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Monthly and Annual Precipitation Probabilities for Climatic Divisions in Ohio

MARVIN E. MILLER

C. R. WEAVER

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
WOOSTER, OHIO

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MARVIN E. MILLER and C. R. WEAVER[1]

INTRODUCTION

This study is the first of a series which will present precipitation probability information for the state of Ohio. Other studies will present (1) distribution of monthly and annual precipitation for approximately 80 locations within Ohio and (2) probable maximum 24-hour precipitation over Ohio. Such information will be useful to engineers in the design and construction of hydrological structures, to industrial management when considering sites for expansion of their businesses, to farmers in planning seasonal crops, to scientific personnel interested in relating precipitation to the project with which they are associated, and to the general meteorologist who is expected to give information to the public.

This publication gives the mean distribution of monthly and annual precipitation within the 10 climatic divisions in Ohio (Figure 1).

DISCUSSION

Monthly precipitation normals, as published by the Environmental Science Services Administration (ESSA) under international agreement, are merely arithmetic means over a specified 30-year period. Annual precipitation normals are sums of monthly normals. The current normal period being used by ESSA is 1931-1960.

When considering statistical frequency distribution curves, the arithmetic mean is one of the variables used in determining the normal or Gaussian distribution. In the normal distribution, the vertical line of symmetry occurs at the mean of the distribution and this value is also the median and the mode. This distribution provides good fits to most climatological variables which are unbounded above or below, such as temperature or pressure. Since precipitation is bounded at the lower end by zero, it seems appropriate to assume that some distribution other than the Gaussian will best fit precipitation data.

Barger and Thom (1), Friedman and Janes (4), and Thom (8) have shown that the incomplete gamma distribution gives good fits to precipitation climatological series. The incomplete gamma frequency distribution as presented by Thom for the random variable X is given by

$$f(x) = \frac{e^{-x/\beta}\, x^{m-1}}{\beta^{m}\, \Gamma(m)} \qquad (1)$$

where X = precipitation amount

β = beta parameter as defined in equation (4). (Beta's size is dependent upon the variability of the rainfall amounts.)

m = gamma parameter as found from equation (3). (Gamma's size is proportional to the magnitude of the rainfall amounts.)

$$\Gamma(m) = \int_0^x e^{-x}\, x^{m-1}\, dx,$$

$$0 \leq x \leq \infty,\ m > 0$$

(This term, the gamma function, is approximated as (M —1) !)

The probability that precipitation will not exceed X amount as well as the precipitation associated with any probability can be found from

$$F(x) = \int_0^x \frac{e^{-x/\beta}\, x^{m-1}}{\beta^{m}\, \Gamma(m)} \qquad (2)$$

Barger, Shaw, and Dale (2) have presented a simple method of calculating the value of precipitation associated with a given probability. In the presentation by Barger, Shaw, and Dale, the gamma parameter is found by solving for m in the quadratic equation

$$12\,(\ln \bar{x} - 1/N \textstyle\sum \ln x)\, m^2 - 6m - 1 = 0 \qquad (3)$$

In the above equation, X is the amount of precipitation (daily, weekly, monthly, annual, etc.). The estimate of beta is given by

$$\beta = \bar{x}/m \qquad (4)$$

[1]State Climatologist, Environmental Science Services Administration, and Statistician, Ohio Agricultural Research and Development Center.

Thom (9) has developed nomograms of Pearson's tables (5) of the incomplete gamma function where curves of the incomplete gamma distribution are related to probability (abscissa) and the ratio X/β (ordinate). In Thom's graphs, the value of precipitation associated with a given probability and gamma parameter is the X term in the ratio X/β.

Strommen, Kronberg, and Purvis (7) followed the procedure outlined by Barger, Shaw, and Dale to calculate monthly precipitation probabilities for seven climatic divisions in South Carolina. Later, Strommen (6) used the same technique to estimate similar monthly probabilities for 10 climatic divisions in Michigan. Annual precipitation probabilities were not included in the above publications because the size of the gamma parameters exceeded the limits of Thom's nomograms.

For Ohio's 10 climatic divisions, the authors were interested in determining the monthly and annual precipitation amounts for the 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 95 percent probability levels. Rather than utilizing the desk calculator as Strommen and colleagues did in the preparation of monthly precipitation probability data for South Carolina and Michigan, Weaver and Miller (11) wrote a computer program for the purpose of computing precipitation associated with selected probabilities. This program utilizes equations 3 and 4 to calculate the gamma and beta parameters. Precipitation, X_i, for a given probability, P, is estimated from

$$X_i = X_j - \frac{X_j}{m}(S) - \frac{P(m)e^{X_j}}{X_j^{m-1}} \qquad (5)$$

where $j = i-1$

$$S = 1 + \frac{X}{(m+1)} + \frac{X^2}{(m+1)(m+2)} + \frac{X^3}{(m+1)(m+2)(m+3)}$$

The initial estimates of X_i begins at $m - 1$; i. e., $X_j = m - 1$. If m is less than 36, the gamma function, $\Gamma(m)$, is calculated following a procedure developed by Collinge (3). For gamma parameter values greater than 36, the gamma functions were found by linear interpolation of Pearson's gamma function tables (5) which were made available to the computer. For Ohio's 10 climatic divisions, the gamma parameter values were less than 36. The annual values were more than 36.

The input data cards used in this study were punched from a publication entitled: Decennial Census of United States Climate—Monthly Averages for State Climatic Divisions 1931-1960, Ohio (Climatography of the United States No. 85-29). This publication presents tabulations of monthly averages of temperature and precipitation for the period 1931-1960 for each of Ohio's 10 climatic divisions. An excerpt from this publication is shown in Table 1. These data are the simple arithmetic average of monthly observations for all stations within each division with both temperature and precipitation records. Since 1931, as the number of temperature and precipitation recording stations increased or decreased, these locations were added or deleted to the station data being averaged.

Figures 1 and 2 show the density of Ohio weather stations in 1960 and 1930, respectively. Spacing of weather stations is important in obtaining homogeneous weather records over large areas. As shown in Figures 1 and 2, the statewide network of weather stations increased from 142 stations in 1930 to 329 stations in 1960. This latter number of cooperative weather stations provides adequate coverage of temperature and precipitation observations within Ohio.

Tables 2 through 11 show the monthly and annual precipitation with probability equal or less than .05, .10, .20, .30, .40, .50, .60, .70, .80, .90, .95 for the 10 climatic divisions in Ohio. To use these tables, follow horizontally across from some month or annual line to the precipitation amount of interest and read the probability shown at the top of the column. For example, suppose that someone is interested in the chance of receiving an average October rainfall of less than 1.75 inches over north central Ohio. Turning to Table 3, that individual would see there is a 0.40 probability; i.e., in 40 of 100 years, the October rainfall over north central Ohio will average less than 1.75 inches.

By subtracting the probability values shown in Tables 2 through 11 from 1.00, the tables can be converted to precipitation with probability equal or greater than values shown. If the above user is interested in the chance of receiving 1.75 inches or more of rainfall during October over north central Ohio, he would find the probability to be 6 of 10 years or 0.60 (1.00 — 0.40).

Since the data from which Tables 2-11 were prepared are average precipitation values for the various climatic divisions, the precipitation values associated with the probability levels should be used with the understanding that they also are average values. Annual precipitation generally increases southward across Ohio. Therefore, assuming equal aerial coverage of precipitation recording stations, precipitation at the 0.50 probability level, as given in

Tables 2-11, should be most representative of areas near the center of each climatic division.

An example of the variation of annual precipitation for selected probability levels within climatic divisions for three stations in north central Ohio is shown in Table 12. It can be seen that averaging of monthly precipitation within climatic divisions tends to reduce the variation of precipitation.

Stations shown in Table 12 are arranged from north to south. Put-In-Bay is located on South Bass Island in Lake Erie and has an annual variation of precipitation different from other weather observation sites within north central Ohio. These differences in precipitation amounts between Put-In-Bay and other north central Ohio locations are greatest in spring. At that time, the mean daily temperature of the water surrounding South Bass Island is lower than the mean daily temperature of north central Ohio's "land" stations. (Surface temperature differences between Put-In-Bay and other north central Ohio locations are greatest during the afternoon, the normal time of maximum surface heating.) Such differences in surface temperatures affect the stability of the lower atmosphere. In this case, the stability differences are related to the variation in precipitation between Put-In-Bay and other north central Ohio weather observation sites.

TABLE 12.—Variation of Annual Precipitation for Selected Probability Levels Within North Central Ohio.

	Annual Precipitation (inches)			
Probability	North Central Climatic Division	Put-In-Bay	Oberlin	Bucyrus
05	26.09	23.47	25.24	25.06
10	27.63	24.67	27.02	26.94
.20	29.57	26.17	29.30	29.35
30	31.02	27.30	31.02	31.17
40	32.30	28.28	32.54	32.78
50	33.53	29.22	34.00	34.34
.60	34.79	30.19	35.51	35.95
70	36.17	31 24	37.17	37.73
80	37.83	32.50	39 18	39.88
90	40 22	34.31	42.08	42.99
.95	42.27	35.86	44.55	45 69

TABLE 1.—Monthly and Annual Divisional Averages.

	TEMPERATURE (°F)													PRECIPITATION (In.)											
YEARS (By Divisions)	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL
NORTHWEST																										
1931	30.4	34.5	34.7	49.7	58.7	71.3	77.1	72.9	69.9	57.1	48.7	38.0	53.6	1.06	1.40	2.39	2.80	2.17	4.27	2.94	2.88	3.78	2.23	2.76	2.88	31.56
1932	37.4	35.1	31.3	46.9	60.8	70.8	74.4	73.3	64.6	53.6	36.1	29.9	51.2	4.76	1.01	1.98	1.98	2.04	2.59	2.94	1.02	3.95	4.35	2.76	4.27	33.65
1933	35.4	29.7	36.0	49.1	62.3	75.0	75.2	71.2	68.7	51.1	37.4	31.4	51.9	1.47	1.59	3.77	3.26	6.50	1.75	2.52	2.43	5.50	1.35	1.11	1.61	32.86
1934	31.7	18.3	32.6	47.5	63.6	76.0	79.2	72.2	67.0	53.4	43.9	26.8	51.0	1.37	.80	2.96	3.13	.79	3.64	1.51	2.92	4.12	.65	1.92	1.52	25.33
1935	27.4	28.4	43.0	45.5	54.3	68.5	76.9	73.1	63.8	52.2	40.0	23.8	49.6	2.29	1.32	2.98	1.58	4.48	2.69	3.99	3.74	2.07	1.37	2.67	1.37	30.51
1936	20.1	17.9	40.9	44.6	61.7	68.7	77.2	75.8	68.4	52.6	36.5	33.1	50.0	1.25	2.58	3.21	2.22	1.96	2.23	1.91	1.92	4.09	3.51	1.96	2.52	29.36
1937	30.8	28.8	32.7	47.9	59.7	68.5	73.2	74.2	62.2	50.3	38.0	26.9	49.4	5.70	1.62	1.53	5.02	3.60	7.05	5.27	2.81	2.80	2.66	1.19	1.71	40.96
1938	27.1	34.6	44.1	51.0	60.4	68.3	74.1	75.3	65.0	55.7	42.4	30.6	52.4	.69	3.05	5.29	3.14	3.84	4.77	4.23	2.44	2.65	.78	1.99	1.68	34.55
1939	30.3	29.3	37.6	45.4	63.4	72.0	73.0	72.0	69.1	54.6	39.3	33.8	51.7	2.44	3.79	3.18	4.17	.76	6.68	4.11	2.15	2.22	3.29	.80	.88	34.47
1940	15.5	28.0	31.9	44.9	57.2	70.3	74.2	72.1	63.0	54.7	38.2	34.0	48.7	1.50	1.65	2.13	4.37	3.82	5.11	2.01	3.18	1.16	2.15	2.43	3.07	32.58
1941	27.4	25.4	32.0	53.9	63.5	70.6	75.1	72.2	69.1	56.6	42.8	35.9	52.0	1.53	.56	1.11	1.67	3.26	3.58	1.78	2.64	1.45	5.12	2.07	1.64	26.41
1942	27.2	24.2	39.8	53.6	62.0	70.7	74.5	70.4	63.3	53.9	42.2	25.0	50.6	1.43	2.69	3.63	2.84	3.28	4.08	4.39	5.03	2.46	1.65	7.71	1.90	37.09
1943	24.8	30.1	35.1	44.9	59.0	74.3	74.0	72.0	61.3	51.9	38.2	27.7	49.4	1.52	.96	2.34	3.03	9.66	4.29	5.90	2.53	2.93	1.98	1.64	.43	37.21
1944	31.6	30.8	33.9	45.3	65.1	73.2	74.2	73.9	65.6	52.6	42.2	23.9	51.0	.54	1.71	3.49	5.46	3.30	3.57	1.51	2.40	1.46	1.45	2.37	1.79	29.05
1945	18.1	28.8	48.9	51.7	53.7	66.7	71.3	71.6	66.9	51.1	42.2	23.5	49.5	.78	1.56	5.23	2.97	5.08	5.10	2.65	1.65	5.21	3.56	1.70	2.26	37.75
1946	28.7	30.4	48.9	49.9	57.6	68.3	73.2	67.8	65.7	58.1	44.8	33.5	52.2	.84	1.52	2.28	.78	4.43	6.40	1.89	1.74	1.32	2.82	2.32	2.39	28.73
1947	31.0	22.2	32.1	47.9	56.5	66.7	70.3	78.2	65.8	61.0	37.2	29.4	49.9	3.60	.41	1.99	4.86	5.06	5.26	2.62	3.58	3.36	2.51	2.01	2.05	37.31
1948	19.8	27.1	37.6	53.5	57.9	68.7	73.9	72.0	67.0	49.9	45.8	32.8	50.5	1.97	2.70	4.44	2.87	4.40	4.15	3.16	2.18	2.85	1.96	4.29	2.75	37.72
1949	33.3	33.4	38.7	47.9	61.3	73.5	77.2	73.0	59.2	58.1	40.8	33.5	52.5	3.96	2.58	1.85	2.48	4.83	3.35	2.90	3.75	2.78	3.43	.88	2.78	35.57
1950	34.7	28.5	33.0	43.0	60.9	68.2	70.6	69.6	63.2	56.6	36.2	22.9	49.0	7.61	4.78	3.05	5.19	1.29	5.00	3.88	2.79	5.30	3.91	4.36	2.22	49.38
1951	28.6	28.2	37.5	47.1	61.2	68.9	72.7	70.0	62.8	56.1	34.6	28.3	49.7	2.86	2.80	3.43	3.62	3.58	5.15	2.89	1.62	2.16	3.47	3.16	4.18	37.93
1952	31.1	31.8	36.4	50.0	58.4	74.4	76.8	71.6	64.9	48.7	43.2	33.5	51.7	3.92	1.73	3.77	3.64	4.62	1.04	2.89	1.80	2.45	.69	2.15	2.01	30.71
1953	31.7	32.9	40.0	45.4	62.1	72.8	74.7	72.8	65.0	56.5	43.5	33.3	52.6	2.38	1.23	2.77	2.72	3.39	2.20	3.05	3.05	1.87	.67	.78	1.71	25.82
1954	28.5	35.9	35.4	53.5	55.8	72.7	72.9	70.4	67.1	54.7	40.3	30.5	51.5	2.34	2.83	3.73	3.30	1.68	3.76	3.70	4.77	1.39	6.05	1.78	1.78	37.11
1955	26.2	29.6	38.1	55.9	62.6	67.6	78.3	75.6	66.7	54.7	37.6	27.1	51.7	2.00	2.03	3.90	2.80	2.05	2.11	4.15	3.06	1.66	4.69	3.90	.48	32.83
1956	24.6	29.7	35.2	46.5	59.0	70.4	72.6	71.6	62.0	58.2	41.1	36.0	50.6	1.43	2.55	3.57	3.51	5.16	3.04	2.78	4.66	.80	.47	1.82	2.36	32.15
1957	21.1	32.6	37.6	49.9	59.3	69.7	73.3	71.6	64.2	50.4	41.0	35.0	50.5	1.93	1.64	1.01	6.13	3.61	5.29	2.40	2.60	3.82	3.99	2.14	3.72	38.28
1958	26.6	22.6	36.1	50.4	59.3	65.0	72.7	70.5	64.4	54.3	43.1	21.7	48.9	1.41	.68	.72	2.65	2.39	5.33	6.74	4.15	2.93	.95	4.10	.33	32.38
1959	22.2	28.2	36.3	49.8	64.5	71.0	73.6	76.6	67.9	52.8	36.6	34.7	51.2	4.03	3.42	2.87	4.43	3.64	2.71	3.54	2.52	3.81	4.35	3.26	2.70	41.28
1960	29.4	27.9	25.7	52.5	58.3	67.7	71.2	72.9	68.1	53.7	43.0	24.3	49.6	3.07	2.63	.89	1.63	3.65	3.93	3.56	2.02	1.03	1.24	1.65	.77	26.07
NORMAL	27.8	28.8	36.8	48.8	60.1	70.3	74.3	72.5	65.4	54.2	40.6	30.0	50.8	2.36	1.99	2.85	3.28	3.61	4.00	3.26	2.80	2.78	2.58	2.32	2.06	33.89
NORTH CENTRAL																										
1931	30.1	33.8	35.1	48.9	58.4	70.0	77.5	73.3	69.9	57.6	49.6	38.8	53.6	1.58	1.55	2.10	3.84	2.60	3.89	1.67	5.23	4.24	2.50	2.31	2.55	34.06
1932	38.6	35.7	32.2	46.1	60.7	70.4	73.6	72.8	65.6	54.3	38.4	31.5	51.7	4.30	1.03	2.78	2.24	2.39	1.96	3.66	1.81	2.36	3.99	3.04	3.34	32.90
1933	36.5	30.9	36.5	48.8	62.2	74.7	75.6	72.2	68.6	52.3	37.8	32.5	52.4	1.41	1.59	3.83	3.02	5.17	1.06	2.08	2.03	4.44	1.15	1.55	1.77	29.10
1934	32.1	18.5	33.6	47.3	63.4	75.7	78.4	71.5	68.2	54.1	45.0	29.0	51.4	1.35	.84	2.69	3.44	.60	2.10	1.87	3.35	3.10	.82	1.62	1.35	23.13
1935	28.2	29.1	43.5	45.2	54.4	66.5	76.6	73.1	64.4	53.4	42.1	25.0	50.1	2.32	1.82	2.24	1.51	3.77	2.82	3.61	4.47	2.08	1.59	2.23	1.79	30.25
1936	21.8	20.1	40.7	44.7	63.7	69.1	75.9	75.1	68.9	53.7	37.0	34.7	50.5	1.02	2.63	3.68	2.28	1.48	1.93	3.49	2.10	3.84	3.28	1.97	1.69	29.39
1937	33.4	30.4	32.8	47.8	59.2	68.8	73.9	74.1	62.9	51.1	39.1	27.8	50.1	7.17	2.11	1.77	4.17	3.58	10.23	4.31	2.66	2.19	3.67	1.86	2.21	44.75
1938	28.2	35.3	44.7	50.7	60.4	68.3	74.0	75.1	64.6	55.6	43.6	31.7	52.7	1.10	3.12	4.11	2.44	3.72	4.86	3.79	2.41	3.42	.84	3.24	1.49	34.54
1939	31.2	30.7	37.8	45.5	62.1	72.2	73.2	72.4	69.2	55.4	40.2	34.6	52.0	2.29	3.65	3.33	4.00	1.09	4.52	3.59	2.02	2.54	2.47	.71	1.12	31.33
1940	16.8	28.2	32.0	44.2	57.5	70.0	73.9	72.0	62.8	53.9	39.7	34.9	48.8	1.17	2.39	2.50	4.38	3.41	5.62	1.90	5.82	2.08	1.77	2.31	3.35	36.70
1941	28.5	26.1	31.9	53.2	62.7	70.6	74.9	71.3	68.9	57.2	43.4	36.9	52.1	1.38	.77	.73	1.80	3.13	4.38	3.26	2.94	1.19	3.65	1.65	1.38	26.26
1942	27.5	24.7	39.9	53.3	62.0	70.6	74.6	70.9	64.1	54.6	42.5	25.6	50.9	1.11	2.57	2.74	3.18	4.12	3.67	4.22	4.11	2.43	2.09	3.54	4.66	36.44
1943	25.6	29.6	35.7	43.9	59.2	74.1	74.1	72.1	61.9	52.2	38.9	28.6	49.7	1.62	1.29	2.57	2.99	7.70	3.85	6.70	2.41	2.54	1.89	.96	.62	35.14
1944	31.8	30.9	34.6	44.5	64.7	73.0	74.2	73.9	65.4	53.2	42.9	25.2	51.2	.93	1.76	3.50	3.68	3.60	4.11	1.15	3.29	1.46	1.13	1.88	1.91	28.40
1945	18.7	28.6	48.7	52.0	54.0	66.5	71.0	71.6	67.2	52.0	43.0	24.9	49.9	1.24	1.61	5.08	2.70	4.00	5.77	2.76	1.59	4.97	3.64	2.08	1.77	37.21
1946	29.7	31.0	48.4	49.4	57.4	68.1	72.4	67.2	65.7	58.0	45.4	33.7	52.2	.81	1.92	2.22	.79	5.37	6.91	3.11	2.15	1.80	2.88	2.40	2.19	32.57
1947	32.2	22.8	32.1	47.8	56.6	66.8	70.2	76.9	66.3	60.8	38.6	30.7	50.1	3.89	.42	1.95	4.36	5.53	6.38	2.56	4.42	3.30	1.87	1.88	1.94	38.50
1948	20.2	27.8	38.3	52.8	56.7	68.2	73.7	71.0	66.3	49.8	46.2	33.7	50.4	1.76	2.38	4.54	2.99	4.39	4.11	2.07	3.63	2.36	2.25	4.35	2.50	37.33
1949	34.4	34.1	38.5	47.3	61.6	73.6	77.2	72.8	60.7	58.9	41.7	34.5	52.9	3.42	2.02	2.08	2.87	4.14	2.72	3.08	3.64	2.83	1.13	1.30	2.28	31.51
1950	36.6	30.1	33.7	43.4	60.1	68.2	70.9	70.0	63.7	57.2	37.8	24.8	49.7	4.76	4.24	2.95	4.73	1.96	4.13	3.71	2.82	5.86	2.47	4.47	2.15	46.25
1951	29.5	29.9	38.4	47.4	60.4	68.6	72.3	69.7	63.7	56.9	35.8	30.2	50.2	2.36	2.68	3.74	2.97	2.71	4.03	2.57	1.43	2.97	2.07	3.99	4.86	36.38
1952	32.3	32.2	36.6	49.8	58.3	73.9	77.0	71.6	65.0	49.9	44.1	34.4	52.1	4.38	1.91	3.81	3.61	2.82	1.93	2.90	2.02	3.26	.59	1.62	4.55	31.40
1953	32.8	33.5	40.5	45.4	61.5	72.0	73.9	72.9	65.1	56.1	44.1	34.0	52.7	3.05	1.03	1.90	2.74	4.55	2.77	3.79	2.63	1.30	.86	1.54	1.78	27.94
1954	29.1	35.9	35.9	54.1	56.1	72.6	72.6	70.6	67.3	55.5	41.9	31.4	51.9	2.48	1.97	3.85	4.48	1.40	2.21	2.37	4.93	1.56	5.73	1.43	1.53	33.94
1955	27.2	30.5	38.8	55.8	62.5	67.5	78.0	75.5	66.9	55.1	38.5	27.9	52.0	1.81	2.20	4.45	3.25	2.56	2.02	3.82	3.43	1.52	3.94	3.46	.54	33.00
1956	26.0	30.5	35.6	46.7	58.1	68.9	72.2	70.3	61.9	57.9	41.9	36.9	50.6	1.70	2.76	3.78	2.69	4.84	4.08	2.93	4.32	1.60	.72	1.51	2.57	33.50
1957	22.7	33.1	38.0	50.9	59.4	70.2	72.9	71.4	64.6	51.0	42.0	35.4	51.0	2.30	2.08	1.23	6.23	3.91	5.95	3.07	2.18	4.50	2.40	2.46	3.54	39.85
1958	27.0	23.0	35.6	50.2	58.7	64.8	72.9	70.4	65.1	54.6	43.9	21.9	49.0	1.46	.85	.73	3.30	2.24	4.97	6.73	3.77	2.86	1.40	4.18	.41	32.90
1959	23.6	29.3	36.6	50.0	64.4	70.5	73.9	76.0	68.9	53.8	38.5	35.0	51.7	4.72	3.69	2.60	4.20	3.62	1.95	4.19	2.51	1.83	3.83	3.14	2.62	38.90
1960	30.3	28.8	25.7	52.3	58.3	68.0	70.6	72.0	67.6	53.5	43.5	24.2	49.6	2.73	2.25	1.15	2.40	3.80	4.28	3.81	3.72	1.14	1.27	1.96	1.04	29.55
NORMAL	28.8	29.5	37.1	48.6	59.8	70.1	74.1	72.3	65.7	54.7	41.6	31.0	51.1	2.45	2.04	2.82	3.24	3.47	3.97	3.29	3.13	2.72	2.26	2.32	2.05	33.76

TABLE 13.—Difference Between 0.50 Probability Values and Arithmetic Normals for Climatic Divisions of Ohio.

Climatic Division	0.50 Probability Value for Year (Inches) A	Arithmetic Normal For Year (Inches) B	B —A (Inch)
Northwest	33.62	33 89	0.27
North Central	33.53	33.76	0.23
Northeast	36.55	36.81	0.26
West Central	36 30	36 63	0.33
Central	37.12	37.37	0.25
Central Hills	37 26	37.47	0.21
Northeast Hills	37.90	38 07	0.17
Southwest	39 63	39.98	0.35
South Central	41.02	41.33	0.31
Southeast	39.12	39.36	0.24

SUMMARY

Monthly and annual precipitation probabilities were prepared for the 10 climatic divisions in Oho. Data for the period 1931-1960, as obtained from a standard Weather Bureau publication, were used in making the calculations of precipitation probabilities. These probabilities were derived from the cumulative distribution of the incomplete gamma function.

APPENDIX

As the arithmetic mean precipitation values get larger (days to weeks to months to years, etc.), the sum of the several component periods approaches a normal distribution.

Thom has suggested that when the gamma parameter approaches 100, the data are normally distributed. While none of Ohio's gamma parameters for the computation of the distribution of annual precipitation exceeded 79, the differences between the 0.50 probability values and arithmetic annual normals as shown in Table 13 do not exceed 1 percent of the respective median values.

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TABLE 2 PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN

STATION	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
N.WEST JAN	.58	.80	1.14	1.45	1.75	2.07	2.42	2.84	3.39	4.26	5.07
N.WEST FEB	.63	.82	1.10	1.34	1.57	1.81	2.07	2.38	2.77	3.39	3.95
N.WEST MAR	1.11	1.37	1.74	2.06	2.35	2.65	2.97	3.35	3.82	4.55	5.20
N.WEST APR	1.46	1.75	2.16	2.49	2.79	3.10	3.43	3.81	4.28	5.01	5.66
N.WEST MAY	1.21	1.55	2.05	2.47	2.88	3.30	3.76	4.29	4.97	6.03	6.99
N.WEST JUN	1.81	2.16	2.65	3.05	3.42	3.79	4.19	4.65	5.23	6.10	6.89
N.WEST JUL	1.58	1.86	2.24	2.55	2.83	3.11	3.41	3.75	4.18	4.83	5.40
N.WEST AUG	1.43	1.66	1.98	2.23	2.46	2.69	2.93	3.21	3.55	4.07	4.53
N.WEST SEP	1.02	1.28	1.66	1.97	2.27	2.57	2.90	3.29	3.78	4.53	5.22
N.WEST OCT	.60	.84	1.22	1.55	1.89	2.25	2.64	3.12	3.74	4.73	5.65
N.WEST NOV	.93	1.14	1.45	1.70	1.93	2.17	2.43	2.73	3.10	3.68	4.21
N.WEST DEC	.63	.82	1.11	1.36	1.61	1.86	2.14	2.46	2.88	3.54	4.15
N.WEST ANN	25.86	27.46	29.48	31.00	32.34	33.62	34.94	36.39	38.14	40.66	42.82

TABLE 3

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
N.CENT JAN	.66	.89	1.25	1.56	1.86	2.18	2.53	2.94	3.48	4.32	5.09
N.CENT FEB	.76	.95	1.22	1.45	1.67	1.89	2.13	2.40	2.76	3.30	3.80
N.CENT MAR	1.12	1.38	1.75	2.05	2.34	2.63	2.95	3.32	3.78	4.49	5.13
N.CENT APR	1.61	1.88	2.25	2.55	2.82	3.10	3.39	3.72	4.13	4.75	5.29
N.CENT MAY	1.30	1.62	2.09	2.47	2.84	3.22	3.62	4.09	4.69	5.61	6.45
N.CENT JUN	1.50	1.87	2.40	2.84	3.26	3.69	4.15	4.69	5.38	6.43	7.39
N.CENT JUL	1.60	1.88	2.27	2.58	2.86	3.14	3.45	3.79	4.22	4.87	5.45
N.CENT AUG	1.55	1.81	2.17	2.46	2.72	2.99	3.27	3.59	3.99	4.59	5.11
N.CENT SEP	1.14	1.39	1.73	2.02	2.28	2.55	2.84	3.18	3.60	4.24	4.83
N.CENT OCT	.66	.88	1.20	1.48	1.75	2.03	2.35	2.71	3.19	3.93	4.62
N.CENT NOV	.91	1.12	1.43	1.68	1.92	2.16	2.42	2.72	3.11	3.69	4.21
N.CENT DEC	.72	.92	1.20	1.43	1.66	1.89	2.14	2.43	2.80	3.38	3.91
N.CENT ANN	26.09	27.63	29.57	31.02	32.30	33.53	34.79	36.17	37.83	40.22	42.27

TABLE 4

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
N.EAST JAN	.87	1.13	1.52	1.85	2.18	2.51	2.88	3.31	3.86	4.72	5.52
N.EAST FEB	.98	1.19	1.48	1.72	1.95	2.17	2.41	2.69	3.05	3.58	4.06
N.EAST MAR	1.40	1.67	2.06	2.37	2.66	2.95	3.26	3.62	4.07	4.75	5.37
N.EAST APR	1.70	1.99	2.40	2.72	3.02	3.32	3.63	3.99	4.44	5.12	5.72
N.EAST MAY	1.45	1.79	2.28	2.68	3.05	3.44	3.85	4.33	4.94	5.88	6.73
N.EAST JUN	1.99	2.29	2.70	3.02	3.31	3.60	3.91	4.26	4.70	5.35	5.92
N.EAST JUL	1.62	1.94	2.38	2.74	3.08	3.41	3.77	4.18	4.70	5.48	6.19
N.EAST AUG	1.65	1.93	2.31	2.61	2.89	3.17	3.47	3.81	4.23	4.87	5.44
N.EAST SEP	1.38	1.64	1.99	2.28	2.55	2.81	3.10	3.42	3.83	4.44	4.99
N.EAST OCT	.64	.90	1.30	1.66	2.01	2.39	2.81	3.31	3.97	5.01	5.99
N.EAST NOV	1.30	1.54	1.85	2.11	2.34	2.58	2.83	3.12	3.48	4.02	4.50
N.EAST DEC	1.08	1.29	1.59	1.83	2.05	2.27	2.51	2.79	3.13	3.65	4.12
N.EAST ANN	28.66	30.29	32.35	33.89	35.25	36.55	37.89	39.35	41.11	43.64	45.81

TABLE 5

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
W.CENT JAN	.48	.73	1.16	1.56	1.97	2.41	2.92	3.54	4.36	5.69	6.94
W.CENT FEB	.73	.94	1.25	1.51	1.76	2.02	2.31	2.64	3.07	3.73	4.33
W.CENT MAR	1.03	1.32	1.76	2.12	2.47	2.84	3.23	3.70	4.29	5.21	6.05
W.CENT APR	1.51	1.82	2.25	2.60	2.93	3.26	3.61	4.02	4.54	5.32	6.02
W.CENT MAY	1.36	1.71	2.22	2.64	3.04	3.46	3.90	4.42	5.09	6.11	7.04
W.CENT JUN	1.66	2.07	2.64	3.12	3.58	4.04	4.54	5.12	5.86	6.98	8.01
W.CENT JUL	1.49	1.82	2.28	2.66	3.02	3.38	3.77	4.21	4.78	5.64	6.43
W.CENT AUG	1.27	1.55	1.95	2.28	2.59	2.90	3.24	3.62	4.11	4.86	5.54
W.CENT SEP	.79	1.07	1.49	1.86	2.22	2.60	3.02	3.52	4.16	5.16	6.08
W.CENT OCT	.63	.86	1.22	1.54	1.85	2.18	2.54	2.97	3.54	4.43	5.25
W.CENT NOV	.88	1.12	1.45	1.73	2.00	2.28	2.58	2.92	3.37	4.06	4.68
W.CENT DEC	.70	.92	1.24	1.52	1.79	2.07	2.37	2.73	3.20	3.92	4.59
W.CENT ANN	27.57	29.36	31.63	33.34	34.85	36.30	37.80	39.44	41.42	44.27	46.73

TABLE 6

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
CENTRL JAN	.62	.91	1.37	1.79	2.22	2.68	3.20	3.82	4.65	5.97	7.23
CENTRL FEB	.84	1.06	1.39	1.66	1.92	2.19	2.49	2.83	3.26	3.93	4.55
CENTRL MAR	1.03	1.35	1.81	2.21	2.60	3.00	3.44	3.96	4.62	5.66	6.62
CENTRL APR	1.70	2.02	2.45	2.80	3.12	3.45	3.79	4.19	4.69	5.44	6.11
CENTRL MAY	1.42	1.78	2.29	2.72	3.12	3.53	3.98	4.50	5.17	6.18	7.11
CENTRL JUN	1.84	2.22	2.74	3.17	3.57	3.97	4.41	4.90	5.53	6.48	7.34
CENTRL JUL	1.88	2.22	2.69	3.06	3.41	3.75	4.12	4.54	5.07	5.87	6.58
CENTRL AUG	1.16	1.46	1.88	2.24	2.58	2.92	3.30	3.74	4.29	5.15	5.93
CENTRL SEP	1.04	1.29	1.64	1.93	2.20	2.48	2.78	3.13	3.57	4.24	4.84
CENTRL OCT	.56	.77	1.08	1.35	1.62	1.90	2.21	2.58	3.06	3.81	4.50
CENTRL NOV	.97	1.20	1.53	1.81	2.07	2.33	2.62	2.95	3.37	4.02	4.60
CENTRL DEC	.88	1.11	1.45	1.73	2.00	2.27	2.57	2.92	3.37	4.05	4.69
CENTRL ANN	29.17	30.81	32.89	34.44	35.81	37.12	38.46	39.93	41.70	44.23	46.41

TABLE 7

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
C.HILL JAN	.66	.94	1.37	1.77	2.16	2.58	3.05	3.61	4.35	5.52	6.63
C.HILL FEB	.85	1.05	1.35	1.60	1.83	2.07	2.33	2.63	3.01	3.60	4.13
C.HILL MAR	1.26	1.56	1.98	2.32	2.65	2.98	3.34	3.76	4.29	5.10	5.84
C.HILL APR	1.59	1.89	2.29	2.62	2.92	3.22	3.54	3.91	4.37	5.07	5.69
C.HILL MAY	1.47	1.82	2.32	2.74	3.14	3.54	3.97	4.48	5.11	6.09	6.97
C.HILL JUN	1.92	2.32	2.87	3.33	3.76	4.19	4.65	5.19	5.86	6.87	7.78
C.HILL JUL	2.00	2.33	2.77	3.13	3.45	3.78	4.12	4.51	5.00	5.73	6.39
C.HILL AUG	1.52	1.83	2.27	2.63	2.97	3.31	3.68	4.09	4.62	5.42	6.13
C.HILL SEP	1.11	1.37	1.75	2.06	2.35	2.65	2.97	3.35	3.82	4.54	5.19
C.HILL OCT	.61	.83	1.16	1.45	1.74	2.04	2.37	2.76	3.27	4.06	4.79
C.HILL NOV	.95	1.18	1.50	1.77	2.03	2.28	2.56	2.88	3.29	3.91	4.47
C.HILL DEC	.74	.97	1.30	1.59	1.86	2.15	2.46	2.83	3.30	4.04	4.72
C.HILL ANN	29.90	31.43	33.36	34.80	36.06	37.26	38.49	39.84	41.46	43.78	45.76

TABLE 8

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
NE HIL JAN	.84	1.13	1.56	1.94	2.31	2.69	3.12	3.63	4.28	5.31	6.27
NE HIL FEB	.85	1.07	1.38	1.65	1.90	2.16	2.44	2.76	3.18	3.82	4.40
NE HIL MAR	1.33	1.64	2.08	2.45	2.80	3.15	3.53	3.97	4.53	5.39	6.17
NE HIL APR	1.54	1.84	2.27	2.61	2.93	3.25	3.59	3.99	4.49	5.24	5.92
NE HIL MAY	1.44	1.80	2.31	2.74	3.15	3.57	4.02	4.55	5.21	6.24	7.18
NE HIL JUN	2.24	2.57	3.01	3.36	3.68	4.00	4.34	4.72	5.18	5.88	6.49
NE HIL JUL	1.96	2.33	2.83	3.24	3.61	3.99	4.39	4.85	5.42	6.29	7.07
NE HIL AUG	1.31	1.62	2.07	2.45	2.80	3.16	3.55	4.01	4.58	5.46	6.25
NE HIL SEP	1.08	1.34	1.72	2.04	2.34	2.65	2.98	3.36	3.85	4.61	5.29
NE HIL OCT	.60	.84	1.20	1.53	1.86	2.20	2.58	3.04	3.64	4.58	5.47
NE HIL NOV	.98	1.21	1.54	1.81	2.06	2.32	2.60	2.92	3.33	3.96	4.53
NE HIL DEC	.90	1.13	1.46	1.74	2.00	2.27	2.57	2.91	3.34	4.01	4.63
NE HIL ANN	31.27	32.66	34.40	35.69	36.82	37.90	39.00	40.19	41.63	43.67	45.42

TABLE 9

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
S.WEST JAN	.70	1.02	1.55	2.03	2.52	3.05	3.64	4.36	5.32	6.85	8.30
S.WEST FEB	.80	1.07	1.47	1.82	2.15	2.51	2.90	3.36	3.95	4.89	5.75
S.WEST MAR	1.14	1.50	2.04	2.50	2.95	3.42	3.94	4.54	5.33	6.55	7.68
S.WEST APR	1.47	1.81	2.29	2.69	3.07	3.45	3.87	4.35	4.96	5.89	6.74
S.WEST MAY	1.32	1.69	2.22	2.67	3.11	3.55	4.04	4.60	5.33	6.45	7.49
S.WEST JUN	1.73	2.12	2.67	3.11	3.54	3.96	4.43	4.96	5.63	6.66	7.59
S.WEST JUL	1.52	1.87	2.37	2.79	3.18	3.58	4.01	4.51	5.15	6.11	7.00
S.WEST AUG	1.62	1.89	2.25	2.54	2.81	3.07	3.35	3.67	4.07	4.66	5.19
S.WEST SEP	1.06	1.34	1.74	2.08	2.40	2.73	3.08	3.50	4.03	4.85	5.60
S.WEST OCT	.66	.88	1.21	1.50	1.78	2.07	2.40	2.78	3.27	4.05	4.77
S.WEST NOV	.97	1.25	1.66	2.01	2.34	2.69	3.06	3.50	4.07	4.93	5.73
S.WEST DEC	1.02	1.28	1.64	1.95	2.24	2.54	2.86	3.23	3.71	4.44	5.11
S.WEST ANN	30.08	32.04	34.52	36.39	38.04	39.63	41.26	43.05	45.21	48.34	51.02

TABLE 10

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
S.EAST JAN	.87	1.17	1.63	2.03	2.42	2.83	3.29	3.83	4.53	5.63	6.65
S.EAST FEB	.91	1.15	1.51	1.81	2.09	2.38	2.70	3.07	3.55	4.28	4.95
S.EAST MAR	1.33	1.66	2.13	2.53	2.91	3.29	3.71	4.19	4.81	5.76	6.62
S.EAST APR	1.66	1.96	2.37	2.70	3.01	3.32	3.64	4.02	4.49	5.19	5.83
S.EAST MAY	1.44	1.82	2.37	2.83	3.27	3.71	4.20	4.77	5.49	6.61	7.64
S.EAST JUN	2.17	2.52	3.01	3.40	3.76	4.11	4.49	4.92	5.46	6.27	6.99
S.EAST JUL	2.59	2.89	3.29	3.60	3.88	4.16	4.45	4.77	5.16	5.74	6.26
S.EAST AUG	1.36	1.71	2.21	2.62	3.02	3.42	3.86	4.37	5.03	6.03	6.95
S.EAST SEP	1.02	1.29	1.67	2.00	2.30	2.62	2.97	3.37	3.88	4.67	5.39
S.EAST OCT	.64	.85	1.17	1.45	1.73	2.02	2.33	2.71	3.19	3.96	4.67
S.EAST NOV	1.01	1.25	1.58	1.86	2.12	2.39	2.68	3.01	3.43	4.08	4.66
S.EAST DEC	1.01	1.26	1.60	1.89	2.16	2.44	2.74	3.09	3.53	4.20	4.81
S.EAST ANN	31.10	32.77	34.86	36.43	37.81	39.12	40.47	41.95	43.72	46.26	48.44

TABLE 11

STATION	PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
S.CENT JAN	1.00	1.35	1.90	2.38	2.85	3.35	3.90	4.55	5.39	6.71	7.93
S.CENT FEB	.85	1.14	1.57	1.94	2.31	2.70	3.12	3.62	4.27	5.29	6.24
S.CENT MAR	1.59	1.97	2.51	2.96	3.38	3.81	4.28	4.82	5.51	6.55	7.50
S.CENT APR	1.62	1.95	2.41	2.79	3.14	3.49	3.87	4.31	4.86	5.69	6.45
S.CENT MAY	1.42	1.79	2.33	2.78	3.21	3.65	4.12	4.68	5.39	6.48	7.48
S.CENT JUN	2.13	2.45	2.89	3.23	3.55	3.86	4.20	4.57	5.04	5.73	6.35
S.CENT JUL	1.99	2.39	2.93	3.37	3.79	4.20	4.64	5.15	5.79	6.76	7.64
S.CENT AUG	1.64	1.96	2.40	2.75	3.08	3.41	3.77	4.17	4.68	5.46	6.15
S.CENT SEP	1.35	1.61	1.97	2.27	2.54	2.81	3.11	3.44	3.86	4.50	5.07
S.CENT OCT	.59	.79	1.10	1.37	1.64	1.91	2.22	2.58	3.05	3.78	4.47
S.CENT NOV	.99	1.24	1.61	1.92	2.21	2.51	2.84	3.22	3.70	4.45	5.13
S.CENT DEC	1.08	1.35	1.74	2.06	2.37	2.69	3.03	3.42	3.93	4.70	5.40
S.CENT ANN	32.05	33.90	36.24	38.00	39.54	41.02	42.54	44.21	46.21	49.09	51.56

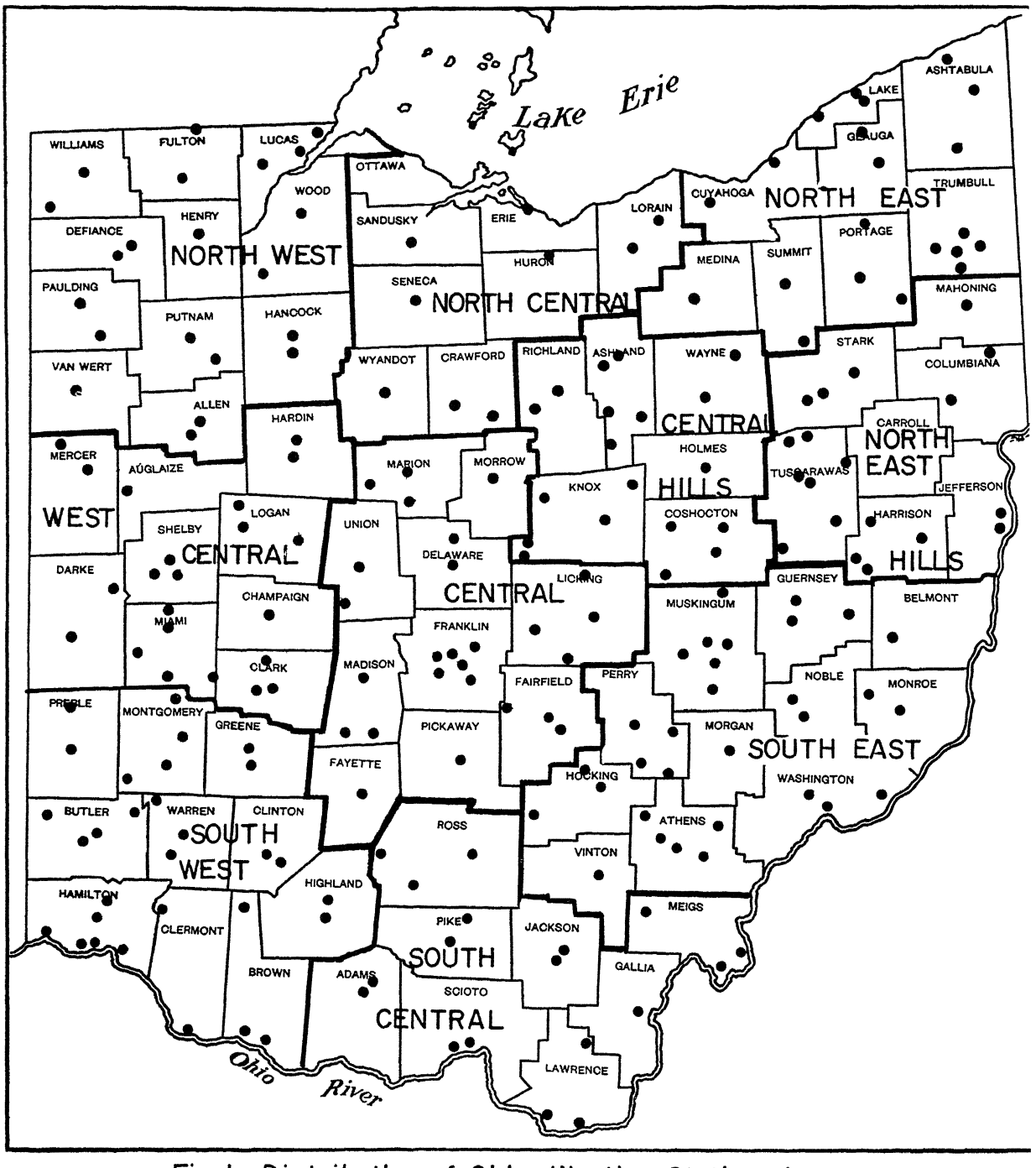

Fig. 1 Distribution of Ohio Weather Stations in 1960.

Fig. 2 Distribution of Ohio Weather Stations in 1930.

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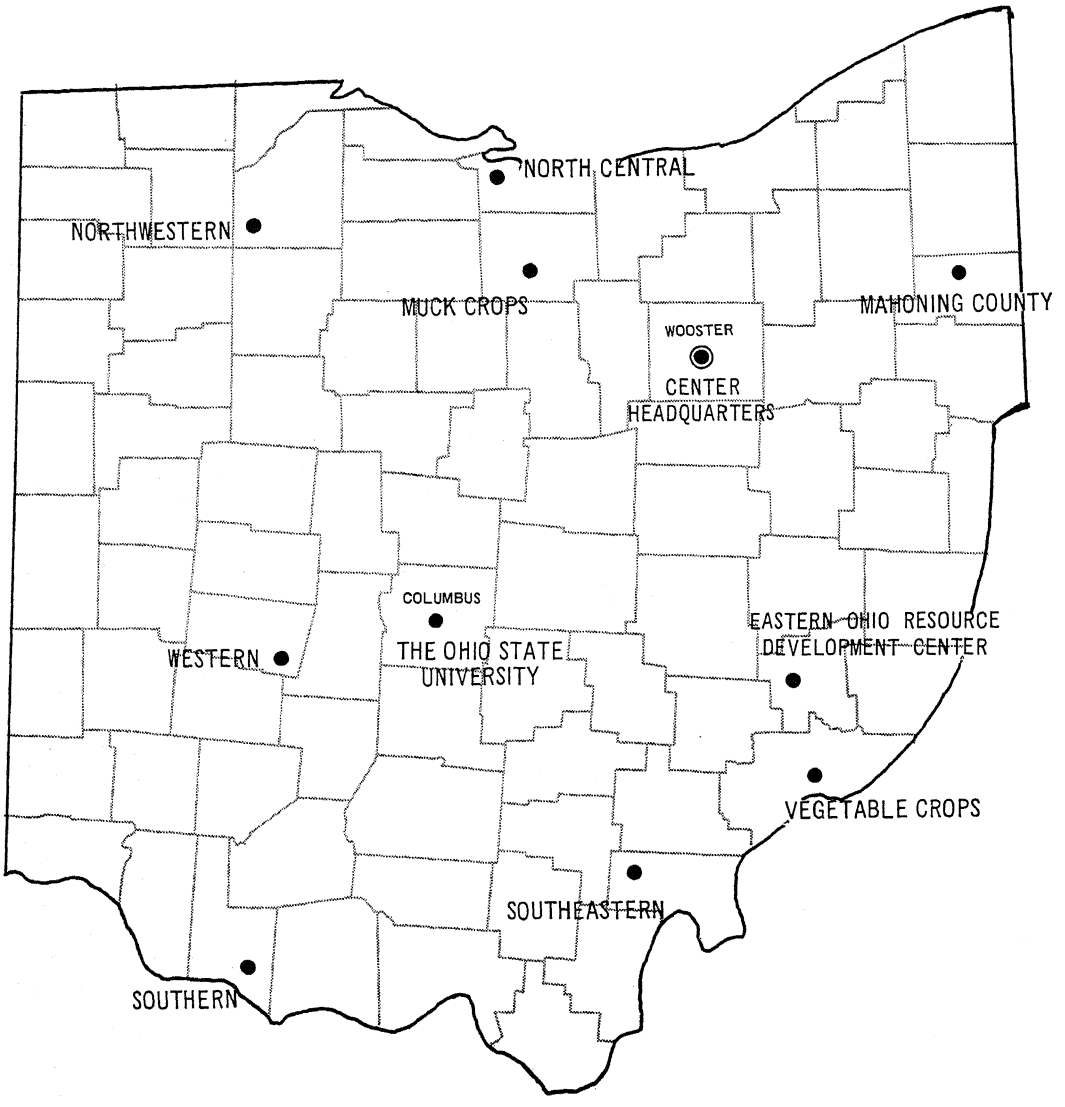

Ohio's major soil types and climatic conditions are represented at the Research Center's 11 locations. Thus, Center scientists can make field tests under conditions similar to those encountered by Ohio farmers.

Research is conducted by 13 departments on more than 6000 acres at Center headquarters in Wooster, nine branches, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1918 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Mahoning County Experiment Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Central Branch, Vickery, Erie County: 335 acres

Northwestern Branch, Hoytville, Wood County: 247 acres

Southeastern Branch, Carpenter, Meigs County: 330 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Marietta, Washington County: 20 acres

Western Branch, South Charleston, Clark County: 428 acres