For the year 1930, the extension No. 1, gives a mean elevation of 6.88 feet, for the year, or 240+6.88=246.88 feet. Extensions Nos. 2 and 3 are given simply to show that considerable error may be made in extending this residual "e," and yet influence the results only 5 per cent of the total maximum swing from highest to lowest mean monthly levels recorded. In order to forecast as closely as possible, one should secure the data to the end of the calendar year; as it is, the extension for the year 1931 indicates that the mean annual level will be about 6.22+240=246.22 feet, still lower than for 1930.

The accuracy of these forecasts depends a great deal in predetermining the path of the double Wolf cycle. In this record of lake levels, these double Wolf cycles do not emerge as perfectly as one could wish. If they were perfect, they would consistently appear in a certain relation to the sun spot maxima and minima. As it is, we can only tentatively extend them. If is self-evident, from a close inspection of curves Nos. 1 and 2, Figure 4, that the double Wolf cycle has reached its peak at 1929, and will trend downward to about 1932–33.

The same remarks apply to lakes with outflow, relative to investigating rainfall and temperature as for no-outlet lakes. It is most important to discover the lag of rainfall behind the temperature oscillations, and if possible the lag of the levels behind that of the rainfall. With lakes having data similar to Lake Ontario, one does not need necessarily to make these rainfall and temperature studies, only as indicated herein, to discover the epochs of the secular swings.

In his chapter headed "The Significance of Climatic Oscillations in Theory and Practise," Brückner says (p. 274).

> Our climatic oscillations can also be modified due to different land conditions. Especially in arid districts, where there is little water, the hydrographic conditions alter greatly, in that they follow the oscillations of the rainfall. A map made during a dry period, will often present an entirely different picture, than if it were made during a wet period. Lakes vanish in dry periods and return in wet; viz, Lake George in Australia, which in 1820 and 1876 was an important lake 20 to 30 kilometers long, and an insignificant lake only in 1850. It was 10 kilometers wide and 5 to 8 meters deep, and in the dry periods, dwindled away completely down to the ground, so that grass grew in its basin. Likewise the neighboring lakes, Cowal and Bathurst, became depleted in the dry periods, and refilled in the wet periods. From a full consideration of these facts, it is clear that lakes Cowal and George behave somewhat like Lake Zurich. Very similar also is lake Hamun-Sumpf of Persia, although this does not completely dry up. Great, also, are the oscillations of Great Salt Lake, whose area changed from its minimum in 1850 to its maximum in 1870 a full 17 per cent, like that of Lake di Fucino, whose area decreased 19.2 per cent from 1816 to 1835. Relatively small, although very definite, are the larger oscillations of the Caspian Sea.

In an attempt to utilize Brückner's ideas, in the past, so many anomalies developed that his work has lain in obscurity. Brückner, himself, was unable to discover any correlation between his cycle and the sun spots. Great credit, therefore, should be given Streiff (2) for his discovery of this relationship, and why its existence had hithertofore escaped us; for until he made it, there was nothing to tie to—our climatic cycle was of a greatly varying period, and no one knew when it would change or end. With out present knowledge, we can turn back to Brückner's book, and use the information it contains to great advantage. Brückner calls attentoin in the extract given above to the difference that may exist in a map made in the dry period as against one made in the wet period. The last major climatic oscillation peak was about 1856, or 74 years ago. Practically all of our important railroad and public highway work has been done since that time. Most of our park systems driveways, and roads of all types for auto travel, in the various States, have been completed within the past 30 years, namely, beginning at the very lowest point of our climatic swing (1900 to 1910). There is every reason to believe, therefore, as the next 20 years comes on apace, we will witness considerable damage to work done during this past régime of weather.

(1) Klimaschankungen seit 1700, by Ed. Brückner, Vienna, 1890. This was also published as Heft II in Penck's Band IV, Geographische Abhandlungen.
(2) A. Streiff in Monthly Weather Review, July, 1926, Washington, D. C.
(3) A. Streiff in Monthly Weather Review, March, 1928, Washington, D. C.
(4) A. Streiff in Monthly Weather Review, October, 1929, Washington, D. C.
(5) United States Geological Survey data.

WEATHER AND CORN YIELDS

By W. A. MATTICE

[Weather Bureau, Washington, April, 1931]

Corn is one of the most widely grown crops of the United States; practically every State grows some corn, whether for grain or silage. The heaviest production is concentrated in nine States, comprising what is known as the "Corn Belt"; here is found about 60 per cent of the Nation's acreage and in 1925 this region produced 70 per cent of the total production. Figure 1 shows the area under consideration. The States outlined contain the Corn Belt proper, but the sections of heavy production do not include the entire region shown, as it is confined to the central parts of the Ohio Valley States, most of Iowa and Missouri, southeastern Minnesota and South Dakota, and eastern Kansas and Nebraska. The figures shown in the State boundaries are the percentages of the total crop area that is planted to corn in each State.

The weather data used in this study were obtained from the State Section Summaries and the original records of observations on file at the central office of the Weather Bureau. The precipitation and mean temperature data are State averages for all meteorological stations, but the maximum temperatures, percentage of possible sunshine, and p. m. relative humidity were obtained by averaging data of selected first-order stations.

As is usual in a study of this type, covering a relatively long period of years, it was necessary to adjust the records available to the several State boundaries, but every effort was made to keep the data representative and comparable. The yield data were obtained from the United States Department of Agriculture reports.

The method developed by Kincer (2) was applied to the several State data, using five weather elements covering the period April 1 to September 30, inclusive. In order to conserve space, and also as the method is familiar to most of the readers of this publication, the various data used in computation of the bases are omitted and only the final computed yields are given. By the expression "bases" is to be understood the computed yields used as a weather index for subsequent calculations. That expression is used for brevity and convenience in discussion. Table 1 shows the actual corn yields in bushels per acre and Table 2 the computed bases; the averages for the section are also given. The subsequent tabulation gives the data used in computation of the final bases and the equations derived therefrom.

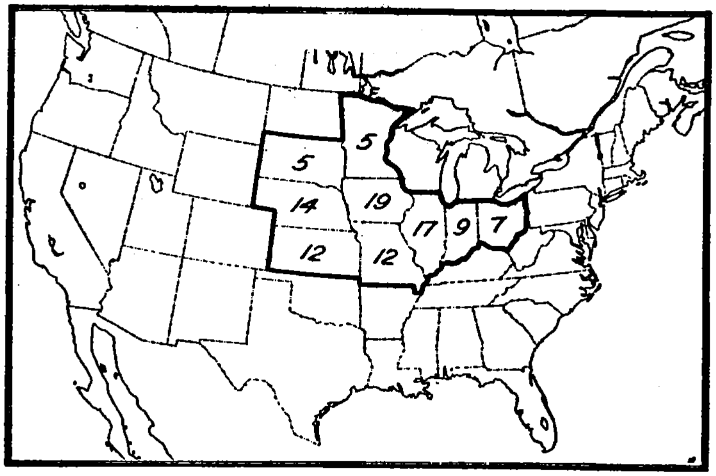

FIGURE 1.—The Corn Belt States. Region outlined shows the area of heaviest production. This area in 1925 grew 59 per cent of the total corn crop of the United States. Figures within State boundaries indicate per cent of total acreage planted to corn in the respective States

A word of explanation is necessary at this point. The weather variables for Ohio were so numerous that the computation of a straight multiple equation was avoided, the data being first combined in groups of three variables

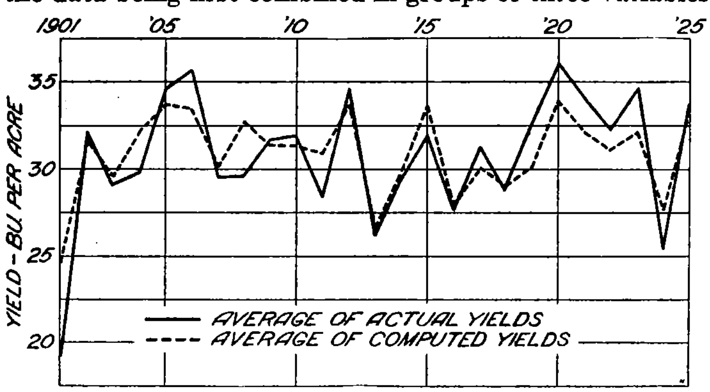

FIGURE 2.—Computed and actual yields of corn, bushels per acre, for the Corn Belt. Arithmetic average of individual State bases

and a final equation computed from them. Thus, this State has three preliminary equations, the results being combined in the final, or fourth, expression.

TABLE 1.—*Yields of corn, bushels per acre*

Years	Ohio	Indiana	Illinois	Minnesota	Iowa	Missouri	South Dakota	Nebraska	Kansas	Average
1901	26.1	19.8	21.4	26.3	25.0	10.1	21.0	14.1	7.8	19.1
1902	38.0	37.9	38.7	22.8	32.0	39.0	18.9	32.3	29.9	32.2
1903	29.6	33.2	32.2	28.3	28.0	32.4	27.2	26.0	25.6	29.2
1904	32.5	31.5	36.5	26.9	32.6	26.2	28.1	32.8	20.9	29.8
1905	37.8	40.7	39.8	32.5	34.8	33.8	31.8	32.8	27.7	34.6
1906	42.6	39.6	36.1	33.6	39.5	32.3	33.5	34.1	28.9	35.6
1907	34.6	36.0	36.0	27.0	29.5	31.0	25.5	24.0	22.1	29.5
1908	38.5	30.3	31.6	29.0	31.7	27.0	29.7	27.0	22.0	29.6
1909	39.5	40.0	35.9	34.8	31.5	26.4	31.7	24.8	19.9	31.6
1910	36.5	39.3	39.1	32.7	36.3	33.0	25.0	25.8	19.0	31.9
1911	38.6	36.0	33.0	33.7	31.0	26.0	22.0	21.0	14.5	28.4
1912	42.8	40.3	40.0	34.5	43.0	32.0	30.6	24.0	23.0	34.5
1913	37.5	36.0	27.0	40.0	34.0	17.5	25.5	15.0	3.2	26.2
1914	39.1	33.0	29.0	35.0	38.0	22.0	26.0	24.5	18.5	29.5
1915	41.5	38.0	36.0	23.0	30.0	29.5	29.0	30.0	31.0	32.0
1916	31.5	34.0	29.5	33.5	36.5	19.5	28.5	26.0	10.0	27.7
1917	38.0	36.0	38.0	30.0	37.0	35.0	28.0	27.0	13.0	31.3
1918	36.0	33.0	35.5	40.0	36.0	20.0	34.0	17.7	7.1	28.8
1919	43.0	37.0	36.0	40.0	41.6	27.0	28.5	26.2	15.2	32.6
1920	43.4	40.5	34.6	37.5	46.0	32.0	30.0	33.8	26.5	37.0
1921	41.0	36.0	34.0	41.0	42.0	30.0	32.0	28.0	22.2	34.0
1922	39.0	37.0	35.5	33.0	45.0	28.5	28.5	25.0	19.3	32.3
1923	41.0	38.5	37.5	36.0	40.5	30.0	34.5	33.0	21.7	34.7
1924	26.0	25.6	33.0	27.0	28.0	24.0	21.3	22.0	21.7	25.4
1925	48.0	43.5	42.0	36.0	43.9	29.5	17.5	26.0	16.6	33.7
Mean	37.7	35.7	34.7	32.6	35.7	27.7	27.5	26.1	19.5	30.8
σ	5.21	5.00	4.44	5.14	5.73	6.16	4.52	5.35	7.12	3.68

TABLE 2.—*Computed yields of corn, bushels per acre*

Years	Ohio	Indiana	Illinois	Minnesota	Iowa	Missouri	South Dakota	Nebraska	Kansas	Average
1901	34.0	26.1	26.9	32.9	35.5	16.2	23.6	15.9	9.5	24.5
1902	34.8	36.0	42.6	26.2	30.2	31.1	25.3	29.9	28.4	31.6
1903	30.9	34.9	34.3	26.8	31.4	30.4	27.6	21.2	28.0	29.5
1904	35.8	32.6	37.7	25.2	38.7	33.8	26.5	31.6	28.3	32.2
1905	37.9	37.3	40.1	34.6	33.5	31.3	33.2	30.1	25.1	33.7
1906	46.3	37.4	31.5	28.9	40.5	29.9	29.9	29.6	26.4	33.4
1907	34.6	36.9	35.2	29.7	31.4	30.2	27.6	23.5	21.6	30.1
1908	41.0	34.3	34.8	31.4	33.7	30.8	31.2	30.3	26.4	32.7
1909	37.3	38.4	34.4	35.8	34.9	26.3	28.9	26.3	19.8	31.3
1910	36.1	41.1	35.5	35.8	32.1	31.8	21.4	25.0	23.3	31.3
1911	37.5	37.6	34.0	37.0	39.4	27.9	22.3	23.8	18.0	30.8
1912	44.8	41.8	39.4	30.8	39.8	29.5	28.9	27.2	20.2	33.6
1913	38.0	35.4	30.2	37.9	34.3	18.4	24.0	15.4	3.2	26.3
1914	37.4	33.5	28.5	34.3	36.7	24.6	27.3	25.7	18.4	29.6
1915	42.5	41.7	35.1	21.3	28.6	38.6	30.1	33.4	31.5	33.6
1916	29.8	31.8	29.5	31.1	35.8	22.3	29.8	24.3	12.0	27.4
1917	34.0	33.0	37.6	31.4	36.8	31.4	26.8	25.9	12.7	30.0
1918	36.4	33.6	36.7	34.4	30.4	21.6	33.4	24.0	9.8	28.9
1919	38.7	30.7	31.7	37.0	40.3	26.4	27.6	24.1	15.3	30.2
1920	38.9	38.1	33.1	36.1	40.4	32.0	34.1	31.7	20.8	33.9
1921	41.1	36.5	35.7	37.9	38.6	26.4	28.1	22.6	21.6	32.1
1922	38.3	37.6	32.5	35.5	41.0	27.5	28.5	21.1	19.1	31.2
1923	39.5	34.2	35.9	34.3	34.8	28.6	27.9	34.1	19.3	32.1
1924	30.0	28.0	34.2	29.1	28.4	31.3	21.9	27.5	18.5	27.7
1925	46.8	43.6	38.9	35.9	43.1	27.5	23.4	24.1	16.1	33.3
Mean	37.7	35.7	34.6	32.4	35.6	28.2	27.6	25.9	19.7	30.8
σ	4.38	4.08	3.64	4.27	4.12	4.74	3.43	4.69	6.69	2.42
Sxy	2.81	2.76	2.52	2.93	4.06	3.90	2.94	3.09	2.76	------
rx	+.84	+.83	+.82	+.82	+.71	+.78	+.76	+.82	+.92	+.89

Ohio.—Equations and variables used.

$$X_1=0.781A-0.489M+1.032B-50.335 \quad (1)$$

$$X_2=-0.595E+0.401K+0.552C+17.755 \quad (2)$$

$$X_3=0.259G+1.744D+0.347F-12.827 \quad (3)$$

$$\overline{X}=0.589X_1+0.413X_2+0.297X_3-11.290 \quad (4)$$

A = Mean temperature, September.
B = Mean temperature, June.
C = Mean maximum temperature, April.
D = Total precipitation, July.
E = P. m. relative humidity, June.
F = Mean maximum temperatures, September.
G = Percentage of possible sunshine, June.
K = P. m. relative humidity, August.
M = Percentage of possible sunshine, July.

Indiana.—Equation and variables used.

$$\overline{X}=2.646A+0.234L+0.433H+0.559D-22.990$$

A = Total precipitation, July.
L = Percentage of possible sunshine, May.
H = Mean maximum temperatures, September.
D = Total precipitation, September.

Illinois.—Equation and variables used.

$$\overline{X}=0.476A-0.412F+1.230K-0.603G-0.722E-0.438J+110.907$$

A = P. m. relative humidity, July.
F = Percentage of possible sunshine, September.
K = Total precipitation, April.
G = Mean maximum temperatures, August.
E = Total precipitation, July.
J = P. m. relative humidity, September.

Minnesota.—Equation and variables used.

$$\overline{X}=0.622A+0.526C+0.154F-0.441I-0.333M-16.187$$

A = Mean temperature, June.
C = Mean maximum temperatures, August.
F = Percentage of possible sunshine, July.
I = P. m. relative humidity, April.
M = Percentage of possible sunshine, April.

Iowa.—Equation and variables used.

$$\overline{X}=0.912A+1.734D-1.122F-0.558I+0.543J+0.130L-30.656$$

A = Mean temperature, September.
D = Total precipitation, April.
F = Total precipitation, May.
I = Mean temperature June.
J = Mean maximum temperatures, May.
L = Percentage of possible sunshine, June.

Missouri.—Equation and variables used.

$$\overline{X} = -0.894B - 723C + 169.102$$

B = Mean maximum temperatures, August.
C = Mean maximum temperatures, July.

South Dakota.—Equation and variables used.

$$\overline{X} = 1.737A + 0.291B + 1.496K + 0.143F + 0.078H - 8.866$$

A = Total precipitation, May.
B = P. m. relative humidity, July.
K = Total precipitation, April.
F = Percentage of possible sunshine, May.
H = Percentage of possible sunshine, September.

Nebraska.—Equation and variables used.

$$\overline{X} = 0.638A - 0.504E - 1.191D - 3.373L + 0.593H + 0.270J + 63.808$$

A = P. m. relative humidity, August.
E = Percentage of possible sunshine, June.
D = Mean temperature, July.
L = Total precipitation, July.
H = Mean maximum temperatures, June.
J = P. m. relative humidity, July.

Kansas.—Equation and variables used.

$$\overline{X} = 0.399A + 0.430B + 0.245O + 0.177L - 45.981$$

A = P. m. relative humidity, August.
B = P. m. relative humidity, July.
O = P. m. relative humidity, May.
L = P. m. relative humidity, September.

One striking feature that is instantly apparent is the fact that every variable in Kansas is relative humidity; this item appears more important in the Plains than elsewhere. Undoubtedly, the relative humidity at the p. m. observation is a fairly good index of the weather conditions as affecting corn, at least in the Plains States. The moisture conditions are more precarious here than farther east, and anything which tends to increase evaporation, would necessarily produce its effect on crops. Evaporation and relative humidity are closely related, so the latter produces an indirect effect on yields through that relation.

The coefficients of correlation, as shown in Table 2, are all fairly high, ranging from 0.71 for Iowa to 0.92 for Kansas. Iowa has always been a rather difficult State for which to correlate corn yields and weather, so the low coefficient there was not surprising. Kansas, on the other hand, has been a favorable one for correlation purposes. One item shown in Table 2, the standard error of estimate, Sxy, needs some explanation. The value shown is derived in the same manner as standard deviation, except that the departures are computed from actual and computed yields. The standard error, compared with the standard deviation of yield, shows the value of the coefficient of correlation instantly, for if the standard error is not sufficiently smaller than the standard deviation, the coefficient is valueless. It might be added that in order to reduce the standard error to 50 per cent of the standard deviation it is necessary to have a coefficient between 0.86 and 0.87.

Figure 2 shows the actual and computed yields of corn in bushels per acre for the Corn Belt as a whole. The two sets of data were obtained by averaging the yields for the nine States. The agreement is very close, except for 1901. The coefficient of correlation between these values is 0.89, a value sufficiently high to justify the statement that yields are largely dependent on the weather, and that we have included the major items necessary.

WEIGHTED CORRELATIONS

It is realized, of course, that the method of obtaining the final computed yields for the Corn Belt as a whole, is open to question, as the method of weighting each State equally would be considered erroneous by some authorities. It was with this thought in mind that the entire ground was again covered in a different manner.

The various States appeared to lend themselves readily to a grouping by sections, as follows: The Ohio Valley, the Mississippi Valley, and the Great Plains. The Ohio Valley States were Ohio, Indiana, and Illinois. The Mississippi Valley States were originally intended to be Minnesota, Iowa, and Missouri, but in examining the coefficients it was found that Missouri did not correlate with the others, in fact, when Minnesota and Iowa had positive coefficients with a certain weather variable, Missouri was negative, etc. Therefore, it was decided to combine only Minnesota and Iowa in the Mississippi Valley and include Missouri in the Great Plains as it correlated with the latter area.

The final grouping of the Great Plains then became: South Dakota, Nebraska, Kansas, and Missouri. The disagreement of Missouri is very interesting, as it indicates that Missouri weather resembles that of the Plains more than that of the Mississippi Valley.

The weights were found by computing the per cent each State acreage was of the total for the group. Thus, the per cent of corn acreage of Ohio was obtained by dividing the acreage of corn in Ohio by the acreage of the Ohio Valley group. This percentage was obtained for each year of the 25 studied, for as the acreage varied, so the weight that should be given to an individual item should vary. The yields were weighted by multiplying each yield figure by its corresponding percentage, then obtaining the sum of the results. Thus, there was obtained a final yield figure that was weighted directly by the importance of the several States.

The selection of the variables to be used was somewhat more complex. As a preliminary step the coefficients of correlation of each State for the five weather items were entered in a table. It was then possible to pick out those months of greatest importance as the coefficients would all be of the same sign, although of various magnitudes. The selected values were then weighted in the same manner as the yields and the coefficients of correlation obtained. From this step on the method is exactly the same as before, so a detailed discussion is not necessary. The equations and variables used are given below.

The Ohio Valley.—Equation and variables used.

$$\overline{X} = 0.575A + 0.745F - 0.658E - 1.161B + 0.180H - 6.450$$

A = P. m. relative humidity, July.
B = Total precipitation, July.
E = Mean temperature, July.
F = Mean temperature, September.
H = P. m. relative humidity, September.

The Mississippi Valley.—Equation and variables used.

$$\overline{X} = 0.643A + 0.177C + 1.784D + 0.115K - 28.043$$

A = Mean temperature, September.
C = Percentage of possible sunshine, May.
D = Total precipitation, April.
K = Percentage of possible sunshine, June.

The Great Plains and Missouri.—Equation and variables used.

$$\overline{X} = 0.433A + 0.258B - 0.661C + 0.205N + 0.341O + 8.881$$

A = P. m. relative humidity, August.
B = P. m. relative humidity, July.

C = Mean maximum temperatures, July.
N = P. m. relative humidity, May.
O = Percentage of possible sunshine, July.

P. m. relative humidity is still of greatest importance in the Great Plains, but elsewhere there is a wider range of the variables.

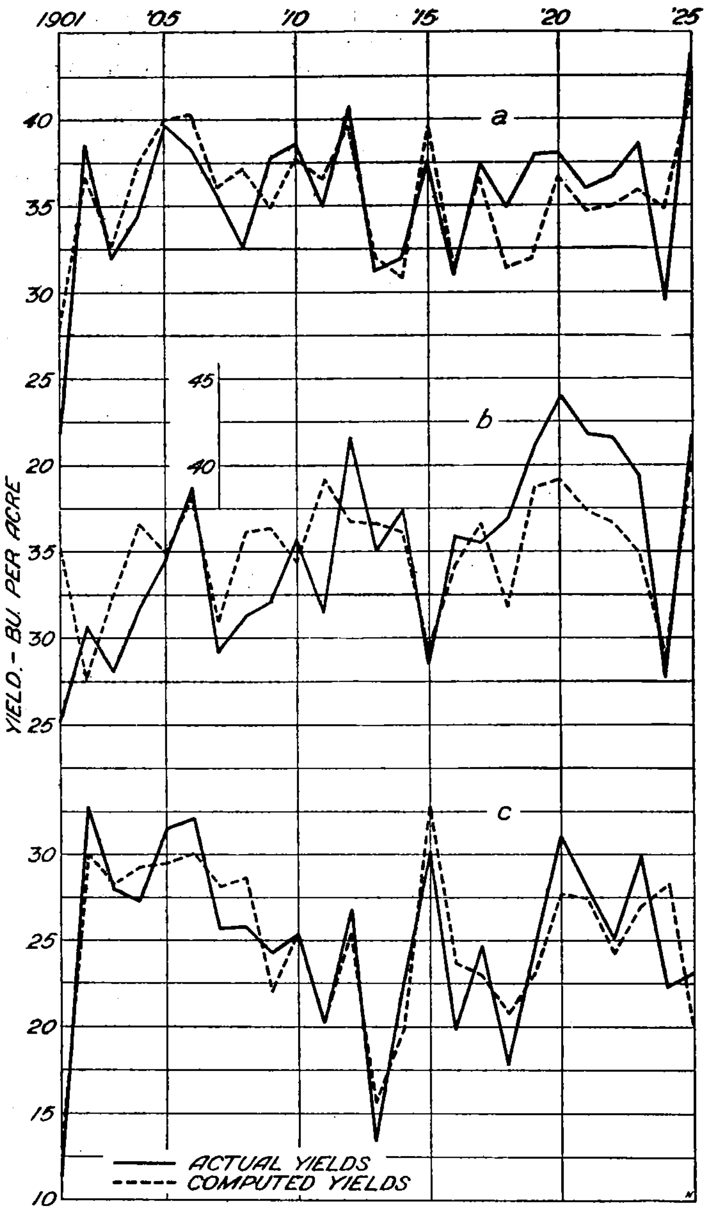

FIGURE 3.—(a) Yields of corn, bushels per acre, for the Ohio Valley, (b) for the Mississippi Valley, and (c) for the Great Plains and Missouri. Yields weighted on acreage-percentage basis

Figure 3 shows the computed and actual yields for these three divisions, "*a*" being that for the Ohio Valley, "*b*" that for the Mississippi Valley, and "*c*" that for the Great Plains and Missouri. The final bases and yields are also given in Table 3. The Great Plains again agrees more closely with actual yields than the others, with a coefficient of 0.88, while the Mississippi Valley coefficient was only 0.63.

TABLE 3.—*Computed and actual yields of corn for the three divisions of the Corn Belt*

Years	The Ohio Valley		The Mississippi Valley		The Great Plains and Missouri	
	Computed	Actual	Computed	Actual	Computed	Actual
1901	28.0	21.9	35.2	25.2	12.8	11.3
1902	36.6	38.4	27.7	30.7	29.9	32.6
1903	32.6	32.0	32.4	28.0	28.0	27.9
1904	37.5	34.4	36.6	31.8	29.2	27.2
1905	39.9	39.7	34.9	34.5	29.4	31.4
1906	40.3	38.3	37.7	38.7	30.0	32.0
1907	36.1	35.7	30.9	29.1	28.2	25.7
1908	37.2	32.7	36.1	31.3	28.6	25.8
1909	34.9	37.7	36.4	32.1	22.1	24.3
1910	37.7	38.6	34.4	35.7	25.4	25.4
1911	36.6	35.0	39.2	31.5	20.3	20.3
1912	39.5	40.7	36.7	41.5	25.3	26.8
1913	32.0	31.3	36.6	35.1	15.6	13.4
1914	30.8	32.0	36.1	37.4	19.9	22.4
1915	39.5	37.6	29.3	28.5	32.6	30.1
1916	31.3	31.1	34.3	35.8	23.7	19.9
1917	36.5	37.4	36.6	35.5	23.0	24.6
1918	31.4	34.9	31.8	36.9	26.8	17.8
1919	32.0	37.9	38.7	41.2	23.2	24.5
1920	36.6	38.0	39.2	44.0	27.7	31.0
1921	34.7	36.0	37.4	41.8	27.4	28.1
1922	35.0	36.7	36.7	41.6	24.3	25.2
1923	35.9	38.6	34.8	39.3	27.0	29.9
1924	34.8	29.6	28.9	27.7	28.3	22.3
1925	41.6	43.7	40.2	41.7	20.2	23.2
σ	35.6	35.6	35.2	35.1	24.9	24.9
Mean	3.32	4.31	3.25	5.21	4.68	5.30
rx	+.77	----------	+.63	----------	+.88	----------

In combining these three divisions to make a final computation for the entire area, two methods were used. First, a simple arithmetic average, and second, by weighting on an acreage-percentage basis. The acreages for the several divisions were divided by the total for the belt and the yearly percentages obtained. The coefficients of correlation were, respectively, for the weighted and unweighted values, 0.83 and 0.78. Figure 4 shows the

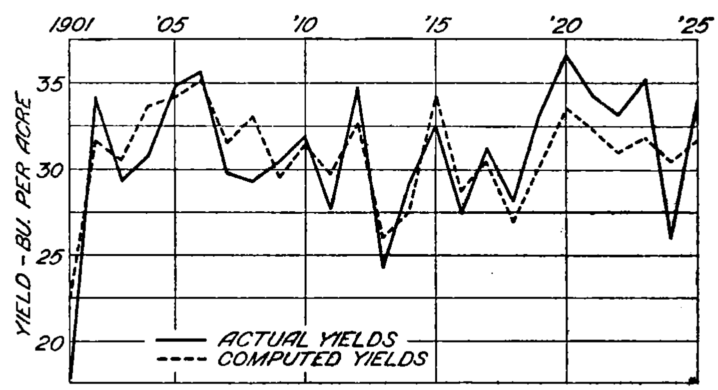

FIGURE 4.—Yields of corn, bushels per acre, for the Corn Belt. Weighted average of the three divisions

computed and actual yields for the weighted values; there is again very close agreement, except for one or two years.

In order to give the weighting method a further test, it was decided to weight the original final bases for the individual States, obtained as before indicated. The percentage of acreage in each State was computed, based on the acreage of the entire region, and these percentages applied to the final bases. The computed yields thus obtained were compared with the actual figures, also weighted, and the final coefficient of correlation was 0.90. This small increase over the original method is very important, as there is an increased reduction of standard deviation of about 2 per cent.

The yields computed in this manner agree a little more closely in those years which were at variance before, thus making this method a little better than the other one. The actual and computed yields are shown in figure 5.

Thus, we have two methods of computing corn yields in the belt. The method of weighting seems to be of slightly more value than that of simple arithmetic averages. The weighting of individual weather items in correlating weather and corn yields does not return as high a coefficient as considering each State individually and then weighting to its proper place in the belt.

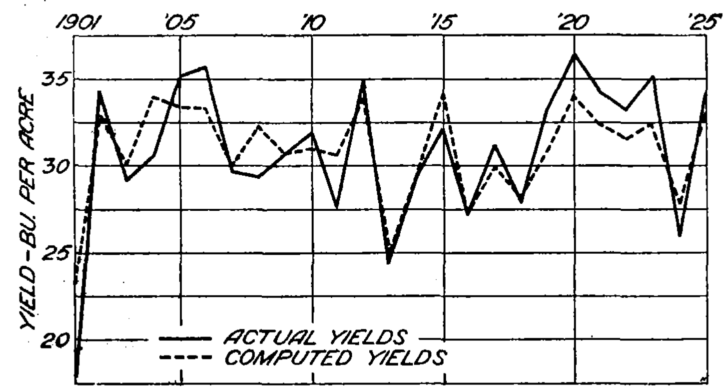

FIGURE 5.—Yields of corn, bushels per acre, for the Corn Belt. Weighted average of individual State bases

THE STATE OF IOWA

In Iowa "Corn is King." The corn crop is to this State what cotton is to the South. It follows, therefore, that any factor that affects the size of the corn crop is of vital interest not only to the State, but to the Nation. The weather is, naturally, the most important element influencing the growth of corn and this paper will attempt to show those periods of most importance.

The average corn production in Iowa for the years 1921–1925 was 426,000,000 bushels, or about 15 per cent of the average of the whole country for the same period. It will be seen, therefore, that the Iowa corn crop is of great importance, and many investigators have studied the effect of weather on the yields of corn in this State, but none in such detail as Wallace (1).

Wallace said, in part:

> In Iowa the multiple coefficient of correlation between yield and May temperature, July temperature, and August rain is disappointingly low * * * superficial examination of the evidence leads to the conclusion that the low correlation coefficient in Iowa is due to the fact that in Iowa there are some seasons and some sections when the yield is short because of the too cool weather during the greater part of the summer, whereas in other years the yield is short because of too hot weather. * * * Obviously, therefore, the method of correlation coefficients is not very well adapted to examining the effect of weather on corn yield in Iowa.

With this conclusion there was set forth a series of tables, based on correlation coefficients, from which could be computed the percentage the crop would be above or below an average determined from a line of secular trend. This was done for two counties, one in the northern and one in the central part of the State, with the main work on Polk County crops. While this method of computing yields is sometimes very satisfactory, it can not be said that it has a strict mathematical foundation, therefore it was decided to apply Kincer's method (2) to the yield and weather data of Iowa.

In a study of this type, based on average yields for a whole State, the stations chosen for the weather data must be well distributed and fairly representative of conditions over the whole section. There are, of course, periods when a complete distribution is difficult to obtain and for such cases the best data available may not completely satisfy the necessary requirements. Iowa is fairly well covered by a network of cooperative stations and the weekly precipitation data are based on the entire number, computed from the climatological records. The regular Weather Bureau stations, of course, do not fully cover the State, but for such data as sunshine, and mean and maximum temperatures they are believed to be adequate. Four stations were chosen for the temperature factor, Dubuque, Des Moines, Charles City, and Sioux City, covering fairly well the section of heaviest production.

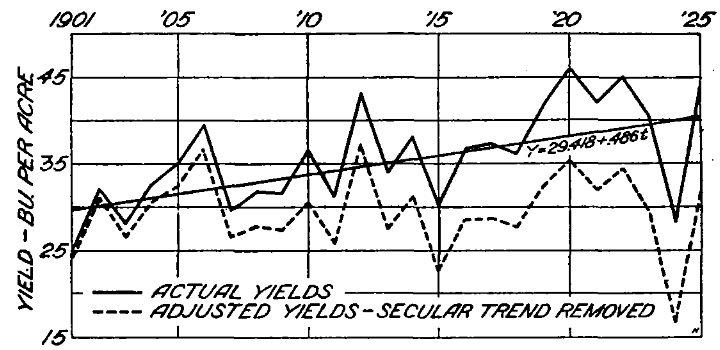

FIGURE 6.—Yields of corn, bushels per acre, for the State of Iowa. Upper solid line shows observed yields, lower broken line shows the adjusted yields after removal of secular trend. Line of secular trend is also shown

The period 1901–1925 was chosen for study as nearly complete records were available for the 25 years An extension of the time backward or forward might be effected, but records become more fragmentary in the earlier years and less ready of access in the later ones.

It was found that the secular trend of corn yields in this period increased at the rate of about 0.5 bushel per year, the complete equation being $y=29.418+0.486t$, where t is the time in years. Wallace had found an annual increase of 0.25 bushel in the Iowa data from 1891 to 1919 and Reed (3) found an increase of 0.283 bushel per year in the years 1890–1926. It would seem, therefore that the period, 1901–1925 was that of greatest increase in yield. Reed's conclusions as to the upward trend are very pertinent to this study and will bear repeating:

> There is a well-defined tendency for corn in Iowa to become more and more damaged by frost before it reaches maturity. * * * This scarcely leaves a doubt that the farmers of Iowa by breeding for large yields per acre have sacrificed maturity of the crop.

The success of this practice is well demonstrated in Figure 6, which shows the yields in bushels per acre for the period under consideration as well as the yields when secular trend has been removed In order to remove the trend, which is obviously unrelated to weather influences, the equation mentioned above was applied to the observed yields. The annual increment was 0.486 bushel and this, multiplied by its proper value of t, was subtracted from the original data. This, as shown, removed the external influence of increased yields and permitted the application of Kincer's method.

The new yield figures can be considered as entirely separate from the original ones and handled as desired. The mean, standard deviation, etc., were computed for the new data as though it had no connection with the original. The operations performed in this paper are as described by Kincer and need no further explanation.

TABLE 4.—*Iowa*

Year	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1901	66	1.1	57	1.3	1.4	55	62	0.9
1902	79	0.9	70	0.9	1.7	55	63	0.6
1903	78	0.4	69	1.1	0.5	46	64	1.4
1904	77	0.2	65	0.7	0.6	67	58	1.2
1905	71	0.5	60	1.1	0.6	72	65	2.6
1906	78	0.8	67	1.7	0.7	58	59	0.4
1907	66	0.6	57	1.2	2.4	33	62	0.0
1908	76	1.0	65	2.0	1.6	56	70	1.0
1909	69	0.5	61	1.0	2.3	44	64	0.2
1910	67	0.7	58	0.0	0.9	64	42	0.8
1911	80	1.0	69	0.4	0.2	67	44	0.2
1912	79	0.3	68	0.2	0.5	68	54	1.4
1913	65	0.5	57	1.0	0.7	36	55	0.6
1914	81	0.5	71	0.6	1.6	60	58	0.9
1915	65	2.3	57	1.6	0.8	28	72	0.3
1916	75	0.1	66	1.3	0.9	52	61	0.4
1917	66	0.4	55	0.6	3.4	51	54	0.1
1918	75	1.1	65	0.6	2.3	59	61	1.2
1919	69	0.1	59	0.9	2.0	58	69	0.6
1920	78	0.1	66	0.3	0.6	74	52	1.9
1921	87	0.6	76	0.5	0.3	70	55	1.1
1922	75	0.8	66	0.3	0.1	38	51	0.5
1923	73	0.3	62	0.8	1.2	61	60	1.2
1924	63	1.1	52	1.4	2.5	60	66	0.4
1925	77	0.3	64	1.4	1.7	86	59	0.1
Mean	73	0.6	63	0.9	1.3	57	59	0.8
σ	6.18	0.47	5.72	0.49	0.84	13.44	7.15	0.60
rx	+.56	−.53	+.52	−.41	−.40	+.40	−.38	+.36

Year	*I*	*J*	*K*	*L*	*M*	*N*	*O*
1901	0.3	55	0.6	63	71	0.5	63
1902	1.6	60	1.7	59	68	0.8	57
1903	0.8	74	3.5	59	69	0.0	61
1904	0.9	64	1.6	57	71	0.3	61
1905	2.0	63	0.2	65	77	1.8	68
1906	1.4	53	1.1	75	81	1.9	71
1907	1.0	78	2.1	42	78	1.2	66
1908	1.1	71	2.7	55	87	0.0	75
1909	2.1	76	1.4	46	77	0.4	69
1910	0.6	62	0.8	40	69	0.7	59
1911	0.6	46	1.0	83	81	0.8	71
1912	0.1	48	0.5	78	75	0.7	67
1913	1.4	55	1.6	76	79	1.0	64
1914	1.0	57	1.4	72	71	1.5	62
1915	0.6	68	3.5	57	74	0.2	66
1916	0.5	60	1.5	59	70	0.0	61
1917	0.8	74	1.8	46	72	0.5	62
1918	1.9	67	2.1	60	69	0.2	60
1919	0.3	74	0.2	30	80	3.0	70
1920	1.1	54	0.7	67	83	0.1	72
1921	1.0	56	1.0	69	75	2.4	67
1922	0.8	48	1.7	77	73	0.8	62
1923	1.5	70	0.1	45	69	2.0	58
1924	2.9	60	0.7	47	65	0.6	57
1925	0.5	52	0.1	84	73	1.0	65
Mean	1.1	62	1.3	60	74	0.9	65
σ	0.64	9.29	0.92	14.09	5.33	0.78	4.89
rx	−.36	−.35	−.35	+.34	+.33	+.33	+.31

A = Average weekly maximum temperatures for the week ending May 26.
B = Average weekly precipitation for the week ending July 28.
C = Average weekly mean temperatures for the week ending May 26.
D = Average weekly precipitation for the week ending June 23.
E = Average weekly precipitation for the week ending June 9.
F = Average weekly percentage of possible sunshine for the week ending May 26.
G = Average weekly p. m. relative humidity for the week ending June 23.
H = Average weekly precipitation for the week ending May 12.
I = Average weekly precipitation for the week ending June 30.
J = Average weekly p. m. relative humidity for the week ending June 9.
K = Average weekly precipitation for the week ending May 26.
L = Average weekly percentage of possible sunshine for the week ending June 9.
M = Average weekly maximum temperatures for the week ending Sept. 15.
N = Average weekly precipitation for the week ending Sept. 22.
O = Average weekly mean temperatures for the week ending Sept. 15.

Table 4 shows the variables used. It will be noted that precipitation data occur seven times, and maximum temperatures, mean temperatures, percentage of possible sunshine, and the p. m. relative humidity twice each. It is significant that precipitation should appear nearly half the number of times, for others have found that the amount of rainfall is very important to corn, especially at certain critical periods. The coefficients are not especially high, running down from 0.56 to 0.31, but their combinations are more important than single coefficients.

TABLE 5.—*Iowa*

Year	A_1	A_2	A_3	A_4	A_5	A_6	A_7	X'	X
1901	25.2	24.8	24.2	25.5	25.3	25.7	26.2	26.7	25.0
1902	30.2	29.0	28.9	28.4	28.3	28.1	28.3	29.3	32.0
1903	31.8	30.7	30.1	30.4	29.5	30.1	29.4	30.8	28.0
1904	32.3	31.6	31.7	31.8	31.1	31.4	31.2	33.1	32.6
1905	29.1	29.8	29.2	28.2	29.1	31.1	31.0	33.4	34.8
1906	30.2	31.8	29.8	29.4	30.4	29.9	30.4	33.3	30.5
1907	27.1	28.1	27.5	27.7	28.1	27.3	26.5	29.9	29.5
1908	28.8	31.7	29.0	29.0	28.2	28.5	28.1	32.0	31.7
1909	28.5	29.3	29.0	27.9	27.5	27.0	26.4	30.8	31.5
1910	27.1	26.2	28.3	28.9	28.7	28.7	28.7	33.6	36.3
1911	30.1	31.7	32.5	32.9	32.6	31.8	32.5	37.8	31.0
1912	32.5	32.7	33.8	34.7	34.3	34.7	35.2	41.0	43.0
1913	27.2	28.4	28.2	27.9	28.1	28.0	28.4	34.7	34.0
1914	32.4	31.7	32.1	32.0	32.5	32.4	32.5	39.3	38.0
1915	20.1	20.5	19.7	20.9	20.6	20.6	20.7	28.0	30.0
1916	32.0	31.1	30.0	30.7	29.8	29.3	29.4	37.2	36.5
1917	27.9	27.6	28.3	28.7	28.3	27.6	27.0	35.3	37.0
1918	28.1	27.2	28.0	27.2	26.6	27.2	27.0	35.7	36.0
1919	30.1	31.4	31.1	31.9	33.8	33.3	32.5	41.7	41.6
1920	33.0	34.9	35.6	35.2	34.2	35.1	35.3	45.0	46.0
1921	33.9	34.0	34.4	34.2	35.4	35.4	35.4	45.6	42.0
1922	29.3	29.2	30.4	30.7	30.5	30.1	30.8	41.5	45.0
1923	30.6	29.6	29.7	29.2	30.3	30.7	30.2	41.4	40.5
1924	24.2	22.6	22.0	20.4	20.5	20.6	21.1	32.8	28.0
1925	31.9	31.7	30.3	30.9	30.9	30.1	30.6	42.8	43.9
Mean	29.3	29.5	29.4	29.4	29.4	29.4	29.4	35.7	35.7
σ	3.06	3.29	3.45	3.50	3.60	3.63	3.65	------	------
rx	.68	.72	.76	.77	.79	.80	.81	------	------

A_1 = Weather indices computed from *A* and *B* (Table 4).
A_2 = Weather indices computed from A_1 and *M* (including *A*, *B*, *M*, Table 4).
A_3 = Weather indices computed from A_2 and *D* (including *A*, *B*, *M*, *D*, Table 4).
A_4 = Weather indices computed from A_3 and *I* (including *A*, *B*, *M*, *D*, *I*, Table 4).
A_5 = Weather indices computed from A_4 and *N* (including *A*, *B*, *M*, *D*, *I*, *N*, Table 4).
A_6 = Weather indices computed from A_5 and *H* (including *A*, *B*, *M*, *D*, *I*, *N*, *H*, Table 4).
A_7 = Weather indices computed from A_6 and *J* (including *A*, *B*, *M*, *D*, *I*, *N*, *H*, *J*, Table 4).
X' = Final computation of yields, A_7 with secular trend inserted.
X = Yields of corn, bushels per acre, Iowa.

Table 5 shows the computed values of corn yields for each successive step in the operation. The base 1, or A_1, was computed from *A* and *B*, columns 1 and 2, Table 1; base A_2 was computed from A_1 and *M*, and so on up to base A_7, which concluded the series as the base A_8 did not raise the coefficient. The coefficients of correlation of these bases with corn yields increase from 0.68 to 0.81. The final base, A_7, is not adjusted as the secular trend remains to be added. This was done in the column headed X', and as column *X* contains the observed yields, they are directly comparable.

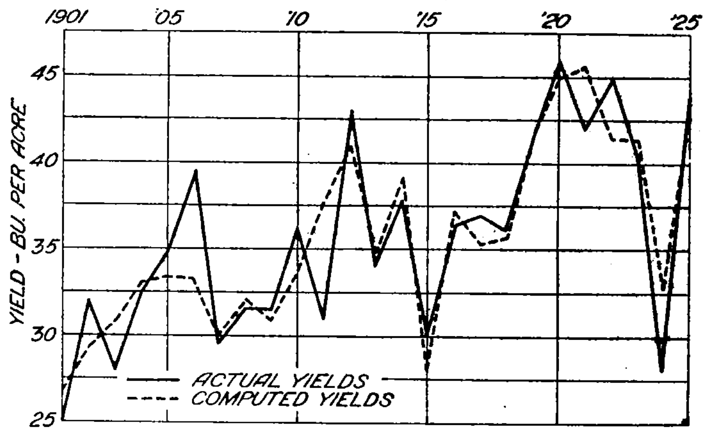

FIGURE 7.—Yields of corn, bushels per acre, for the State of Iowa. The solid line represents the actual yields and the broken line shows the computed yields

Figure 7 shows the computed and actual yields of corn for the years 1901–1925. There are two striking years of crop failure noted, one being in 1915 and the other in 1924. The 1915 depression is a combination of several weather influences, which are fairly well represented by the computation equation, while that in 1924 was not so well indicated as many items entered into the unfavorable conditions prevailing that season which are not represented in the equation and could not be included, under the limitations of the present data available. The season in 1924 was very late, reaching three weeks behind the average at one time, and the fall frosts cut the corn yield to a large extent. In the other years, 1906 is a conspicuous failure of the equation, but otherwise a very good relationship was obtained.

As mentioned above, the yield in 1924 was tremendously reduced; the fall frosts ended the growing season when only 32 per cent of the crop was reported fully mature, and as the average maturity at time of frost was 88 per cent, the reduction was 56 per cent, or nearly two-thirds, of the normal. The average amount of corn fit for seed was 51 per cent, but in 1924 only 16 per cent was saved. Thus, omitting 1924 from the calculations will not upset a regular sequence of years, as the recurrence of the abnormal conditions prevailing at that time can be expected only very infrequently.

TABLE 6.—*Iowa*

Year	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
1901	0.3	48	55	1.1	0.6	66	55	60	0.9	57
1902	1.4	74	55	0.9	1.7	79	60	72	0.6	70
1903	0.5	60	46	0.4	3.5	78	74	66	1.4	69
1904	1.0	66	67	0.2	1.6	77	64	70	1.2	65
1905	1.3	68	72	0.5	0.2	71	63	70	2.6	60
1906	0.4	70	58	0.8	1.1	78	53	77	0.4	67
1907	0.3	61	33	0.6	2.1	66	78	65	0.0	57
1908	0.1	55	56	1.0	2.7	76	71	60	1.0	65
1909	0.4	55	44	0.5	1.4	69	76	71	0.2	61
1910	0.5	65	64	0.7	0.8	67	62	69	0.8	58
1911	0.2	55	67	1.0	1.0	80	46	64	0.2	69
1912	0.7	62	68	0.3	0.5	79	48	71	1.4	68
1913	0.4	55	36	0.5	1.6	65	55	62	0.6	57
1914	0.7	62	60	0.5	1.4	81	57	73	0.9	71
1915	0.1	60	28	2.3	3.5	65	68	64	0.3	57
1916	0.0	52	52	0.1	1.5	75	60	52	0.4	66
1917	0.4	54	51	0.4	1.8	66	74	70	0.1	55
1918	0.6	62	59	1.1	2.1	75	67	54	1.2	65
1919	0.8	54	58	0.1	0.2	69	74	68	0.6	59
1920	1.4	61	74	0.1	0.7	78	54	56	1.9	66
1921	1.2	66	70	0.6	1.0	87	56	66	1.1	76
1922	1.4	64	38	0.8	1.7	75	48	69	0.5	66
1923	0.4	53	61	0.3	0.1	73	70	75	1.2	62
1925	0.4	57	86	0.3	0.1	77	52	62	0.1	64
Mean	0.6	60	57	0.6	1.4	74	62	66	0.8	64
σ	0.43	6.21	13.70	0.47	0.98	5.92	9.48	6.32	0.61	5.35
rx	+.58	+.58	+.50	−.49	−.49	+.44	−.44	+.40	+.38	+.37

Year	*K*	*L*	*M*	*N*	*O*	*P*	*Q*	*R*	*S*	*T*
1901	99	55	0.0	1.3	61	63	1.4	1.3	0.5	86
1902	81	37	0.7	2.4	64	79	1.7	0.9	0.8	73
1903	82	78	2.9	0.2	75	62	0.5	1.1	0.0	72
1904	81	51	0.9	1.0	55	80	0.6	0.7	0.3	77
1905	88	66	1.5	0.0	52	62	0.6	1.1	1.8	79
1906	80	51	0.5	0.4	63	61	0.7	1.7	1.9	70
1907	84	72	0.9	1.0	68	72	2.4	1.2	1.2	75
1908	84	84	2.0	1.1	68	65	1.6	2.0	0.0	73
1909	85	78	1.2	0.0	58	64	2.3	1.0	0.4	74
1910	87	70	0.6	1.7	58	74	0.9	0.0	0.7	74
1911	83	70	1.2	1.4	57	78	0.2	0.4	0.8	70
1912	76	51	1.0	0.6	59	69	0.5	0.2	0.7	67
1913	87	60	0.3	1.0	72	72	0.7	1.0	1.0	76
1914	87	69	0.5	0.0	57	59	1.6	0.6	1.5	75
1915	80	78	2.0	2.5	76	87	0.8	1.6	0.2	71
1916	93	76	1.1	1.3	68	67	0.9	1.3	0.0	81
1917	86	49	1.8	0.4	59	59	3.4	0.6	0.5	74
1918	87	69	2.7	0.0	64	53	2.3	0.6	0.2	76
1919	86	52	2.0	0.7	59	64	2.0	0.9	3.0	75
1920	84	80	0.7	0.7	52	57	0.6	0.3	0.1	74
1921	89	64	1.6	0.4	61	61	0.3	0.5	2.4	78
1922	83	52	0.5	0.0	67	49	0.1	0.3	0.8	72
1923	89	40	0.9	2.0	42	77	1.2	0.8	2.0	78
1925	85	64	0.7	0.8	39	68	1.7	1.4	1.0	74
Mean	85	63	1.2	0.9	61	67	1.2	0.9	0.9	75
σ	4.57	12.88	0.73	0.73	8.78	9.00	0.82	0.49	0.80	3.86
rx	−.36	−.36	−.34	−.33	−.33	−.32	−.30	−.30	+.30	−.30

A = Average weekly precipitation for the week ending Aug. 25.
B = Average weekly p. m. relative humidity for the week ending Aug. 25.
C = Average weekly percentage of possible sunshine for the week ending May 26.
D = Average weekly precipitation for the week ending July 28.
E = Average weekly precipitation for the week ending May 26.
F = Average weekly maximum temperatures for the week ending May 26.
G = Average weekly p. m. relative humidity for the week ending June 9.
H = Average weekly p. m. relative humidity for the week ending Sept. 22.
I = Average weekly precipitation for the week ending May 12.
J = Average weekly mean temperatures for the week ending May 26.
K = Average weekly maximum temperatures for the week ending July 21.
L = Average weekly percentage of possible sunshine for the week ending Sept. 22.
M = Average weekly precipitation for the week ending June 2.
N = Average weekly precipitation for the week ending Sept. 29.
O = Average weekly p. m. relative humidity for the week ending May 26.
P = Average weekly p. m. relative humidity for the week ending Sept. 29.
Q = Average weekly precipitation for the week ending June 9.
R = Average weekly precipitation for the week ending June 23.
S = Average weekly precipitation for the week ending Sept. 22.
T = Average weekly mean temperature for the week ending July 21.

Omitting 1924, a new grouping of the variables occurs which is shown in Table 6, and the number is increased from 15 to 20. The exclusion of the abnormal year enables the weather data to fit the yield data better, as it was found in the previous calculations that the year 1924 was at variance with the remainder of the years when computing correlation coefficients. The coefficients of the new variables decrease from 0.58 to 0.30, a somewhat wider range than before, while the precipitation data occupy the same important position they did in the other grouping. Thus, it can be said that the rainfall is the dominant feature of the weather influence on corn yields, but that other influences modify it.

TABLE 7.—*Iowa*

Year	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	X''	X'	X
1901	25.5	21.9	23.4	22.3	23.4	23.8	22.6	22.9	23.1	23.7	25.0
1902	30.8	31.6	30.8	32.5	32.7	31.8	32.0	31.7	31.0	32.2	32.0
1903	28.5	29.6	27.0	27.2	26.1	26.5	26.9	26.7	25.3	27.2	28.0
1904	31.2	30.8	30.2	30.8	30.9	30.0	30.3	30.5	29.8	32.3	32.6
1905	31.6	30.5	31.5	32.2	31.8	32.0	31.6	31.9	30.6	33.7	34.8
1906	26.8	28.5	28.7	30.1	30.5	30.8	31.2	31.1	33.0	36.7	39.5
1907	27.0	27.1	26.4	26.8	27.1	26.8	27.0	26.4	26.2	30.5	29.5
1908	25.0	25.6	24.3	24.1	23.7	24.0	24.3	24.5	25.2	30.2	31.7
1909	27.8	28.2	28.1	27.4	27.4	27.6	27.6	27.3	27.3	32.9	31.5
1910	27.6	28.0	28.6	29.3	29.7	29.2	29.0	29.2	29.5	35.7	36.3
1911	25.4	27.0	27.5	26.9	27.0	26.4	26.7	27.1	28.3	35.1	31.0
1912	29.6	32.4	32.9	32.5	32.5	32.2	32.9	33.0	34.2	41.6	43.0
1913	27.8	27.6	27.4	26.8	27.5	27.2	27.1	26.5	26.2	34.3	34.0
1914	29.0	29.1	28.9	29.1	29.6	30.0	29.7	29.7	30.1	38.8	38.0
1915	21.1	22.2	20.4	21.5	21.2	20.2	21.0	20.6	21.2	30.5	30.0
1916	27.3	25.4	25.5	24.7	24.9	25.0	24.4	24.5	23.9	33.8	36.5
1917	28.1	28.5	27.9	27.1	26.7	27.3	27.2	27.1	26.7	37.2	37.0
1918	26.8	26.5	25.8	26.5	25.5	26.5	26.4	26.6	26.1	37.3	36.0
1919	28.5	28.6	29.8	28.7	28.1	28.3	28.2	28.2	28.0	39.8	41.6
1920	33.2	33.8	33.9	33.2	33.3	33.7	33.6	33.8	33.4	45.8	46.0
1921	30.8	30.0	30.2	30.8	30.4	30.7	30.2	30.5	29.3	42.3	42.0
1922	31.1	32.3	31.4	31.5	31.9	32.9	32.9	32.1	31.6	45.2	45.0
1923	28.4	27.5	29.0	27.9	28.1	27.5	27.2	27.4	26.9	41.2	40.5
1925	28.4	28.8	30.1	29.4	29.7	29.6	29.5	30.3	31.6	46.5	43.9
Mean	28.2	28.4	28.3	28.3	28.3	28.3	28.3	28.3	28.3	-----	-----
σ	2.52	2.83	3.00	3.09	3.13	3.18	3.20	3.23	3.29	-----	-----
rx	+.69	+.78	+.82	+.85	+.86	+.87	+.88	+.89	+.91	-----	-----

A_1 = Weather indices computed from *A* and *D* (Table 6).
A_2 = Weather indices computed from A_1 and *T* (including *A*, *D*, *T*, Table 6).
A_3 = Weather indices computed from A_2 and *E* (including *A*, *D*, *T*, *E*, Table 6).
A_4 = Weather indices computed from A_3 and *B* (including *A*, *D*, *T*, *E*, *B*, Table 6).
A_5 = Weather indices computed from A_4 and *M* (including *A*, *D*, *T*, *E*, *B*, *M*, Table 6).
A_6 = Weather indices computed from A_5 and *P* (including *A*, *D*, *T*, *E*, *B*, *M*, *P*, Table 6).
A_7 = Weather indices computed from A_6 and *K* (including *A*, *D*, *T*, *E*, *B*, *M*, *P*, *K*, Table 6).
A_8 = Weather indices computed from A_7 and *C* (including *A*, *D*, *T*, *E*, *B*, *M*, *P*, *K*, *C*, Table 6).
X'' = Weather indices computed from X_1, X_2, and X_3.
X' = Weather indices $-X''$ with secular trend added.
X = Yields of corn, bushels per acre, Iowa (1924 omitted).

Table 7 shows the new bases computed. There is one more base this time than before, and a new computation for X. The coefficients increase from 0.69 to 0.91, which is more satisfactory, as the increase of 10 points in the correlation coefficient at this stage means 18 per cent increase in the reduction of standard deviation (4). The bases range from A_1, computed from A and D, Table 6, to A_8 and X''.

Due to the large number of bases, embracing nine variables, it was decided to compute the final equation on a somewhat different basis than before. The nine variables, A, B, C, D, E, K, M, P, and T, were combined in groups of three as follows: A, B, and C; D, E, and K; and M, P, and T, with the usual multiple correlation method used for each group. The equation for the first group was $\overline{X}_1 = 1.829A + 0.215B + 0.100C - 8.603$; that for the second, $\overline{X}_2 = -2.237D - 1.978E - 0.436K + 69.471$; and that for the third, $\overline{X}_3 = -2.359M - 0.170P - 0.408T + 73.121$. These three equations were then used to compute three new bases, X_1, X_2, and X_3, from which the final equation was derived. The final equation was $\overline{X} = 0.577X_1 + 0.480X_2 + 0.548X_3 - 17.183$. The computed yields derived from this equation were better in fit than those for base A_8, due, no doubt, to a better correlation of the respective variables than would be obtained in the complicated method used before. The value of the coefficient thus obtained was 0.91, an improvement over that of base A_8 of 0.02.

This final computation was still incomplete, so the secular trend was added to make it comparable with the observed yields, as shown in column X', Table 7.

Figure 8 shows the computed and actual yields with secular trend added. It will be noted that there is a much closer fit of the data than when 1924 is included and that the year 1906, which was a bad fit before is now much better.

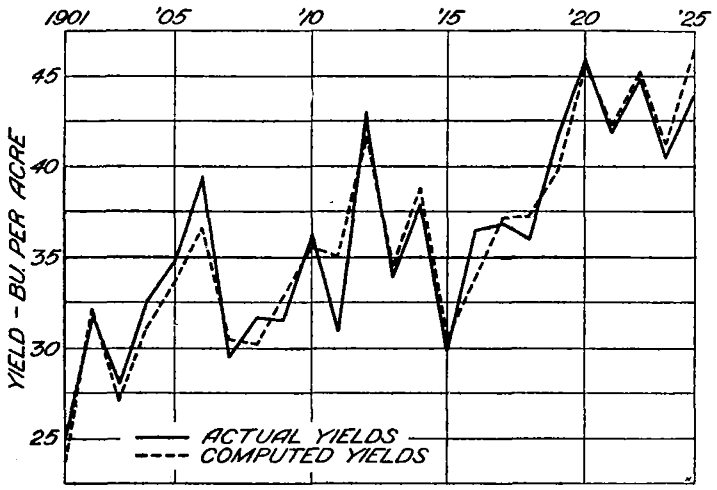

FIGURE 8.—Yields of corn, bushels per acre, for the State of Iowa. The solid line represents the actual yields and the broken line shows the computed yields. In this figure the yield data for 1924 have been omitted

No final attempt was made to forecast yields from these computations as this method of study, while it fits the data very well, is not strictly applicable for this purpose. The use of a straight-line trend in a case of this kind is limited in value. It satisfies the data under consideration, but can be of no value in forecasting, for the yields can not continue to rise indefinitely, as would be assumed from the direction of the line. Other types of curves might fit the data better, but in fitting a mathematical curve to yield data it must be remembered that extrapolation is at best very hazardous.

In computing the bases by Kincer's method, there is no effort made to reconcile the various stages of plant progression to the weather variables used and it is learned with real interest that the periods used coincide closely with the development of the corn plant in Iowa. Mr. Reed commented on this phase as follows:

I was much interested in the nine variables selected for this study. I note that they seem to have a distinct bearing on the critical planting, germination, cultivation, and pollination periods. * * * The period around May 12 is the average planting date of the bulk of the crop, and frequent rainy days, and a large total of precipitation, keeping farmers out of the fields at that time, results in a delay that is important in both yield and maturity.

The maximum temperature, the mean temperature, and the sunshine, for the week ending May 26, have a very distinct bearing on the germination. * * * The negative correlation between corn yield and rainfall in June is, I think, wholly a question of weed killing. The Iowa Experiment Station has shown that cultivation is of no value whatever except for weed killing, and that luxuriant weeds are the most serious cause of decreased yields.

It is thought that this study will serve to show the weather influences most effective in the growth of corn in Iowa. It is believed that the production of this crop will need to reach a more settled state than at present before valuable forecasting can be done from weather conditions. The farmers have developed the production of corn to procure a high yield per acre, but there is from time to time a considerable percentage spoiled by immaturity at the time of frost. Therefore it is probable that agriculture in this State will reach a settled stage when large yields per acre will be recognized as valuable, but not at the expense of full maturity, and a high-yielding corn will be developed, with a large per cent maturing before frost.

It must be admitted that, at the present stage of the development of agricultural meteorology in this country, data are usually unsatisfactory in many ways. The yield and production data are probably as satisfactory as can be obtained. The absence of organized phenological services is to be regretted as the study of crop development and its corresponding weather influences must necessarily be mere gropings in the dark until such data are available. It has been learned that a beginning in the collection of such phenological records has been made by the section director of the Weather Bureau at Des Moines, Mr. Reed, covering the whole section under his supervision, and it is earnestly hoped that nothing interferes with their continuance.

Grateful acknowledgment is made to Mr. J. B. Kincer for his kind advice and assistance in this and other papers, and to Mr. C. D. Reed for his helpful suggestions.

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