after which the wind produces an off-shore wave of comparatively slight intensity.

The general character of the pressure changes in storms other than easterly is shown by the accompanying barograph trace for December 17, 1912 (fig. 2). Further study would be needed to determine the characteristic trace, if any, accompanying the easterlies.

A thorough study of storms of this locality would greatly increase the value of warnings by allowing them to be issued earlier and enabling the correct direction and force to be forecast more frequently. It is also probable that types of pressure changes as shown on the barograph records could be classified and reported by one word in such extent of detail as to be of great value to the forecaster at the district center.

WEATHER AS A BUSINESS RISK IN FARMING.[1]

By William Gardner Reed and Howard R. Tolley.

[*Authors' abstract*, dated: Office of Farm Management, Washington, D. C., July 11, 1916.]

No type of agriculture can be successfully established in a region where the risk of loss by the occurrence of unfavorable weather conditions is not more than balanced by the profits at other times. It is necessary for the farmer's success as a business man to know the risk involved in raising particular crops. Climatic data as usually presented in averages and extremes give a general idea of the character of the region, but show nothing regarding the frequency of departures from the average conditions. The study of the occurrence of dates of last killing frost in Spring and first killing frost in Fall shows that it is possible to determine with a fair degree of accuracy the chance of killing frost after a given date in Spring or before a given date in Fall for places having records of 20 years or more. This possibility depends upon the demonstrable fact that the distribution of dates of last (or first) frost is that of the so-called normal frequency curve. A careful study of the frost records of 33 stations with a total of 823 observations shows the close relation between the normal frequency curve and the frequency polygon of the dates of last killing frost (see fig. 1). The properties of the normal frequency curve have been carefully investigated by Karl Pearson and others. From the results of this work it is possible to compute the percentage of occurrence of cases falling outside of any given date or to compute the date on which the percentage of cases falls to a given value. The characteristics of any phenomenon in which the distribution follows that of the normal frequency curve may be expressed by a single number known as the "standard deviation." When the standard deviation of the dates of last killing frost in Spring is known for any station the frost risk may be computed for any date by Table 1.

Table 1.—*Risk of killing frost in spring.*

Risk of occurrence.	Number of days after the average date.	Example, La Crosse, Wis.
Per cent.		
50	Average date	Apr. 26.
40	0.25×standard deviation	Apr. 26+(0.25×14.4)=Apr. 30.
30	0.52×standard deviation	Apr. 26+(0.52×14.4)=May 4.
25	0.67×standard deviation	Apr. 26+(0.67×14.4)=May 6.
20	0.84×standard deviation	Apr. 26+(0.84×14.4)=May 9.
10	1.28×standard deviation	Apr. 26+(1.28×14.4)=May 15.

The autumn date when the risk of killing frost rises to a given per cent may be determined by subtracting from the average date the numbers obtained by the use of the standard deviation of the date of first killing frost.

The distribution of frost conditions in the United States is indicated by figures 2 and 3. Figure 2 shows the standard deviations of the dates of last killing frost in Spring. The isograms were drawn from the standard deviations determined for 569 stations fairly well distributed over the country. The lines are of necessity somewhat general. Figure 3 is a similar map of the standard deviations of first killing frost in autumn.

To compute the time available for plant growth in a given proportion of the years the most satisfactory method is that based on the risk at each end of the growing season. If the chance of safety on a given date in Spring is one-half and that on a given date in Fall is one-half, the chance of safety for the whole period between is one-half multiplied by one-half—that is, one-fourth. For many important crops about a four-fifths chance of safety is essential for continued success. A period in which the probability of no killing frost is four-fifths and of which the beginning is definitely known may be determined for any station as follows: Given the standard deviation of the date of last killing frost in spring, the date upon which the chance of killing frost falls to 10 per cent may be determined from Table 1. The date on which the chance of Fall killing frost rises above 10 per cent may be determined from the standard deviation of the dates of first killing frost in Fall and Table 1. Therefore, for any place the length of the available growing season (that is, number of days for which the chance is four in five), beginning at the date when the frost risk falls to 10 per cent, is the number of days between this date and the date on which the chance of fall frost rises to 10 per cent. Although this method of determining business risk is subject to limitations because of the shortness of the individual records, a careful examination of the records shows that in the large the computed dates on which the frost risk rises (or falls) to 10 per cent, when compared with the actual number of occurrences, is a very close agreement. From a total of 27,157 observations the lack of agreement between the computed and counted cases was but 17 in 10,000.

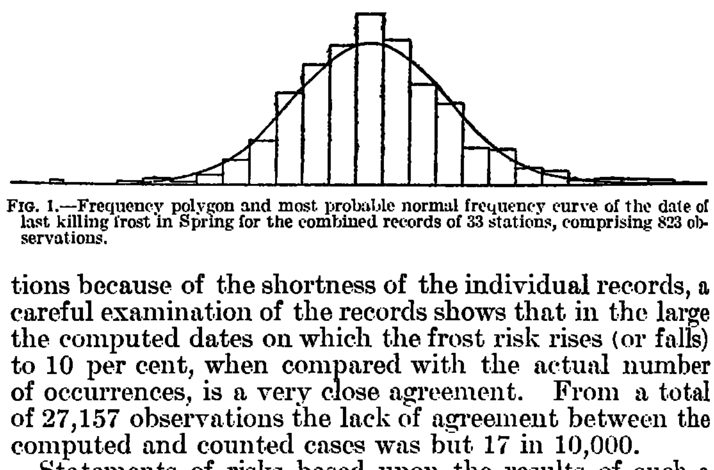

Fig. 1.—Frequency polygon and most probable normal frequency curve of the date of last killing frost in Spring for the combined records of 33 stations, comprising 823 observations.

Statements of risks based upon the results of such a study as this should not be regarded as seasonal forecasts. They simply represent, as far as may be determined from the data now available, the chances the farmer must meet if his business is to be permanently successful. The risks of loss which may profitably be carried varies with the crop and the economic conditions. For those crops in which the early production results in higher prices, e. g., garden vegetables, a considerable risk may be assumed with frequent losses and profit in the long run. In the case of other crops, e. g., corn, early production is of little or no advantage, and the risk which can be assumed is much smaller.

The occasional occurrence of unfavorable weather conditions is a risk which must be recognized by successful farmers. In the case of phenomena whose distribution follows the "normal law of frequency" this risk may be determined with a fair degree of accuracy. The method of determining the risk of frost occurrence has been described in this paper; the distributions of other phenomena seem to be more complicated, but further studies along this line will doubtless result in determining a method of computing the risks from their occurrence.

[1] *See* Geographical Review, New York, July, 1916, 2: 48-53.

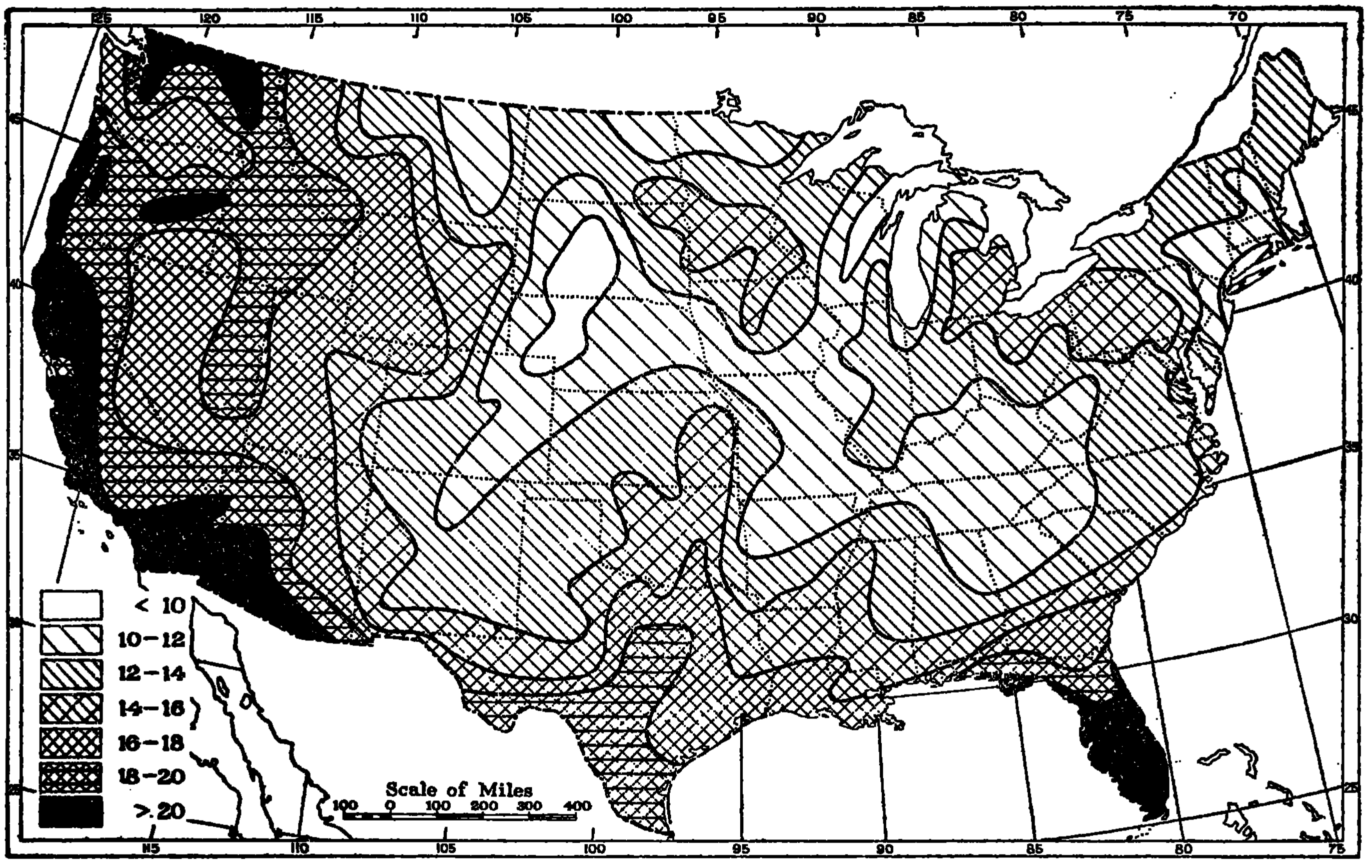

FIG. 2.—Standard deviations of dates of last killing frost in Spring (records of 569 stations).

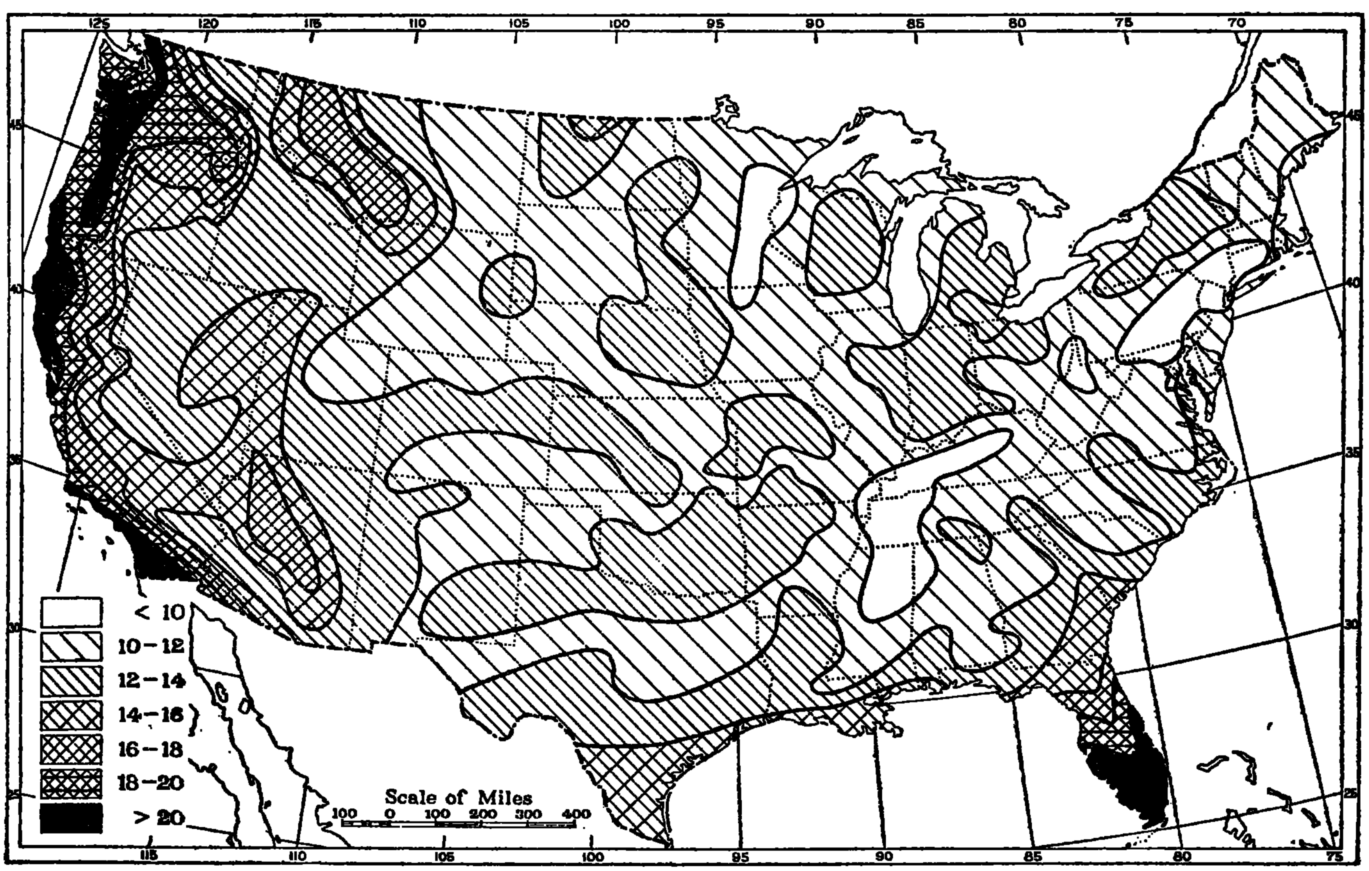

FIG. 3.—Standard deviations of dates of first killing frost in Fall (records of 569 stations).