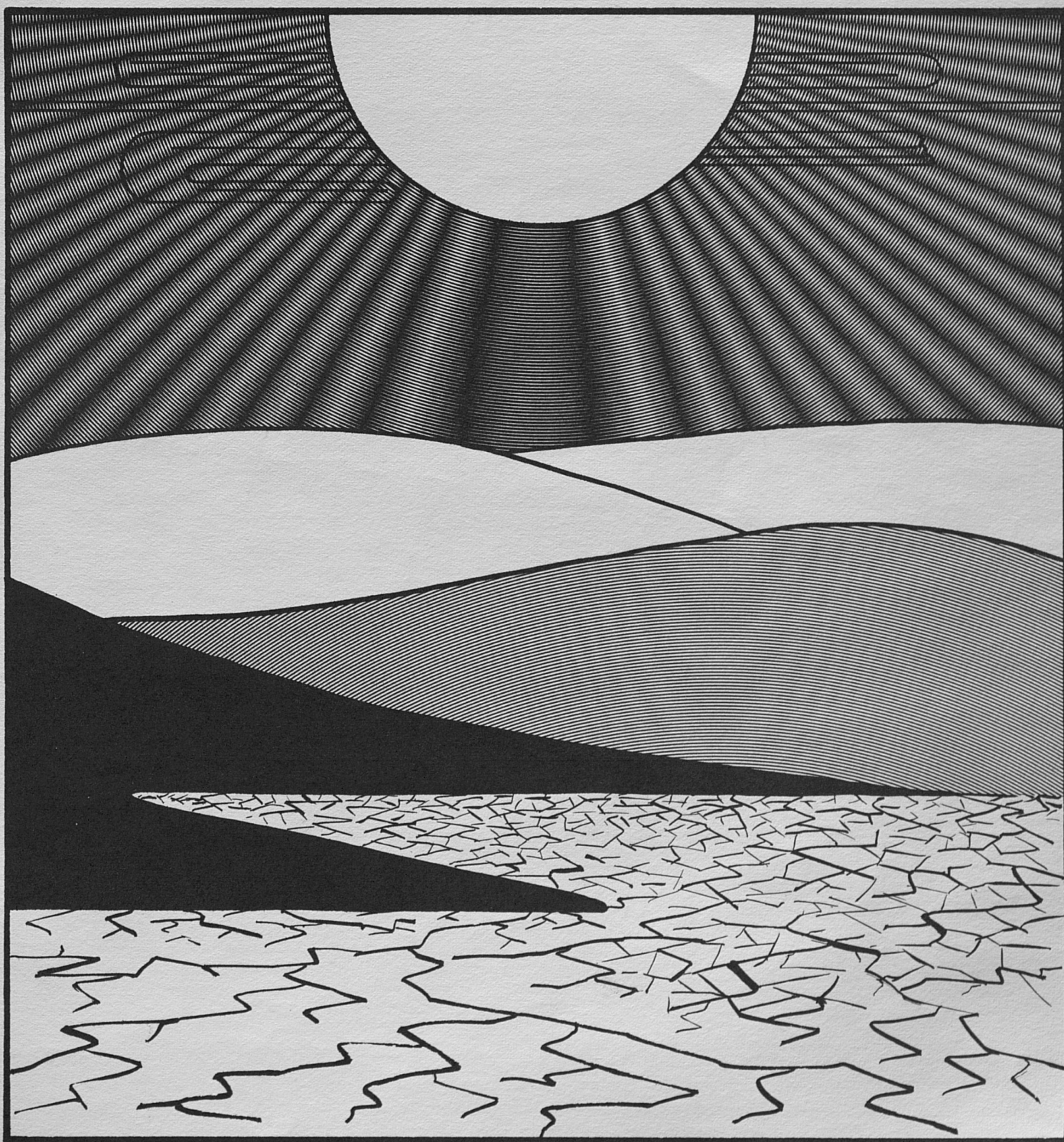
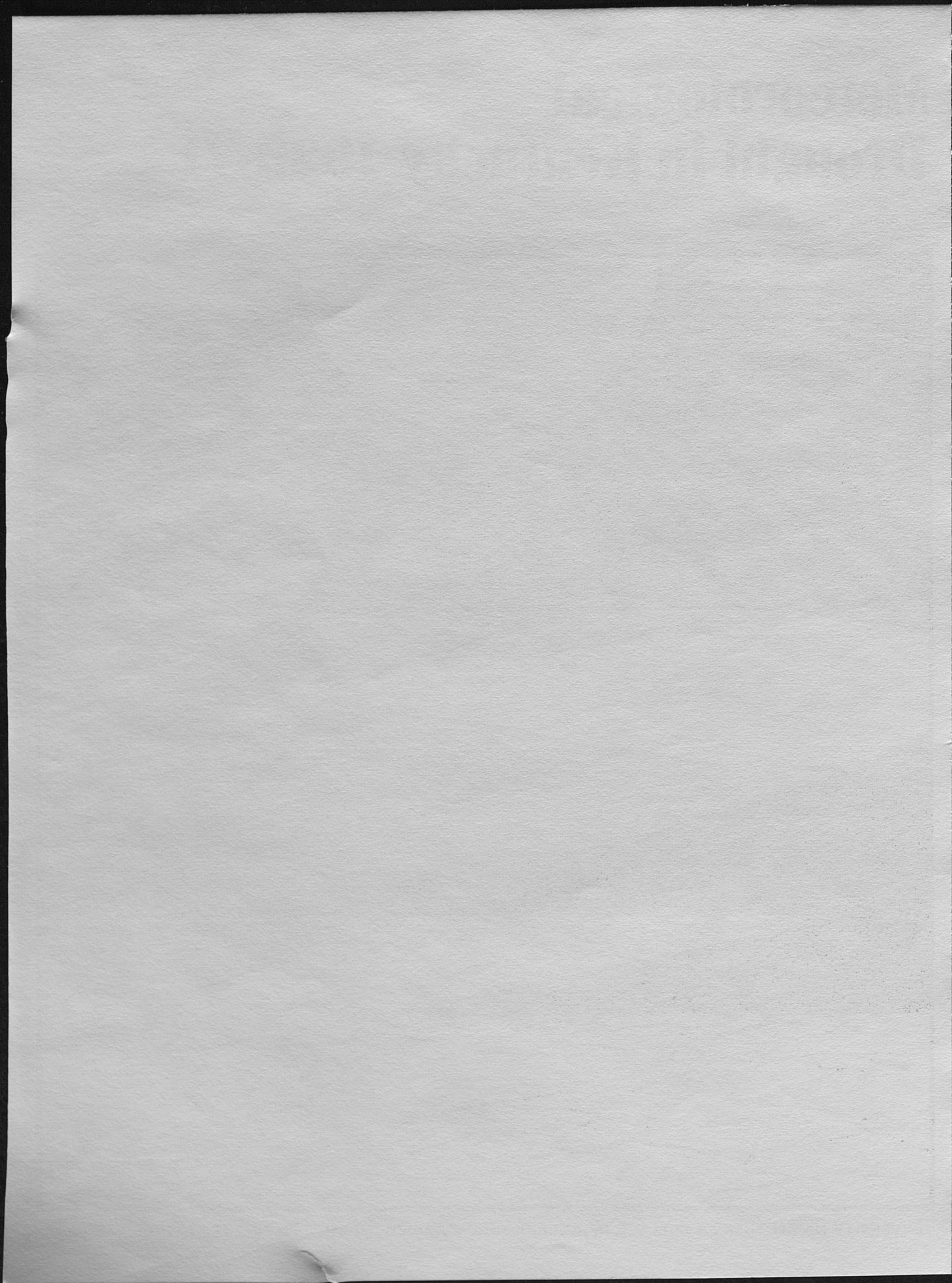


# Meteorological Drought in Kentucky 1929-71

PROGRESS REPORT 209

by Allen B. Elam, Jr.





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#### ABSTRACT

The need for an objective procedure in the evaluation of drought is considered, followed by a discussion of the Palmer Drought Index, major Kentucky droughts, the occurrence of severe and extreme drought, and the need for further studies. Palmer Drought Index values for the years 1929-71 are listed and graphed for each of Kentucky's four climatic divisions. Additional figures document for each division the percentage occurrence by month of severe and extreme drought; summarize percentage occurrence of four drought categories.

# Meteorological Drought in Kentucky, 1929-71

By ALLEN B. ELAM, JR.<sup>1</sup>

A survey of the resources of an area necessarily includes a study of the occurrence of drought. Drought vitally affects the welfare of everyone, and it is of special interest to the farmer, agronomist, horticulturist, hydrologist, and economist as well as to the meteorologist and climatologist. Drought over a period of 43 years in Kentucky intermittently caused drastic reductions in farm productivity and stream flow. One purpose of this study is to point out that drought has to be reckoned with. Such an awareness will assist planners in managing water resources, in establishing contingency plans for periods of droughts, and in channeling community and/or industrial growth to those areas having the water resources potential capable of sustaining further growth and having sufficient water even in time of drought. As stated in a recent publication (1), "Kentucky water resources as a whole are far greater than demands for any predictable time in the future, but there are places within the State which suffer water shortages. . . . "If a series of historical (low) streamflows are repeated, these cities (listed) will have inadequate supplies to meet existing and/or projected demands."

Drought has been and may be studied from many points of view, depending on the interest involved and/or the definition of drought considered. There have been many definitions of drought, but it can be considered a strictly meteorological phenomenon—a prolonged and abnormal moisture deficiency. This report is a study of drought conditions in Kentucky in terms of the Palmer Drought Index. The Index was developed by Wayne C. Palmer of NOAA's Environmental Data Service Research Laboratory. It provides an index number which indicates not only the drought severity but also the unusualness of extended periods of excessive moisture supply.

## DROUGHT FACTORS AND PROCEDURE

The Palmer Drought Index treats drought severity as a function of accumulated, weighted differences between the actual rainfall and the computed moisture requirement. It considers not only existing moisture conditions but also preceding moisture conditions. The underlying concept of the Index is that the amount of precipitation required (computed) for a no-drought or near-normal condition for a specified area and period is dependent on the average climate of the area and on the prevailing meteorological conditions both during and preceding the month in question. More specifically, the computed precipitation requirement depends on the carryover of previous rainfall as well as the evaporation, moisture recharge and runoff which would be climatically appropriate for the particular time and place being investigated.

Thus the "average" requirement is for normal rainfall, but individual periods may require much above or even less than normal rainfall to prevent drought, depending on the character of the preceding weather and the temperature of the period in question (2,3,4).

The procedure consists of a monthly water balance accounting (2,4) computed at NOAA's National Climatic Center. The basic input data were the average monthly precipitation and temperature values, 1929-71, for the climatic divisions shown in Fig. 6; the divisions are those for which current climatic data for Kentucky are published each month (5). The results of the analysis are in terms of monthly index numbers which range from extremely wet through normal conditions to extreme drought.

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Palmer's index was designed to evaluate the scope, severity, and frequency of prolonged periods of abnormally dry weather by considering all aspects of an area's water needs, including streamflow and water storage. However, since a modest shower will often help crops but do little toward refilling a reservoir, he developed a second standard, the Crop Moisture Index. This index responds rapidly to the occurrence or non-occurrence of rain and considers only the weekly moisture used by crops as compared to the amount required for normal crop growth. The NOAA Environmental Data Service began publishing Crop Moisture Index in the national Weekly Weather and Crop Bulletin in the April 15, 1968 issue (14).

### THE PALMER DROUGHT INDEX (PDI) VALUES

The Index values computed for Kentucky are listed in Tables 1-4 and are graphed on facing pages in Fig. 1-4.

The following descriptive names are those assigned by Fieldhouse and Palmer to the various ranges of the index values (2). Since normal weather produces an index of zero, all the descriptions are to be interpreted with respect to normal; e.g., "moderately wet" means moderately wetter than normal, etc.

#### INDEX VALUES FOR CLASSES OF WET AND DRY PERIODS, PALMER DROUGHT INDEX (PDI)

<u>Monthly Index Value</u>	<u>Character of Recent Weather</u>
$\geq$ 4.00	extremely wet
3.00 to 3.99	very wet
2.00 to 2.99	moderately wet
1.00 to 1.99	slightly wet
0.50 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.50 to -0.99	incipient drought
-1.00 to -1.99	mild drought
-2.00 to -2.99	moderate drought
-3.00 to -3.99	severe drought
$\leq$ -4.00	extreme drought

The monthly index values make possible the comparison of the moisture conditions at a particular time and place with the average moisture conditions at that place and provide a basis for comparison with other areas for the same or other periods. The index provides a measure of the character of the dry spells (or wet spells) themselves but does not directly measure the effects of the dry weather. This is a subject for further study by those who may wish to correlate the index numbers with general crop conditions; with water supplies in streams, lakes and reservoirs; with forest fire danger; or with various economic disruptions caused by abnormal moisture conditions. The values that seem most useful for preparing drought maps and water resource planning are the figures corresponding to moderate, severe and extreme drought (2).

Rough rule-of-thumb comments follow. Incipient drought corresponds to a dry spell of a couple of weeks' duration in which the need for rain becomes apparent. Extreme drought, however, is a very serious situation which results from many months, or even years, of weather which is rather consistently drier than normal. During extreme drought, nearly all established enterprises suffer from a water shortage: agricultural crops are a complete failure, economically; and municipalities and industries may face the need for rationing water. Thus, extreme drought is essentially a disaster (6).

## MAJOR KENTUCKY DROUGHTS, 1929-71

A comparison of PDI values with comments published during some major recognized droughts in Kentucky and the Ohio Valley region is instructive. Figure 1 and Table 1 for the Western Climatic Division indicate a total of 13 months of extreme drought during the 18-month period July 1930-December 1931. Some of the highest temperatures of Kentucky record occurred in 1930. Table 1 indicates the maximum or peak severity reached—5.84 in February 1931.

The peak drought severity for the Blue Grass Climatic Division for the period 1929-71 was -6.98, in January 1931 (Table 3) following the very dry year 1930. As a matter of interest, the data available indicate that 1930 was the driest year of record in the Louisville area (Central Climatic Division) 1841-1971; and in the Lexington area (Blue Grass Climatic Division), 1858-1971. It has been stated that, "The great drought of 1930 was the most severe and prolonged dry spell ever known in Kentucky . . . . Surface water supplies were greatly depleted and in many places no streamflow was visible. Pasture lands were badly affected and many cattle were sold at a sacrifice. Water use and consumption were restricted in many towns and cities; some smaller communities were forced to haul or ship water from other sections" (7). Figures 1-4 show that all Kentucky climatic divisions also experienced extreme drought (PDI value minus 4.00 and below) during this period. This drought came to an abrupt end in August 1931 in the west, in October 1931 in the Blue Grass Climatic Division, and in December 1931 in the Central Climatic Division. In the Eastern Climatic Division the severity decreased in the latter part of 1931 but persisted as mild-to-moderate drought throughout the greater part of 1932, ending in October 1932.

Figures 1-4 and Tables 1-4 indicate several months of moderate-to-extreme drought in all climatic divisions in 1936 when some of the highest temperatures on record occurred. Figures 1-4 also reveal a number of months of PDI values indicating severe and/or extreme drought in all climatic divisions for the periods 1941-42 and 1953-54. It was stated (7) that, "The severe dry spell during the late summer and fall of 1953 produced unusually low flows on most Kentucky streams. Generally throughout the State, streamflow minimums were as low, or lower than minimum flows of record for the preceding 15 or 20 years. In some sections the effect on streamflow approached the proportion of the outstanding drought of 1930."

Tree kill associated with the drought of the 1950s was extensive in Kentucky, especially in the Dawson Springs area of western Kentucky (Western Climatic Division) where the kill extended to vigorously growing stands (8). Table 1 and Fig. 1 show that some degree of drought in the Western Climatic Division lasted 5 years, 1952-57, the longest of record (1929-71) for any climatic division in Kentucky.

During 1963-64 several months of severe and/or extreme drought occurred in the Western Climatic Division. However, that period produced only one month of severe drought in the Blue Grass Climatic Division and no severe or extreme drought in the Central and Eastern Climatic Divisions. It was stated (7) that, ". . . this severe dry spell started in September 1963 and continued for 6 months through February 1964, . . . finally relieved by the storms and floods of early March. The effect on water conditions, however, was most evident during October and early November, 1963, when surface and ground water receded to low levels . . . Drought conditions prevailed throughout the State but were most severe in Western Kentucky. In some areas of the State reported conditions were the driest ever known but Statewide water conditions in the 1963 drought were not as critical as those of the 1930 and 1953 droughts."

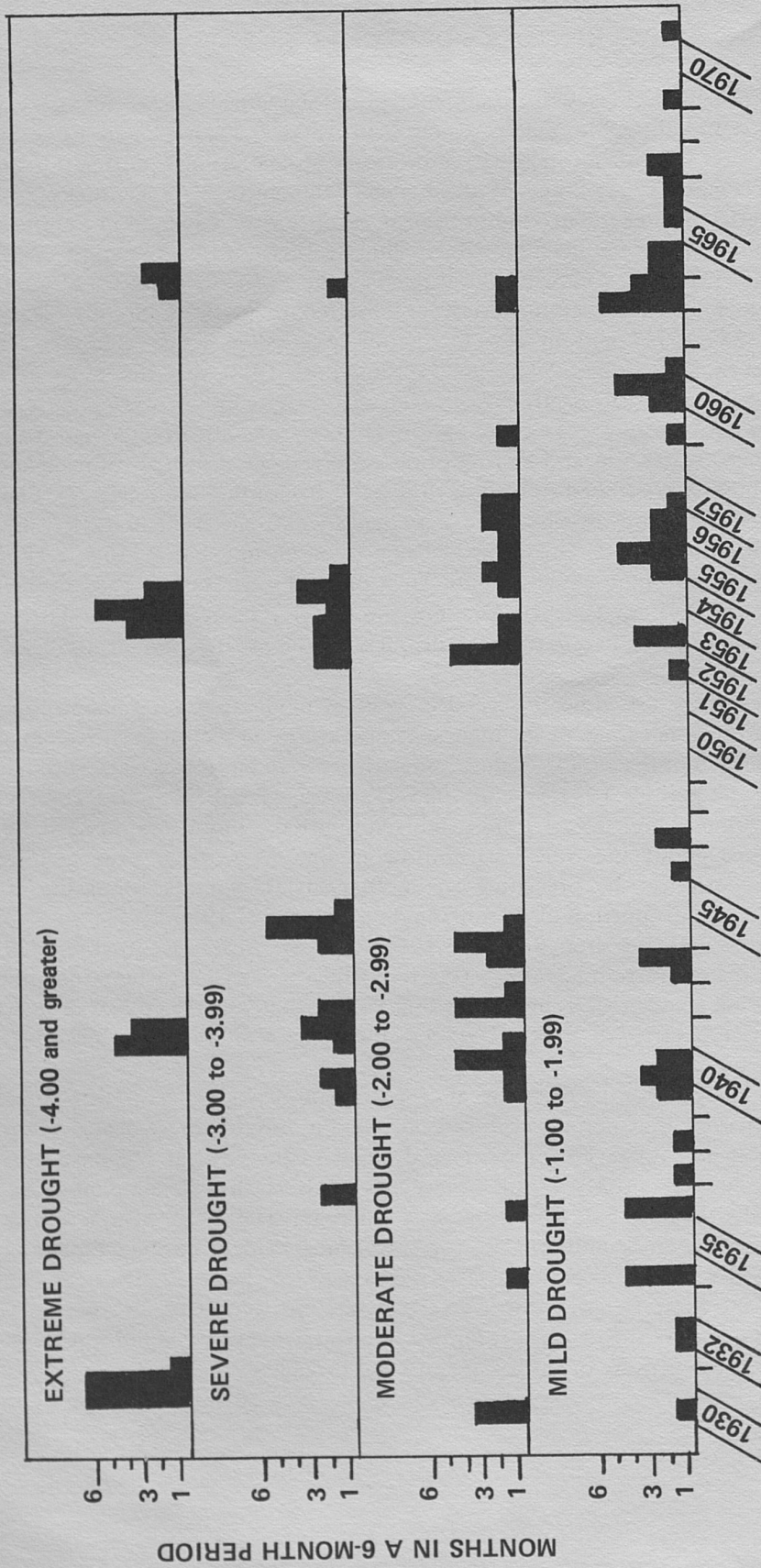


Fig. 1.—Number of drought months in each 6-month period, 1929-71, Western Climatic Division, Kentucky.

(This figure indicates continuous drought from early in 1952 through early 1957. In 1952 there was one month of mild drought in the January-June, 6-month, period; in the July-December, 6-month, period of 1952 there were 4 months of moderate drought and 2 months of severe drought. See Table 1 on the facing page for specific months.)



Table 1.—Palmer Drought Index Values (PDI) by Month, 1929-71, Western Climatic Division, Kentucky.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1929	.14	.37	-.74	-.82	1.27	1.39	1.04	1.10	2.01	2.11	2.02	2.00
1930	2.59	-.16	-1.11	-2.12	-2.52	-2.82	-4.01	-4.51	-4.23	-4.20	-4.69	-5.39
1931	-5.72	-5.84	-5.56	-5.00	-4.79	-4.59	-4.55	.75	.29	.14	.13	.54
1932	1.54	1.20	1.19	1.13	-.99	-1.10	-1.17	.28	1.06	1.65	1.45	2.39
1933	2.06	2.22	2.59	2.89	3.31	2.05	2.87	2.27	2.58	2.55	-.49	-.26
1934	-1.05	-1.15	-1.06	-1.55	-2.11	.36	.23	.67	2.14	1.57	1.56	1.46
1935	1.51	.80	2.58	2.60	3.08	4.66	4.38	-.05	-.31	-.16	-.32	-.65
1936	-1.20	-1.50	-1.53	-.91	-1.73	-2.61	-3.16	-3.96	-.01	.18	.09	.28
1937	3.27	-.49	-1.46	1.00	-.56	-.40	-.34	-.63	-.79	1.07	-.28	-.18
1938	-.39	-.76	-.20	-1.01	.37	.47	2.26	2.66	2.61	1.90	1.65	1.08
1939	1.34	2.70	2.44	3.29	-.67	-.52	-.55	-.67	-1.67	-1.99	-2.60	-3.22
1940	-3.56	-3.09	-2.83	-1.80	-1.72	-1.64	-1.90	-1.85	-2.25	-2.90	-2.66	-2.66
1941	-2.92	-3.42	-4.14	-4.62	-5.22	-5.27	-4.58	-4.25	-4.88	-3.63	-3.62	-3.78
1942	-3.61	-3.33	-2.01	-2.74	-2.69	-2.54	-2.65	.86	.72	.82	.93	.97
1943	-.86	-1.52	.89	.63	1.00	-.31	-.85	-1.71	-1.26	-1.57	-2.17	-2.86
1944	-3.50	-3.24	-2.91	-2.18	-2.39	-2.96	-3.62	-3.30	-2.95	-3.43	-3.59	-3.33
1945	-3.25	.81	1.44	1.68	1.93	2.72	2.32	2.02	2.48	2.37	2.52	2.23
1946	1.98	2.54	-.63	-1.40	.72	.14	.07	.69	.31	.18	.41	.43
1947	.46	-1.00	-1.44	.83	1.30	1.42	-.07	-.20	.06	.18	-.09	-.56
1948	-.96	.15	.70	.19	.19	.10	1.72	.17	.25	.35	1.84	2.51
1949	3.01	3.48	3.66	2.72	1.97	2.33	1.82	2.33	2.11	3.37	2.70	3.37
1950	4.80	5.30	4.71	4.35	4.34	4.55	5.24	6.56	6.91	6.04	6.31	5.67
1951	5.90	5.43	4.75	4.19	2.78	3.43	2.86	2.25	2.64	2.10	2.96	4.21
1952	3.77	3.73	3.65	-.33	-.68	-1.81	-2.63	-2.95	-2.57	-2.73	-3.15	-3.11
1953	-3.03	-3.20	-2.28	-1.83	-1.24	-1.87	-2.22	-3.08	-3.85	-4.16	-4.70	-5.09
1954	-4.57	-4.41	-4.81	-4.61	-4.01	-3.97	-4.32	-4.17	-3.50	-2.96	-3.61	-3.08
1955	-3.49	-2.47	-2.15	-1.62	-1.24	-.68	-.93	-1.24	-1.24	-1.17	-1.42	-2.21
1956	-2.15	-.79	-1.28	-.83	-.75	-1.14	-.89	-.95	-1.56	-1.93	-2.22	-2.60
1957	-2.02	-1.66	-2.31	.40	1.92	2.20	2.45	2.14	1.56	1.90	4.62	5.36
1958	4.43	3.44	3.29	2.89	2.66	2.63	3.87	3.52	3.31	-.38	-.27	-.85
1959	-.61	-.62	-1.47	-2.19	.13	-.20	.37	1.30	1.52	2.02	1.95	2.16
1960	-.42	-.57	-.84	-1.27	-1.21	.69	-.23	-.61	-1.08	-1.31	-1.30	-1.25
1961	-1.70	.53	.83	1.75	2.70	3.00	3.16	3.03	2.21	1.79	2.17	2.63
1962	2.45	3.31	2.99	2.30	1.57	1.81	1.42	1.41	2.78	2.97	-.22	-.30
1963	-1.02	-1.68	-1.03	-1.73	-1.90	-2.10	-1.80	-1.18	-1.85	-2.87	-3.32	-4.17
1964	-4.49	-4.79	2.92	-.33	-1.05	-1.63	-1.86	-1.84	1.02	.40	.15	.60
1965	.38	.70	1.38	-.14	-.97	-.77	-.42	-.89	1.50	.00	.43	-1.22
1966	.46	.59	-1.30	1.55	2.12	-.48	-1.15	-.97	-.48	-.44	-.73	-.18
1967	-.81	-.99	-1.55	-1.96	1.04	1.22	2.42	2.60	2.62	3.04	3.18	3.90
1968	2.95	2.09	2.17	2.27	2.83	2.21	2.13	1.60	1.76	1.28	1.36	1.64
1969	2.11	-.51	-1.02	-.45	-.95	1.16	1.13	1.33	.86	1.28	1.53	2.20
1970	1.18	1.10	1.20	2.08	1.40	1.96	1.34	1.22	.89	2.24	1.91	2.32
1971	1.79	2.32	-.87	-1.49	.15	.14	.70	1.22	1.67	#-.17	#-.54	#-.54

# Preliminary

LEGEND\*

4.00 : extremely wet		-1.00 : mild drought
3.00 : very wet	0.50 : incipient wet spell	-2.00 : moderate drought
2.00 : moderately wet	.00 : near normal	-3.00 : severe drought
1.00 : slightly wet	-0.50 : incipient drought	-4.00 : extreme drought

\*Note: In each instance the qualitative description is to be interpreted in comparison to normal, e.g. above 4.00 = extremely wet as compared to normal.

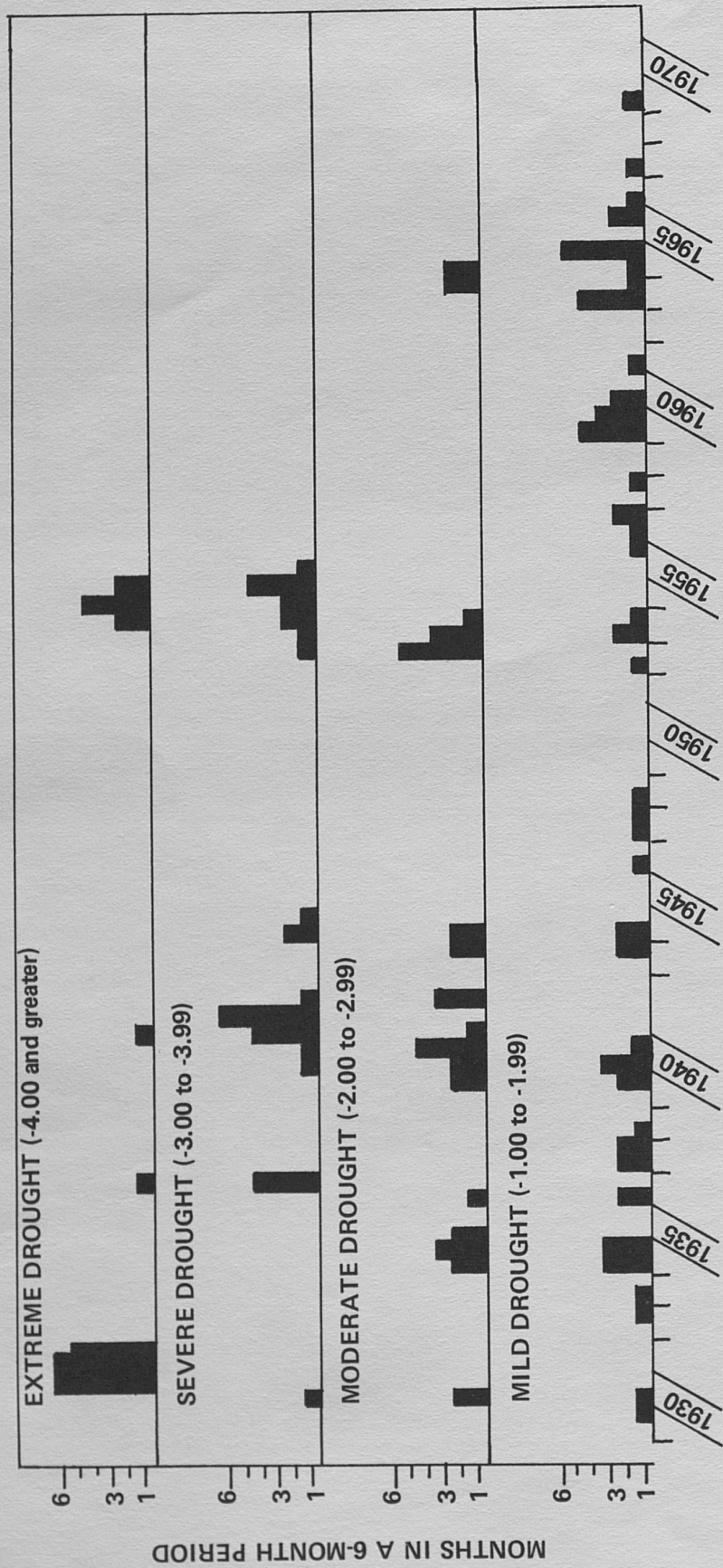


Fig. 2.—Number of drought months in each 6-month period, 1929-71, Central Climatic Division, Kentucky.

Table 2.—Palmer Drought Index Values (PDI) by Month, 1929-71, Central Climatic Division, Kentucky.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1929	-.05	.05	-.72	-.80	1.29	-.07	-.52	-1.25	.09	1.01	1.18	1.24
1930	1.40	-.08	-1.11	-2.25	-2.55	-3.05	-4.18	-4.85	-4.89	-5.08	-5.39	-6.03
1931	-6.37	-6.38	-6.11	-5.40	-5.34	-5.39	-5.68	-4.86	-4.74	-4.61	-4.01	.32
1932	1.23	.78	.87	1.07	-.93	-.98	-1.26	.11	.20	.72	.26	.55
1933	.50	.64	.85	1.33	1.71	-1.02	.71	.89	1.58	1.54	1.02	1.52
1934	-.74	-1.09	-1.22	-1.97	-2.49	-2.40	-2.46	-1.75	-1.06	-1.56	-2.01	-2.61
1935	-2.09	-2.28	1.21	1.46	2.58	3.49	3.61	3.47	3.13	2.80	2.77	-.09
1936	-.58	-.93	-1.08	.53	-1.08	-2.75	-3.27	-4.23	-3.84	-3.31	-3.22	.09
1937	3.49	-.54	-1.52	-1.25	-.97	-.79	-1.04	-.99	-1.03	.90	-.17	-.04
1938	-.26	-.75	-.22	-1.00	.49	.39	1.50	2.25	2.98	2.13	2.16	1.61
1939	1.68	2.60	2.63	3.32	-.84	.58	.78	-.29	-1.29	-1.45	-2.17	-2.93
1940	-3.42	-2.87	-2.15	-1.28	-1.21	-1.62	-1.98	-2.16	-2.41	-3.04	-2.60	-2.52
1941	-2.82	-3.33	-3.95	-3.88	-4.45	-3.89	-3.32	-3.07	-3.81	-3.12	-3.08	-3.10
1942	-3.08	-2.94	-2.87	-2.88	.05	.47	.12	1.17	1.30	1.85	2.26	2.97
1943	1.83	1.04	2.36	2.25	2.52	-.12	-.24	-1.19	-.93	-1.27	-2.00	-2.66
1944	-3.27	-3.02	-2.35	-1.66	-1.80	-2.71	-3.37	.84	1.57	.97	.43	.25
1945	.01	.80	1.01	.81	1.01	1.41	-.10	-.46	-.73	-.74	-.28	-.40
1946	-.64	.63	-.22	-1.11	.71	.42	.93	1.37	1.33	1.08	1.09	1.09
1947	1.20	-.91	-1.37	.61	1.73	1.80	2.04	-.03	-.27	-.48	-.62	-1.18
1948	-1.42	.59	1.08	1.26	-.28	-.63	-.12	-.36	-.71	.20	1.60	1.90
1949	2.08	2.51	2.43	2.16	1.39	2.27	2.01	2.48	1.76	2.43	1.83	2.81
1950	4.48	4.56	3.70	3.27	4.01	4.64	5.29	5.57	6.20	5.44	5.82	5.24
1951	5.48	4.99	4.71	4.11	3.12	3.00	2.44	2.23	2.63	2.35	3.30	4.80
1952	4.30	3.45	3.98	-.76	-.95	-1.54	-2.28	-2.64	-2.71	-2.58	-2.86	-3.03
1953	-2.92	-3.21	-2.70	-2.17	-1.49	-1.84	-1.73	-2.39	-3.05	-3.70	-4.23	-4.81
1954	-4.20	-4.22	-4.72	-4.31	-3.99	-3.94	-4.37	-4.02	-3.41	-3.01	-3.33	-3.02
1955	-3.46	1.40	1.78	1.14	1.20	1.52	-.18	-.73	-.60	-.23	-.40	-1.10
1956	-1.07	1.49	1.26	1.37	-.20	-.48	.52	.52	-.48	-.70	-1.11	-1.07
1957	.29	.33	-.81	.41	.82	1.39	-.31	-1.09	.50	.89	2.59	3.25
1958	2.51	1.77	1.15	1.55	1.40	1.56	2.95	3.10	3.19	2.85	2.75	-.50
1959	-.36	-.45	-1.14	-1.65	-1.30	-1.59	-1.22	-1.01	-1.55	.87	1.23	1.66
1960	-.53	-.22	-.41	-1.43	-1.49	1.17	-.45	-.72	-.51	-.81	-.70	-.74
1961	-1.32	.25	.53	1.21	2.33	2.72	3.08	3.11	2.22	1.83	1.88	2.41
1962	2.17	3.28	2.97	2.36	1.76	1.81	1.51	.89	1.70	2.62	2.47	.04
1963	-.83	-1.21	.76	-1.00	-1.35	-1.45	.98	1.04	-.51	-1.65	-2.01	-2.84
1964	-2.98	-2.99	2.08	-.18	-.70	-1.32	-1.12	-1.25	-.65	-1.19	-1.17	.80
1965	.43	.66	1.14	-.27	-.79	-.82	-.42	-1.06	.92	1.23	-.36	-1.27
1966	-.95	-.62	-1.76	1.18	1.12	-.56	-.55	.59	.76	.86	1.07	1.76
1967	-.80	-1.05	.10	.14	1.26	1.23	2.99	3.49	3.36	3.41	3.72	3.93
1968	2.85	1.75	2.00	2.39	3.48	-.42	-.41	-.69	-.72	-.85	-.73	-.80
1969	-.68	-.99	-1.57	.35	.28	.89	.51	.90	.31	.21	.19	.85
1970	-.79	-.54	-.72	1.72	1.01	1.33	1.47	1.91	2.62	3.55	3.31	3.62
1971	2.87	3.05	1.90	1.30	1.87	1.73	2.85	2.78	2.70	#1.90	#1.32	#1.16

# Preliminary

LEGEND\*

4.00 : extremely wet		-1.00 : mild drought
3.00 : very wet	0.50 : incipient wet spell	-2.00 : moderate drought
2.00 : moderately wet	.00 : near normal	-3.00 : severe drought
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\*Note: In each instance the qualitative description is to be interpreted in comparison to normal, e.g. above 4.00 = extremely wet as compared to normal.

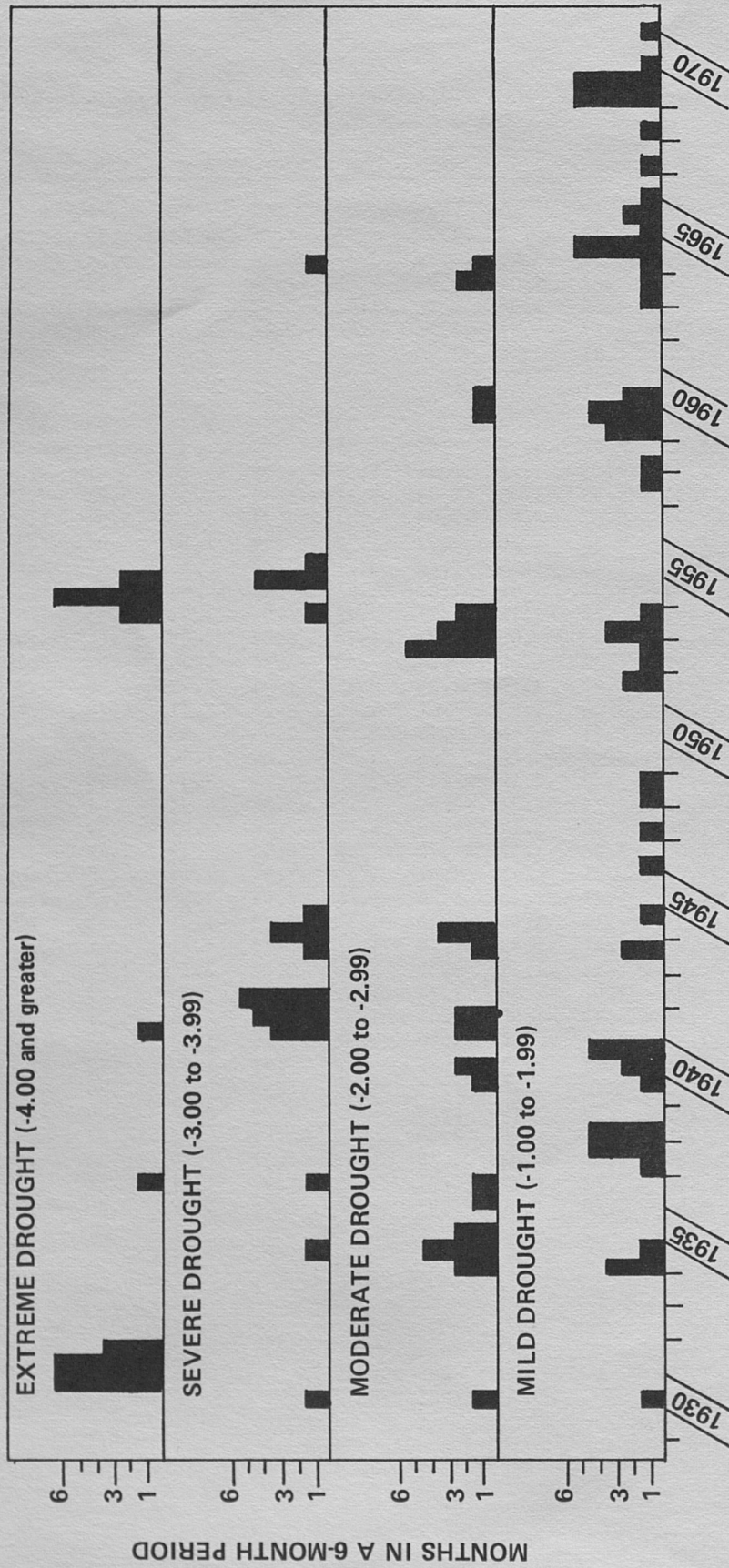


Fig. 3.—Number of drought months in each 6-month period, 1929-71, Blue Grass Climatic Division, Kentucky.

Table 3.—Palmer Drought Index Values (PDI) by Month, 1929-71, Blue Grass Climatic Division, Kentucky.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1929	-.04	-.07	-.61	-.96	1.31	.00	.03	-.66	.86	1.65	2.14	-.01
1930	-.09	-.22	-.99	-1.94	-2.39	-3.19	-4.56	-4.98	-4.98	-5.16	-5.79	-6.54
1931	-6.98	-6.96	-6.74	-5.73	-5.66	-5.75	-5.45	-4.54	-4.53	.37	-.39	.43
1932	1.24	.87	1.18	1.16	.16	.20	.30	.74	.89	1.42	1.43	1.69
1933	1.87	1.86	1.98	2.19	2.55	1.47	1.63	1.31	2.27	2.12	1.51	1.95
1934	-.71	-1.13	-1.02	-1.74	-2.64	-2.82	-2.84	-2.37	-1.60	-2.25	-2.75	-3.27
1935	-2.78	-2.86	1.17	1.24	2.70	3.56	3.75	4.20	4.24	4.11	4.43	4.19
1936	-.22	-.63	-.74	-.03	-.79	-2.27	-2.98	-4.12	-3.94	.41	.14	.17
1937	2.99	-.25	-1.19	-.67	-.78	-.65	-1.09	-.89	-1.48	-.78	-1.23	-1.40
1938	-1.64	-1.90	-1.57	-1.88	.71	.58	1.44	1.67	1.61	-.85	-.64	-.93
1939	.21	1.45	1.73	2.59	1.48	2.20	2.30	-.09	-.78	-.67	-1.36	-2.07
1940	-2.70	-2.13	-1.52	-1.11	-.61	-.76	-1.21	-.89	-.92	-1.74	-1.72	-1.89
1941	-2.17	-2.75	-3.34	-3.68	-4.31	-3.68	-3.30	-3.37	-3.95	-2.89	-2.83	-3.00
1942	-3.17	-3.10	-3.07	-3.23	-3.09	.68	1.31	2.90	3.01	3.25	4.14	5.17
1943	4.01	3.11	3.94	3.75	3.98	3.50	3.38	-.92	-1.07	-1.37	-2.31	-3.18
1944	-3.73	-3.69	-2.88	-2.23	-2.40	-3.24	-3.94	.72	.95	-.33	-.92	-1.08
1945	-.99	1.01	1.37	1.30	1.73	1.80	-.05	-.47	-.88	-.86	-.18	-.18
1946	-.59	-.12	-.31	-1.14	.72	1.24	1.29	1.79	1.77	1.75	1.48	1.41
1947	1.66	-.79	-1.35	.23	.93	1.06	1.07	.98	1.20	-.33	-.34	-.82
1948	-1.06	.52	.84	1.89	-.05	-.22	-.14	-.60	-1.21	.19	1.05	1.57
1949	1.81	2.10	.04	-.06	-.43	-.19	-.49	-.05	-.35	-.29	-.66	.60
1950	2.70	2.73	2.14	1.77	2.21	2.99	3.81	3.61	4.38	3.90	4.79	4.25
1951	4.71	4.57	4.24	-.29	-.54	-.89	-1.74	-1.96	.25	-.23	1.03	2.46
1952	2.43	1.90	2.38	-.52	-.54	-1.05	-1.76	-2.08	-2.24	-2.25	-2.40	-2.39
1953	-2.23	-2.66	-2.31	-1.94	-1.58	-1.76	-1.83	-2.40	-2.93	-3.55	-4.26	-4.89
1954	-4.69	-4.96	-5.08	-4.99	-4.81	-4.95	-5.22	-4.37	-3.67	-3.34	-3.52	-3.31
1955	-3.57	1.25	1.97	1.14	1.19	1.22	1.60	1.02	1.10	1.57	1.70	1.22
1956	.83	2.30	2.44	2.47	2.22	2.30	2.90	2.61	2.86	2.40	2.11	2.47
1957	2.22	2.03	.97	1.75	1.86	1.81	-.49	-1.17	.41	.65	1.55	2.37
1958	-.50	-.84	-1.31	.44	.73	1.07	2.32	2.50	2.61	2.23	2.26	-.41
1959	-.14	-.36	-.99	-1.34	-1.56	-1.93	-1.70	-1.75	-2.53	-1.53	-1.07	-.79
1960	-1.13	-.63	-1.19	-2.17	-.03	1.35	1.12	1.11	1.18	1.20	.01	-.24
1961	-.77	.05	.25	1.12	2.28	2.48	3.11	2.92	2.12	1.49	1.34	1.49
1962	1.23	2.09	2.00	1.42	1.49	1.25	1.58	.90	1.25	1.88	2.07	1.95
1963	-.80	-1.24	1.02	-.88	-.61	-.79	.68	.76	-.49	-1.52	-2.11	-2.98
1964	-3.11	-2.96	2.57	.02	-.77	-1.01	-1.08	-1.54	-1.26	-1.70	-1.97	.43
1965	.09	.16	.57	.75	-.98	-1.60	-1.40	-1.70	1.49	2.18	-.25	-.95
1966	-.70	-.51	-1.60	.99	-.09	-.96	-.90	.31	.74	.77	1.09	1.75
1967	-.95	-1.25	.32	.21	1.19	.82	1.24	1.15	1.14	1.19	1.69	1.98
1968	-.69	-1.45	.46	.70	2.05	1.34	1.64	1.91	-.08	-.10	.06	.18
1969	-.69	-1.18	-1.86	-1.73	-1.78	-1.66	-1.72	-1.25	-1.39	-1.52	-1.34	-.84
1970	-1.60	-.01	-.07	1.53	-.38	-.44	-.70	-.67	.57	.91	.73	1.17
1971	.70	1.12	-.73	-1.14	.95	.77	1.46	1.52	2.17	#1.34	#.89	#.83

#Preliminary

LEGEND\*

4.00 : extremely wet		-1.00 : mild drought
3.00 : very wet	0.50 : incipient wet spell	-2.00 : moderate drought
2.00 : moderately wet	.00 : near normal	-3.00 : severe drought
1.00 : slightly wet	-0.50 : incipient drought	-4.00 : extreme drought

\*Note: In each instance the qualitative description is to be interpreted in comparison to normal, e.g. above 4.00 = extremely wet as compared to normal.

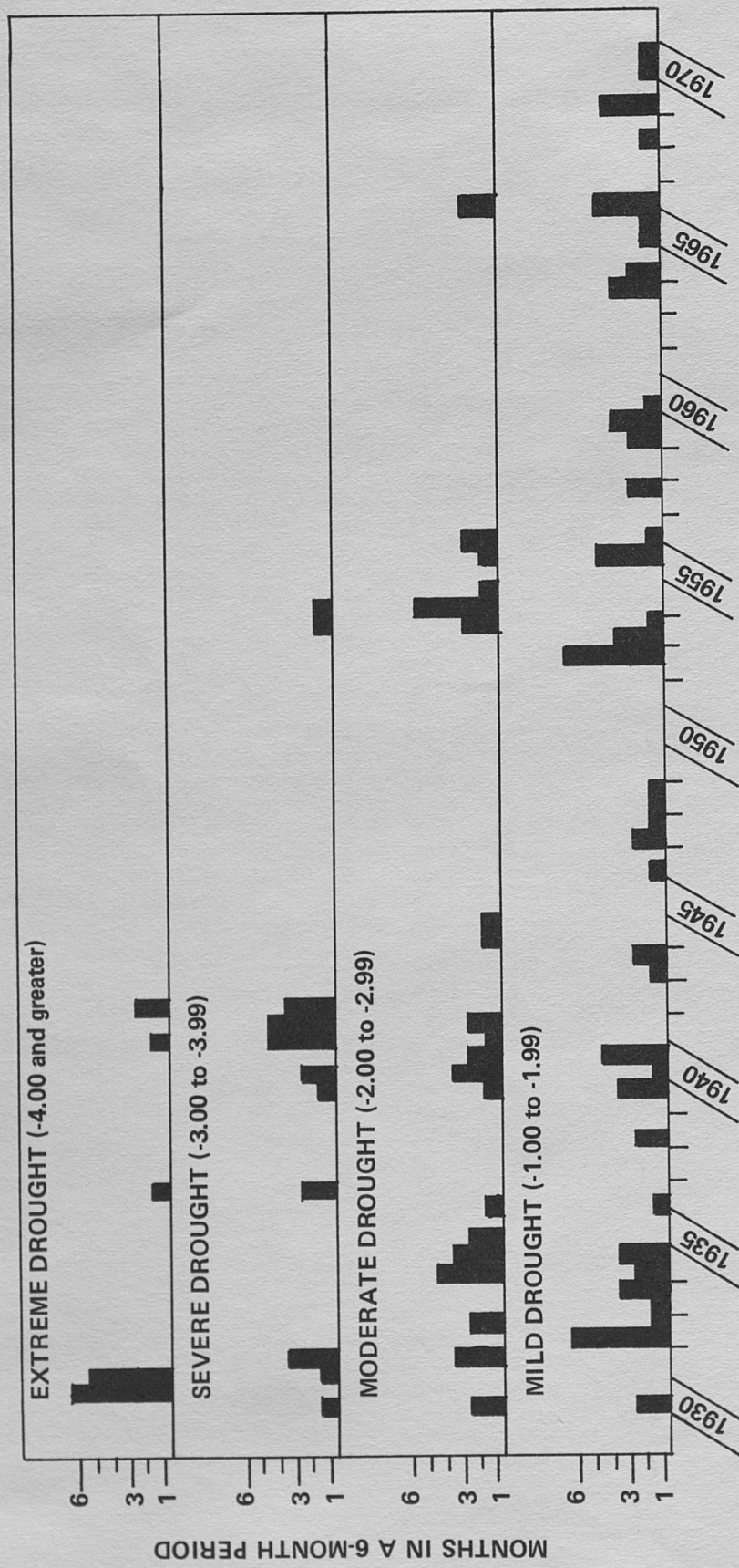


Fig. 4.—Number of drought months in each 6-month period, 1929-71, Eastern Climatic Division, Kentucky.

Table 4.—Palmer Drought Index Values (PDI) by Month, 1929-71, Eastern Climatic Division, Kentucky.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1929	-.14	-.14	.44	-.44	1.08	1.22	1.45	.97	1.57	2.43	3.06	-.29
1930	-.98	-1.26	-1.74	-2.72	-2.82	-3.59	-4.66	-4.84	-5.20	-5.11	-5.35	-5.59
1931	-5.99	-5.96	-5.76	-4.40	-3.78	-4.14	-3.87	-2.83	-3.03	-2.85	-3.24	-2.33
1932	-1.70	-1.61	-1.25	-1.38	-1.95	-1.09	-1.42	-2.07	-2.40	.86	.67	.82
1933	.67	.89	.55	.37	1.30	-1.31	-.91	-.60	-.66	-1.19	-1.91	-1.84
1934	-2.33	-2.24	-1.05	-1.33	-2.20	-2.16	-2.47	-1.67	-1.42	-1.67	-2.05	-2.77
1935	-2.41	-2.51	1.61	1.89	3.28	3.69	3.76	-.03	-.27	.03	.42	-.08
1936	-.12	-.57	-.52	.54	-1.20	-2.71	-3.05	-3.66	-4.00	.17	-.18	.25
1937	2.38	1.95	.78	.77	.87	1.34	1.04	1.21	.72	1.98	-.34	-.54
1938	-.75	-1.36	-1.50	.06	.68	1.12	1.51	2.03	2.16	1.10	1.63	1.18
1939	1.04	2.76	2.44	2.55	-.79	-.82	-.57	-1.02	-1.67	-1.81	-2.57	-3.05
1940	-3.63	-3.17	-2.74	-2.36	-2.23	-1.78	-1.55	-1.34	-1.31	-1.90	-2.14	-2.47
1941	-2.94	-3.68	-3.87	-3.54	-4.47	-3.94	-2.65	-2.71	-3.15	-3.00	-3.09	-3.29
1942	-3.51	-3.68	-3.57	-4.32	-4.15	.55	1.39	2.35	2.81	3.15	3.41	4.56
1943	-.90	-1.41	.77	1.14	1.14	.97	.94	-.87	-.98	-.82	-1.29	-1.83
1944	-2.43	.79	1.10	1.31	-.74	-.88	-2.34	.44	1.24	.88	.46	.49
1945	.35	.97	.35	.22	1.04	1.20	-.32	-.55	-.72	-.87	1.04	1.00
1946	1.32	.01	-.65	-1.27	.28	.46	.55	1.45	1.58	1.99	1.64	1.47
1947	2.17	-.82	-1.19	-1.80	.33	.54	.97	1.45	1.36	-.62	-.76	-1.41
1948	-1.36	.50	.56	.67	-.13	-.27	-.42	-.87	-1.29	.00	1.09	1.25
1949	1.31	-.21	-.46	.52	-.42	-.80	-.78	-.90	-.89	.80	.39	.67
1950	2.35	2.22	1.62	.73	1.49	2.27	3.02	3.14	3.87	3.48	4.26	3.61
1951	3.62	3.81	3.56	3.70	2.91	2.73	2.05	1.66	2.31	1.92	3.11	4.27
1952	4.20	3.24	3.85	3.32	3.58	-.54	-1.55	-1.01	-1.31	-1.52	-1.13	-1.12
1953	-.81	-1.10	-1.25	-1.19	.79	.52	-.22	-.80	-1.17	-2.09	-2.67	-3.10
1954	-2.31	-2.90	-2.85	-3.18	-2.78	-2.86	-2.89	.16	.19	.27	-.24	.63
1955	-.68	.98	2.53	-.47	-.79	-.51	-.75	-1.36	-1.59	-1.46	-1.84	-2.47
1956	-2.49	-1.92	-2.44	3.26	2.57	2.27	3.16	2.69	2.86	2.44	1.93	2.82
1957	3.60	3.37	-.82	-.58	-.89	-.62	-1.18	-1.87	1.43	1.67	2.79	2.73
1958	1.84	1.43	.98	2.34	2.74	2.52	3.17	3.74	3.79	3.43	3.26	-.50
1959	-.52	-.85	-1.36	-.92	-.88	-1.22	-1.24	-1.58	-1.89	.76	1.26	1.33
1960	-.50	-.22	-.31	-1.30	0.00	1.18	1.59	1.74	2.03	2.25	1.98	1.74
1961	1.30	1.18	.86	1.69	1.75	2.36	3.26	3.07	2.42	2.45	2.10	2.87
1962	2.71	3.60	3.28	3.60	3.06	3.43	3.62	2.70	2.96	2.85	3.18	2.96
1963	1.89	1.32	2.54	1.25	1.45	1.40	2.17	0.00	-.16	-1.21	-1.14	-1.67
1964	-1.66	.10	.58	.74	-.63	-1.08	-.04	.10	1.06	1.70	1.78	2.29
1965	1.94	1.32	2.08	2.16	-.83	-1.06	.73	.44	.73	1.06	-.46	-1.71
1966	-1.68	-1.46	-2.27	-1.25	-1.58	-2.28	.21	.83	1.82	2.21	2.62	2.93
1967	1.87	1.31	1.71	1.39	2.45	2.04	3.38	2.98	3.06	3.00	3.52	3.78
1968	-.64	-1.61	.47	.84	1.69	1.05	.98	1.10	.81	1.42	-.08	-.03
1969	-.49	-.71	-1.43	-1.32	-1.52	.31	-.28	-.25	-.29	-.42	.02	1.18
1970	-.92	-.76	-1.07	1.18	-.59	-.54	-1.03	.61	1.45	2.74	2.56	2.55
1971	2.36	2.15	1.26	1.06	2.17	2.07	3.07	2.82	3.51	#2.96	#2.47	#1.82

# Preliminary

LEGEND\*

4.00 : extremely wet		-1.00 : mild drought
3.00 : very wet	0.50 : incipient wet spell	-2.00 : moderate drought
2.00 : moderately wet	.00 : near normal	-3.00 : severe drought
1.00 : slightly wet	-0.50 : incipient drought	-4.00 : extreme drought

\*Note: In each instance the qualitative description is to be interpreted in comparison to normal, e.g. above 4.00 = extremely wet as compared to normal.

## OCCURRENCE OF SEVERE AND EXTREME DROUGHT BY MONTH, 1929-71

On the basis of this 43-year record, Fig. 5 shows the percent of years that severe and extreme meteorological drought existed in the four climatic divisions for each of the 12 calendar months.

In the Western Climatic Division November through February had severe or extreme drought about 16-20% of the time, which was more frequent than in any other division during this period and about twice as frequent as in the Eastern Climatic Division. In the Western, Central and Blue Grass Climatic Divisions severe and extreme drought were relatively infrequent in spring but somewhat more frequent in midsummer; in the Eastern Climatic Division, relatively infrequent in all months. It is probable that much of the month-to-month differences that appear in Fig. 5 are probably accidental, owing to the short period of record used. However Fig. 5 suggests that the threat of severe or extreme drought increases markedly in the Western Climatic Division in November and decreases in March. Actually these four cold months November-February account for 50% of the 64 months of severe or extreme drought that occurred in western Kentucky in 43 years. Therefore, this winter maximum of the frequency of abnormally dry weather probably is real.

When one considers the four climatic divisions, Fig. 5 shows that the Eastern Climatic Division has experienced noticeably fewer occurrences of severe or extreme drought than have the other divisions. This illustrates the fact that precipitation is fairly reliable the year around in the eastern part of the state and that prolonged periods of abnormally dry weather occur rather infrequently. The greater likelihood of dry periods in Western Kentucky and the more reliable precipitation in Eastern Kentucky have been indicated in other studies (9,10,11).

The total percentage occurrence of severe and extreme drought, all months combined, (Fig. 6) decreases from about 12% in the west to about 7% in the east (the greater part of this decrease in the extreme drought category). As a matter of interest, Palmer (3) found that, "The areal distribution of the frequency of occurrence of various classes of drought severity shows that most areas in the Great Plains have endured severe or extreme drought from 15 to 25 percent of the time in the past 30 years (1931-60); but most of the area to the east had serious drought less than 10 percent of the time."

Considering the total occurrences of all categories of drought from mild to extreme, we find that there is little difference from one division to the next, occurrences ranging from about 33% in the west to about 30% in the east. Palmer (3) found that over much of the nation for areas for which data were analyzed that there was some degree of abnormal dryness about one-third to two-fifths of the time at all places studied.

## FURTHER STUDIES

Additional possibilities for further study of the Kentucky drought data include the following:

1. *Comparison of drought analyses for points within climatic divisions with analysis for climatic divisions.* Areal averages were analyzed for the climatic divisions indicated in Fig. 6, since the original objective was to study the effect of moisture shortage on areas. By definition, a significant drought is one that is prolonged and often widespread. Also, point data can be extremely variable and difficult to analyze, especially in the summer months when spotty showers often contribute a sizeable portion of the total rainfall. However, drought severity varies from point to point within a climatic division owing to variations in temperature, rainfall, and



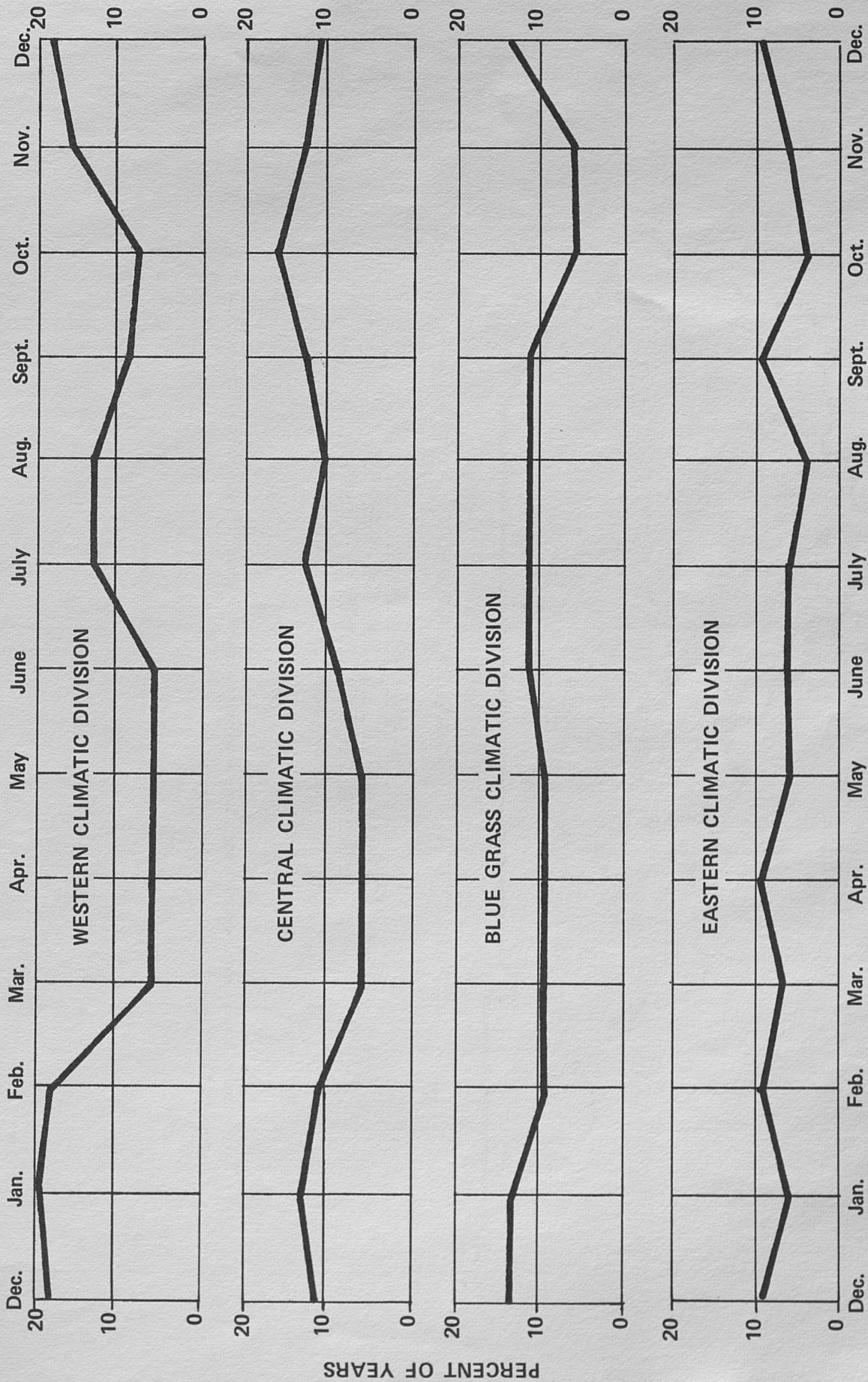


Fig. 5.—Percentage occurrence by month, severe and extreme drought (PDI), 1929-71, Western, Central, Blue Grass and Eastern Climatic Divisions, Kentucky.

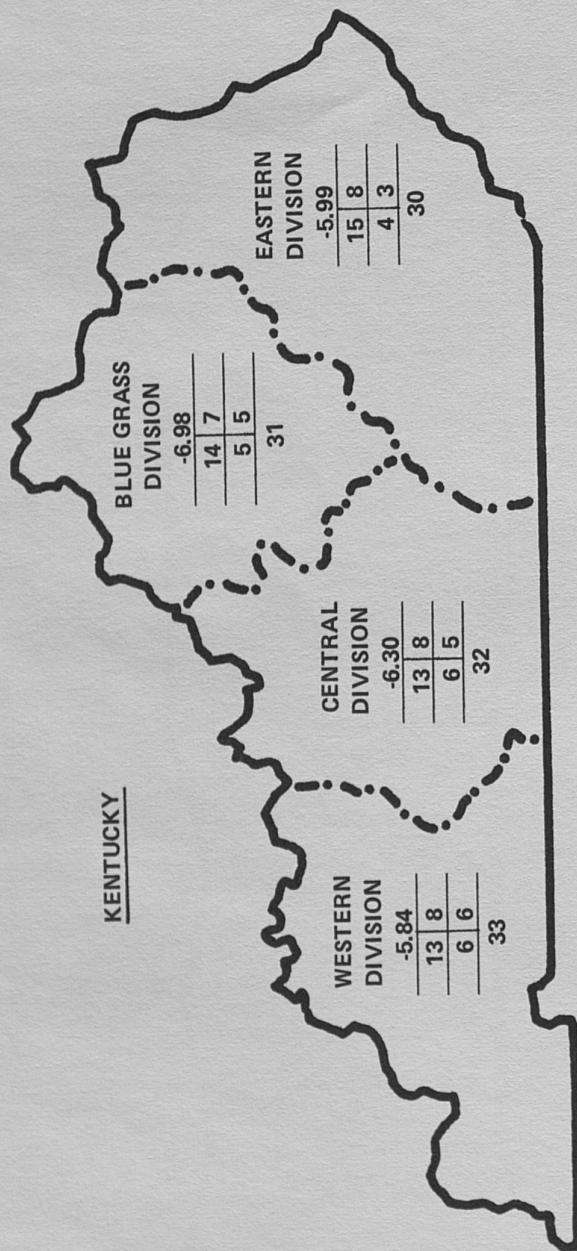


Fig. 6.—Locator-data map, showing: climatic divisions; drought summary (PDI), 1929-71, for each climatic division, Kentucky.

soil characteristics. It is likely that the variability is greatest when the drought is less severe and widespread.

2. *Persistence of drought once begun in a particular month.* On the basis of the data in Table 1 one could surmise that a drought that begins in that division in a fall month tends to persist for a number of months. If such persistence is real for this or other divisions, it would have important applications for agriculture and other interests.

3. *Areal or point analyses of drought on the basis of records for a much longer period than used in the current study.* For example, data from which PDI values could be computed are available for locations in the Louisville area (Central Climatic Division) beginning in 1841.

Also, it would probably be worthwhile to use the methods of Julian and Fritts (12) to study droughts and tree rings for a period predating the Louisville record. For example, old oak trees in the southeastern Kentucky mountains could tell us much of the occurrence of droughts occurring as far back as the 1700s. It is estimated that there are several hundred trees several hundred years old in southeastern Kentucky (8). As a matter of interest, Collins (13) noted the occurrence of a drought in 1805.

When drought analysis has been extended backward in time to include a long period of record, it would be worthwhile to compute return periods for length-of-drought periods and intensity of drought, etc.

4. *Some further studies noted previously.* These are mentioned in the section "The Palmer Drought Index (PDI) Data," on page 6.

## CONCLUSIONS

With the current and projected increasing population and demands on the water resources of Kentucky, the study of the reliability of such resources assumes an increasing importance. The serious drought of 1930-31 and several subsequent drought periods would be even more serious if they occurred today. Those planning for community and agricultural water supplies are increasingly concerned with the problem. The full potential for the use of the index values in this publication cannot be realized until there is greater distribution and study of the index values and associated summaries. It is hoped that this progress report will serve this purpose.

## ACKNOWLEDGEMENTS

The drought index values used in this study were obtained by the method developed by Wayne C. Palmer (4), Project Scientist, Bioclimatology Project, Environmental Data Service, National Oceanic and Atmospheric Administration, Department of Commerce. Mr. Palmer's suggestions and review of this study were of great assistance. The data were machine computed at the NOAA National Climatic Center, Asheville, N. C.

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