4	61.8	67.8	84.1
1940	75.0	70.4	62.3	66.0	77.3	74.4	62.4	81.6	84.0	66.7	69.8	81.9
1941	75.6	69.0	62.5	69.8	79.6	76.8	70.7	83.4	85.0	72.1	73.2	83.7
1942	75.7	65.8	63.1	71.7	78.8	79.4	76.0	83.0	83.9	74.4	74.4	81.7
1943	77.4	62.8	64.6	73.6	80.6	83.1	80.3	84.9	84.4	77.1	75.7	80.0
1944	76.6	63.9	66.1	74.3	80.6	83.5	82.7	83.8	83.5	79.0	76.6	77.5
1945	73.0	62.6	66.9	72.8	81.9	84.6	84.3	81.7	79.8	79.5	77.1	79.1
1946	71.7	64.0	67.8	72.7	83.2	84.1	82.4	81.1	80.6	78.8	76.3	78.0
1947	70.1	65.5	69.7	74.4	86.2	81.9	81.6	81.7	83.6	80.4	76.9	80.9
1948	71.2	67.3	73.4	76.1	87.7	80.2	79.6	82.4	84.4	80.9	77.4	80.6
1949	73.3	68.0	75.2	75.9	89 4	81.6	77.7	82.2	86.1	81.9	78.2	82.7
1950	77.3	69.0	78.9	81.4	90.7	81.3	77.3	83.2	92.0	83.6	78.3	83.9
1951	77.9	67.5	79.2	81.9	92.9	78.2	82.8	85.2	89.3	86.7	81.7	84.0
1952	81.6	69.7	80.6	85.3	94.9	84.3	79.2	88.7	90.0	89.7	80.8	84.7
1953	94.3	82.1	90.8	91.8	96.4	92.0	81.5	89.7	92.0	92.4	78.6	88.2
1954	94.6	85.6	94.2	92.4	95.7	94.0	82.5	93.2	93.6	91.6	78.8	93.0
1955	92.9	86.7	93.6	96.6	98.5	96.9	89.5	95.0	93.1	96.5	86.9	97.2
1956	91.5	89.6	95.9	100.9	99.7	102.3	92.3	98.3	96.8	100.2	91.4	105.5
1957	95.4	92.7	98.7	103.4	104.2	103.8	99.2	102.3	100.8	103.5	97.6	110.4
1958	98.5	96.5	103.0	107.3	110.3	106.8	102.3	109.1	102.1	108.9	103.7	114.1
1959	102.1	99.9	106.2	110.3	115.3	108.9	105.0	112.7	105.1	113.0	109.8	118.4
1960	105.6	103.4	109.7	113.5	120.6	111.2	105.3	118.1	107.7	117.4	115.9	122.6

1/ See table 13 for methodology used. Column (8) of table 13 gives the trend yield for district 1.

Table 16.-Yield weather indexes, Iowa Corn Yield Test districts, 1929-60

Year	District											
	1	2	3	4	5	6	7	8	9	10	11	12
1929----:	105	102	113	134	103	90	90	125	129	123	136	108
1930----:	86	95	132	78	100	95	75	71	98	100	100	104
1931----:	62	73	80	43	52	83	114	88	101	107	128	89
1932----:	94	139	88	142	122	129	155	108	141	109	127	108
1933----:	110	97	145	88	120	100	98	102	101	122	109	102
1934----:	95	99	118	102	98	108	48	44	77	20	6	76
1935----:	123	104	99	83	90	98	99	100	100	74	100	104
1936----:	45	75	88	40	67	62	23	53	36	40	24	53
1937----:	113	81	122	128	82	104	88	108	116	94	113	118
1938----:	104	81	110	139	126	103	88	101	117	112	98	93
1939----:	113	113	102	137	104	91	137	106	115	85	124	122
1940----:	85	154	84	130	84	82	96	94	96	163	115	111
1941----:	97	90	64	104	106	88	107	97	101	73	82	78
1942----:	108	114	60	126	135	129	120	112	106	105	100	89
1943----:	100	99	122	109	121	104	110	100	103	110	107	110
1944----:	107	98	100	77	92	124	120	95	92	93	97	96
1945----:	77	83	90	62	63	111	97	106	70	116	82	105
1946----:	97	113	107	105	68	94	106	93	100	144	118	89
1947----:	91	48	65	82	52	74	73	60	85	60	44	79
1948----:	114	59	96	127	116	120	124	118	107	118	126	133
1949----:	102	123	124	82	59	85	102	83	107	69	137	108
1950----:	73	88	82	85	101	74	93	108	73	98	101	97
1951----:	61	88	67	92	100	82	75	87	100	70	99	95
1952----:	124	124	110	104	113	97	120	117	112	101	140	130
1953----:	108	101	120	124	109	84	108	107	90	104	147	93
1954----:	94	128	116	105	122	110	88	106	114	64	92	104
1955----:	136	139	92	59	86	95	58	92	99	56	56	96
1956----:	98	72	109	74	79	80	83	81	100	73	84	117
1957----:	96	103	102	98	97	110	106	89	64	91	97	68
1958----:	96	101	95	102	100	98	113	103	99	101	117	108
1959----:	106	97	85	99	105	102	102	105	109	99	94	102
1960----:	84	53	98	102	95	96	98	103	91	107	105	91

Table 17.-Production weather indexes, corn in Iowa, by Crop Reporting districts, 1929-60 1/

Year	District									State
	1	2	3	4	5	6	7	8	9	
1929	120	102	102	90	125	130	123	136	108	111
1930	81	97	113	74	70	97	99	99	103	87
1931	52	62	81	114	88	101	107	128	89	85
1932	118	130	108	155	108	141	109	128	108	122
1933	99	108	122	98	102	100	122	109	102	105
1934	97	98	113	47	44	77	20	6	74	66
1935	102	96	97	98	99	99	73	99	103	96
1936	41	69	74	22	52	35	39	23	52	44
1937	119	82	113	88	107	116	94	112	117	103
1938	114	104	106	88	101	116	112	97	93	103
1939	125	108	96	137	106	115	85	124	122	112
1940	108	119	83	96	94	96	162	114	111	104
1941	100	98	76	107	97	101	73	82	78	92
1942	116	124	93	120	112	106	104	99	89	109
1943	103	110	113	110	99	102	109	105	108	106
1944	91	93	110	116	94	91	91	96	96	97
1945	69	72	99	94	106	70	115	81	105	86
1946	102	89	100	106	93	100	120	118	88	101
1947	84	48	67	69	57	81	56	41	75	64
1948	120	88	108	124	118	107	118	125	133	113
1949	92	91	104	102	83	107	68	137	108	94
1950	79	94	78	92	108	73	98	100	96	89
1951	74	90	73	69	86	100	67	97	94	81
1952	114	118	103	119	117	112	100	140	130	115
1953	116	105	102	107	107	90	104	147	93	105
1954	99	123	113	87	105	115	64	91	103	101
1955	98	113	94	58	92	99	56	56	96	83
1956	76	76	94	71	76	99	73	82	117	83
1957	97	100	106	105	89	64	90	97	68	88
1958	94	96	90	110	101	96	98	114	106	99
1959	97	98	88	100	102	106	97	91	100	98
1960	89	71	90	103	100	88	105	100	88	90

1/ Production weather indexes are yield weather indexes adjusted for abandoned acres.

Table 18.-Actual corn yields, Iowa Crop Reporting districts, 1929-60 1/

Year	District									State
	1	2	3	4	5	6	7	8	9	
	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel	Bushel
1929	39.5	39.0	38.9	42.9	42.9	42.5	40.2	32.6	37.7	40.2
1930	32.7	37.1	38.1	31.8	33.8	40.5	34.0	26.8	31.3	34.0
1931	27.0	26.9	29.7	32.2	38.9	39.9	33.0	34.8	36.5	32.9
1932	38.2	41.4	43.4	42.3	46.1	50.3	44.0	37.4	44.6	43.0
1933	40.8	42.4	38.6	37.0	44.0	44.3	40.8	31.7	36.3	40.0
1934	34.2	34.4	37.3	17.6	21.9	34.2	3.6	1.8	10.8	23.0
1935	37.8	40.7	40.4	34.0	43.3	44.7	29.1	29.8	38.7	38.0
1936	14.8	22.7	24.0	7.7	26.0	31.7	8.5	8.6	15.4	17.7
1937	44.5	42.4	39.2	38.3	55.5	54.5	36.0	41.1	52.1	45.0
1938	48.7	51.5	47.6	42.0	53.5	52.6	33.7	31.9	44.0	46.0
1939	54.0	54.1	54.1	47.6	59.2	63.4	40.6	38.5	52.0	52.2
1940	50.0	51.1	51.4	52.6	58.7	55.6	50.7	46.6	52.2	52.5
1941	51.5	50.4	47.1	51.6	57.3	56.0	46.2	41.1	49.6	51.0
1942	59.5	58.1	53.9	63.2	66.6	66.5	52.3	51.8	59.8	60.0
1943	49.1	57.1	60.0	53.1	61.5	62.7	50.4	44.8	53.0	55.0
1944	55.5	51.9	53.6	53.2	52.9	57.3	49.5	40.7	50.5	52.5
1945	44.1	40.8	42.5	42.8	50.3	51.4	43.7	34.6	45.0	44.5
1946	52.3	54.3	56.1	57.6	63.4	64.9	53.7	49.5	57.6	57.0
1947	34.3	32.0	30.4	29.8	28.7	37.4	28.3	18.5	27.1	30.5
1948	59.8	57.6	56.5	61.0	65.1	67.1	55.5	55.6	62.9	60.5
1949	44.6	43.1	51.0	43.2	46.9	60.2	44.9	44.0	49.8	47.0
1950	44.1	46.9	45.4	49.9	50.5	52.8	52.5	45.1	49.0	48.5
1951	39.6	44.4	45.5	42.6	49.5	54.4	35.6	30.3	42.3	43.5
1952	61.5	64.0	61.5	61.2	67.3	71.2	57.7	50.0	60.2	62.5
1953	55.2	56.2	57.7	50.1	56.1	57.7	48.2	40.2	46.0	53.0
1954	59.9	61.6	63.8	49.1	56.9	64.8	34.3	35.1	53.5	54.5
1955	46.3	51.3	52.1	42.2	54.5	57.6	36.7	41.0	51.4	48.5
1956	44.4	62.9	68.3	38.1	51.8	68.6	43.0	45.3	52.1	53.0
1957	58.0	62.5	64.5	58.0	69.1	71.3	53.1	51.8	62.8	62.0
1958 2/	53.5	67.2	68.2	67.3	72.7	72.3	62.6	60.1	68.5	66.0
1959 2/	58.3	66.8	66.0	64.1	71.9	72.4	60.5	53.3	65.5	65.0
1960 2/	63.8	61.1	58.6	65.3	66.0	66.1	62.2	51.0	51.4	62.0

1/ Yields per harvested acre.
2/ Preliminary.

Table 19.-Acreage of corn planted, Iowa Crop Reporting districts, 1929-60

Year	District									State
	1	2	3	4	5	6	7	8	9	
	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres
1929----	1,667	1,282	903	1,802	1,642	1,022	1,145	782	803	11,048
1930----	1,700	1,349	947	1,848	1,687	1,050	1,224	832	813	11,449
1931----	1,734	1,401	963	1,914	1,754	1,069	1,246	869	841	11,791
1932----	1,712	1,395	998	1,900	1,746	1,106	1,272	854	866	11,849
1933----	1,691	1,374	984	1,885	1,658	1,047	1,234	805	815	11,493
1934----	1,367	1,130	843	1,528	1,394	877	1,026	666	670	9,501
1935----	1,505	1,230	875	1,604	1,498	972	1,004	576	661	9,925
1936----	1,635	1,355	939	1,744	1,641	1,050	1,134	703	778	10,979
1937----	1,650	1,348	981	1,778	1,682	1,141	1,081	674	803	11,138
1938----	1,546	1,260	925	1,668	1,527	1,015	1,066	668	754	10,448
1939----	1,393	1,154	833	1,520	1,378	914	953	589	665	9,400
1940----	1,366	1,122	797	1,475	1,314	880	922	548	628	9,051
1941----	1,362	1,115	802	1,462	1,329	906	908	562	651	9,096
1942----	1,437	1,162	863	1,569	1,400	958	974	596	666	9,626
1943----	1,608	1,314	963	1,775	1,588	1,058	1,090	672	724	10,792
1944----	1,762	1,391	1,006	1,830	1,618	1,096	1,071	674	776	11,224
1945----	1,698	1,364	984	1,682	1,641	1,097	1,019	619	743	10,847
1946----	1,678	1,409	987	1,760	1,693	1,109	1,083	668	787	11,172
1947----	1,650	1,397	977	1,737	1,656	1,107	1,022	628	762	10,935
1948----	1,678	1,437	1,002	1,724	1,672	1,129	1,026	694	852	11,213
1949----	1,713	1,487	1,032	1,793	1,710	1,130	1,102	730	852	11,549
1950----	1,448	1,268	967	1,484	1,438	1,044	901	576	712	9,837
1951----	1,568	1,385	991	1,595	1,566	1,062	886	593	742	10,386
1952----	1,590	1,429	1,017	1,592	1,599	1,111	987	668	790	10,782
1953----	1,675	1,498	1,046	1,669	1,660	1,137	1,057	671	800	11,213
1954----	1,505	1,375	1,038	1,528	1,504	1,109	995	685	800	10,540
1955----	1,586	1,414	1,062	1,556	1,559	1,145	992	664	822	10,799
1956----	1,533	1,389	1,087	1,521	1,502	1,150	976	653	773	10,583
1957----	1,506	1,399	1,077	1,405	1,476	1,167	877	583	759	10,249
1958 1/--	1,559	1,389	1,085	1,392	1,453	1,168	777	513	748	10,085
1959 1/--	1,948	1,769	1,261	1,779	1,809	1,306	1,058	651	911	12,493
1960 1/--	1,905	1,709	1,230	1,800	1,811	1,300	1,107	664	894	12,419

1/ Preliminary.

Table 20.-Acreage of corn harvested, Iowa Crop Reporting districts, 1929-60

Year	District 1	2	3	4	5	6	7	8	9	State
	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres
1929	1,667	1,282	903	1,802	1,642	1,022	1,145	782	803	11,048
1930	1,683	1,335	937	1,829	1,670	1,040	1,212	823	805	11,335
1931	1,725	1,339	958	1,904	1,745	1,064	1,240	864	837	11,732
1932	1,712	1,395	998	1,900	1,746	1,106	1,272	854	866	11,849
1933	1,691	1,374	984	1,885	1,658	1,047	1,234	805	815	11,493
1934	1,366	1,130	843	1,497	1,379	876	988	628	650	9,358
1935	1,490	1,218	866	1,588	1,483	963	994	570	654	9,826
1936	1,603	1,328	920	1,710	1,608	1,028	1,112	689	763	10,759
1937	1,642	1,341	976	1,770	1,674	1,135	1,076	670	799	11,082
1938	1,542	1,256	922	1,683	1,522	1,012	1,063	666	752	10,417
1939	1,393	1,154	833	1,520	1,378	914	953	589	665	9,400
1940	1,362	1,118	795	1,470	1,310	878	919	546	626	9,024
1941	1,358	1,112	799	1,458	1,325	903	905	561	649	9,069
1942	1,427	1,160	851	1,563	1,395	955	961	594	664	9,568
1943	1,601	1,310	963	1,767	1,578	1,052	1,073	660	712	10,716
1944	1,736	1,365	993	1,774	1,591	1,085	1,052	668	773	11,037
1945	1,671	1,337	974	1,634	1,635	1,092	1,009	611	742	10,706
1946	1,674	1,401	985	1,755	1,687	1,107	1,080	664	781	11,134
1947	1,602	1,348	933	1,644	1,570	1,055	950	586	722	10,410
1948	1,673	1,434	1,000	1,722	1,669	1,127	1,024	691	851	11,191
1949	1,710	1,485	1,030	1,790	1,709	1,128	1,099	727	849	11,527
1950	1,444	1,263	963	1,477	1,433	1,040	899	572	707	9,798
1951	1,538	1,360	982	1,532	1,552	1,059	851	579	738	10,190
1952	1,588	1,424	1,015	1,581	1,598	1,110	981	665	788	10,750
1953	1,668	1,497	1,045	1,660	1,656	1,135	1,053	668	798	11,180
1954	1,491	1,349	1,036	1,512	1,494	1,105	992	680	794	10,453
1955	1,582	1,411	1,061	1,549	1,554	1,142	984	663	822	10,767
1956	1,361	1,387	1,086	1,300	1,408	1,143	974	638	771	10,067
1957	1,504	1,397	1,076	1,391	1,473	1,166	872	581	758	10,218
1958 1/	1,476	1,335	1,016	1,361	1,425	1,134	755	499	732	9,733
1959 1/	1,862	1,708	1,181	1,737	1,774	1,265	1,035	626	889	12,077
1960 1/	1,816	1,638	1,139	1,757	1,767	1,252	1,081	634	860	11,945

1/ Preliminary.

Table 21.-Actual corn production, Iowa Crop Reporting districts, 1929-60

Year	District 1	2	3	4	5	6	7	8	9	State
	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.
1929	65.9	50.1	35.1	77.4	70.5	43.5	46.1	25.5	30.2	444.1
1930	55.0	49.6	35.7	58.1	56.5	42.1	41.2	22.0	25.2	385.4
1931	46.6	37.4	28.4	61.4	67.9	42.5	41.0	30.1	30.6	386.0
1932	65.3	57.7	43.3	80.4	80.5	55.6	56.0	32.0	38.6	509.5
1933	69.0	58.3	38.0	69.8	72.9	46.4	50.3	25.5	29.5	459.7
1934	46.7	38.9	31.4	26.3	30.2	30.0	3.6	1.1	7.0	215.2
1935	56.3	49.6	34.9	54.0	64.2	43.0	29.0	17.0	25.3	373.4
1936	23.6	30.1	22.1	13.1	41.8	32.6	9.4	5.9	11.7	190.4
1937	73.0	56.9	38.3	67.8	92.9	61.9	38.7	27.5	41.6	498.7
1938	75.1	64.7	43.8	70.7	81.5	53.2	35.8	21.2	33.1	479.2
1939	75.2	62.4	45.1	72.4	81.6	57.9	38.7	22.7	34.6	490.7
1940	68.1	57.2	40.8	77.3	76.9	48.8	46.6	25.4	32.7	473.8
1941	69.9	56.1	37.7	75.2	75.9	50.6	41.8	23.1	32.2	462.5
1942	84.9	67.3	45.9	98.8	92.9	63.5	50.3	30.6	39.7	574.1
1943	78.5	74.8	57.8	93.8	97.1	66.0	54.1	29.5	37.7	589.4
1944	96.3	70.9	53.2	94.4	84.2	62.2	52.1	27.2	39.0	579.4
1945	73.6	54.5	41.4	69.9	82.2	56.1	44.1	21.2	33.4	476.4
1946	87.5	76.0	55.3	101.1	106.9	71.8	58.0	32.9	45.0	634.6
1947	55.0	43.2	28.4	49.1	45.1	39.5	26.9	10.9	19.6	317.5
1948	100.1	82.6	56.5	105.0	108.6	75.6	56.8	38.4	53.5	677.1
1949	76.3	64.4	52.5	77.4	80.0	67.9	49.0	32.0	42.4	541.8
1950	63.7	59.2	43.7	73.7	72.4	54.9	47.2	25.8	34.6	475.2
1951	60.9	59.0	44.7	65.3	76.7	57.5	30.3	17.5	31.2	443.3
1952	97.7	91.1	62.5	96.7	107.6	79.0	56.6	33.3	47.5	671.9
1953	92.1	84.1	60.3	83.2	93.0	65.5	50.8	26.9	36.7	592.5
1954	89.3	83.1	66.0	74.3	85.0	71.6	34.0	23.9	42.5	569.7
1955	73.3	73.4	55.2	65.3	84.7	65.7	36.2	27.2	42.2	522.2
1956	60.5	87.2	74.1	49.5	72.9	78.4	41.9	28.9	40.1	533.6
1957	87.3	87.3	69.4	80.6	101.8	83.1	46.3	30.1	47.6	633.5
1958 1/	78.9	89.7	69.3	91.5	103.5	81.9	47.3	30.0	50.2	642.4
1959 1/	108.5	114.1	78.0	111.3	127.5	91.5	62.6	33.4	58.3	785.0
1960 1/	115.8	100.1	66.8	114.8	116.6	82.7	67.3	32.3	44.2	740.6

1/ Preliminary.

Table 22.-Corn yields and production, adjusted for the influence of weather, Iowa, 1929-60

Year	Yield 1/	Production
	Bushels	Million bushels
1929	36.1	398.3
1930	38.5	436.6
1931	38.5	451.1
1932	35.3	418.3
1933	38.5	442.0
1934	34.6	323.5
1935	39.0	383.7
1936	39.6	425.7
1937	43.4	481.3
1938	44.7	465.8
1939	46.5	437.2
1940	49.8	449.4
1941	55.4	502.9
1942	54.8	524.4
1943	51.5	551.5
1944	53.1	586.0
1945	51.1	547.0
1946	56.3	626.5
1947	45.5	473.4
1948	53.2	595.9
1949	49.8	573.7
1950	54.2	530.7
1951	52.5	535.0
1952	54.2	582.2
1953	50.2	561.5
1954	53.7	561.7
1955	58.2	626.4
1956	61.5	619.3
1957	70.0	714.8
1958	64.2	624.8
1959	64.0	772.7
1960	66.3	792.1

1/ Per harvested acre.

Table 23.-Deviations in July temperatures, by Iowa Crop Reporting districts, 1929-60 1/

Year	District								
	1	2	3	4	5	6	7	8	9
	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
1929------	-0.5	-0.9	-0.3	-1.8	-1.8	-0.9	-1.9	-1.9	-1.8
1930------	3.2	1.8	1.1	3.7	3.6	1.9	3.1	2.6	2.0
1931------	1.4	2.3	3.0	1.0	1.5	3.0	1.2	1.3	1.3
1932------	.9	0	.6	.3	.3	.5	.6	.6	-.4
1933------	1.0	1.2	1.1	1.0	1.0	.1	.4	.7	0
1934------	1.6	2.2	3.0	3.7	4.1	3.6	7.1	7.5	6.1
1935------	4.7	3.8	4.3	5.2	3.4	3,5	5.1	3.4	2.8
1936------	8.3	7.8	6.8	9.3	7.6	6.3	8.7	8.6	8.5
1937------	1.0	1.0	.8	1.1	0	-.2	1.3	.1	-.4
1938------	.7	.8	.7	1.2	1.1	.8	2.1	1.9	1.1
1939------	1.1	1.3	.8	1.5	.6	-.1	1.0	1.2	.2
1940------	1.4	1.9	1.4	1.0	1.3	1.1	1.2	.8	1.4
1941------	-.3	.1	.2	-.4	-.6	-.4	-.3	-.3	-.4
1942------	-1.4	-1.8	-1.3	-1.0	-1.3	-.6	-.8	-1.0	-.8
1943------	.1	.2	.6	-.3	-.4	.5	-.5	-.4	.1
1944------	-3.0	-3.0	-2.5	-2.9	-3.0	-2.4	-2.9	-2.8	-2.2
1945------	-3.1	-3.1	-3.0	-3.3	-2.8	-3.5	-3.6	-3.5	-3.5
1946------	-1.1	-1.3	-1.2	-1.4	-1.7	-1.4	-2.0	-2.0	-1.8
1947------	-1.9	-2.1	-2.6	-2.2	-2.2	-3.1	-2.9	-3.1	-3.0
1948------	-.7	.5	.1	-.4	.1	-.1	-1.4	.4	-.8
1949------	1.0	1.7	1.5	.4	1.1	1.7	-1.0	0	1.2
1950------	-6.5	-4.8	-5.0	-6.3	-5.0	-4.6	-7.4	-6.2	5.2
1951------	-3.8	-3.0	-3.1	-3.5	-3.0	-2.8	-1.5	-3.1	2.8
1952------	-1.4	-.7	.5	-1.7	-.7	.9	-1.5	.9	.1
1953------	-1.2	-1.4	-1.3	-.6	-.8	-.2	-.5	-.1	.5
1954------	1.1	1.1	.8	2.8	2.3	1.5	4.1	3.9	2.2
1955------	4.5	4.5	4.6	4.7	4.5	4.9	4.1	3.8	4.3
1956------	-3.3	4.2	-3.3	-2.7	-2.2	-1.8	-2.7	-1.9	-1.4
1957------	3.1	3.3	1.6	2.5	2.8	2.4	2.9	2.6	2.2
1958------	-4.7	-4.7	-4.6	-5.6	-5.2	-4.1	-5.1	-5.1	-4.2
1959------	-2.2	-2.2	-2.9	-3.2	-3.0	-2.5	-4.4	-3.6	-3.0
1960------	-2.0	-1.8	-2.9	-2.8	-2.7	-2.6	-3.7	-3.1	-3.0
	Average temperature								
1929-60---	74.4	73.7	73.4	75.9	75.4	75.1	77.2	76.5	76.8

1/ Deviations from 1929-60 average.

Table 24.-Deviations in July precipitation, by Iowa Crop Reporting districts, 1929-60 1/

Year	District								
	1	2	3	4	5	6	7	8	9
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1929------	-0.36	-0.46	-0.84	0.59	1.48	1.85	3.15	0.91	1.68
1930------	-2.68	-.69	-.86	-2.20	-2.32	-1.71	-2.32	-2.27	-2.31
1931------	-1.01	-1.76	-1.71	-1.03	.51	-.97	-.84	-.20	.67
1932------	-.86	-.52	-.96	-.94	-.60	-.16	-.45	.07	1.71
1933------	1.98	.93	1.45	.23	.10	-.69	-.39	-1.53	-1.86
1934------	1.62	1.27	1.91	.70	1.06	2.79	-2.17	-2.21	-1.09
1935------	-.09	-.73	-.65	-.94	.78	-.45	-1.53	1.07	1.86
1936------	-2.52	-2.82	-2.89	-2.94	-3.13	-2.93	-3.01	-2.80	-3.22
1937------	-1.11	-2.86	-2.48	-.84	-1.49	-.27	1.77	.33	-.21
1938------	1.88	1.50	.84	2.49	.70	1.27	-.15	-.82	-.38
1939------	-.18	-1.04	-.10	.25	-.52	.40	.53	-1.04	-.80
1940------	-.53	1.51	3.23	1.90	1.71	-.51	1.44	1.79	-.26
1941------	-1.29	-1.00	-2.18	-1.60	-1.22	-.89	-1.26	-1.22	-.02
1942------	.77	2.43	2.69	1.56	1.77	.88	-.27	1.94	1.45
1943------	1.77	1.81	.17	1.37	2.39	-.07	-.29	.74	2.31
1944------	2.74	.30	.72	.89	.86	-.99	-.16	-.58	-1.02
1945------	.98	.37	-1.09	1.10	-1.28	-1.87	1.25	-1.28	-2.30
1946------	-1.90	-.92	-1.79	-1.68	-.32	-1.88	-1.58	.56	.72
1947------	-2.25	-1.67	-.28	-1.89	-2.75	-.17	-1.69	-2.16	-2.44
1948------	.35	-1.41	-1.48	1.04	1.24	2.25	1.08	.69	2.70
1949------	-.12	.53	-.61	-.24	-.83	.76	.33	.96	-.02
1950------	3.04	2.15	2.71	1.37	-1.58	1.27	2.55	.50	-.26
1951------	1.57	.28	2.54	.43	.85	1.48	2.11	.16	1.18
1952------	1.60	1.61	.29	1.94	.26	-.46	-.19	-.68	-.82
1953------	.16	1.19	2.91	-1.61	-.48	.07	-1.41	-1.06	-1.51
1954------	-.82	.26	-1.14	-1.90	-2.27	-1.92	-3.00	-2.30	-1.99
1955------	-.26	1.00	.06	-.17	1.07	-1.20	-1.41	.44	-1.41
1956------	-.52	1.78	.82	.17	.25	.92	2.57	2.75	.71
1957------	1.17	-.29	.30	-.11	.26	-.31	-1.72	.22	1.16
1958------	-.24	.98	.62	5.31	5.45	1.88	9.66	8.30	5.16
1959------	-2.73	-1.69	-1.13	-2.55	-1.10	.71	-1.33	-.20	.50
1960------	-1.19	-1.36	-.56	-.77	-.70	.84	-1.18	-1.17	.05
	Average precipitation								
1929-60---	3.31	3.44	3.75	3.48	3.50	3.37	3.43	3.15	3.38

1/ Deviations from 1929-60 average.