Drought Years in Central Oklahoma from 1710 to 1959 Calculated From Annual Rings of Post Oak Trees[1]

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Severe drought has greatly reduced agricultural production in Oklahoma during many seasons within the last 70 years. Information obtained over a longer period would be helpful in determining whether drought years are associated with climatic cycles or whether they appear at irregular intervals in the climatic pattern. The growth rate of tree rings has been used to collect information on seasons of below average rainfall in

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many areas. This procedure was recently employed to gather data on drought frequency over a 250-year period in central Oklahoma.

REVIEW OF LITERATURE

Bogue (1905) compared rainfall and the growth of five soft maple and two fruit trees from October, 1898, to September, 1901, at Stillwater, Oklahoma. The circumference of one- and two-year-old trees was measured each month. Most rapid growth occurred in May and June, with July and August growth depending on the quantity of summer rain.

Robbins (1921) studied the relationship between precipitation and the growth of oak trees at Columbia, Missouri, and found that width of annual rings from 1890 to 1919 was correlated directly with rainfall for March, April, May, and June. A decided drop in ring width occurred when rainfall was less than 12 inches during these four months.

Hawley (1941) found a better correlation between the growth of 15 oak trees and rainfall from November 1 to October 31 the following year than for rainfall between January 1 and December 31 in the northern Mississippi river drainage area. These trees grow more rapidly when summer temperatures were low.

Johnston (1941) studied the annual height increase of 20 specimens of white, black, and post oak and short leaf pine in two areas of the Missouri Ozarks. The trees were eight years old. Height increase of the oak trees occurred early in the season and was not affected appreciably by wet or dry seasons. The terminal growth of the oak trees was produced in 19 days. Ninety percent of this growth occurred in 11 days between April 27 and May 7.

Will (1946) obtained tree-ring records for 534 years from bur oaks in the Northern Great Plains and observed that drought periods and favorable years did not follow a definite pattern. Total annual rainfall was comparable to tree-ring width in 41 of the 54 years for which rainfall data were available. The longest wet period was 39 years and occurred from 1663 to 1702. The longest drought was a 20-year period from 1576 to 1596. The duration of wet or dry periods usually was not less than five years. Occasionally, one to three dry years were followed by one to three wet years. Seven dry periods varied in length from 13 to 16 years. A drought from 1922 to 1937 was one of the four longest in the 534 years of tree-ring records.

Weakly (1943) compared tree-ring width and precipitation in western Nebraska using red cedar and ponderosa pine as indicator trees. Annual rainfall was significantly correlated with annual growth of tree rings. However, a single dry year between a group of wet years did not always restrict tree growth. Thirteen droughts lasted five years or more over a 400-year period. Six drought periods lasted more than ten years, and two drought periods more than 20 years. Severe droughts occurred in the Northern Great Plains from 1858 to 1866, from 1880 to 1895, from 1905 to 1912, and from 1931 to 1940. No rainfall cycles were apparent in this study. October 1 to September 30 of the following year was a better index of rainfall and tree growth than rainfall from January 1 to December 31.

Schulman (1942) made an extensive study of the relation between annual growth of Douglas fir and precipitation from southern Arizona to Mesa Verde, Colorado. Trees under stress from limited soil moisture gave the best correlation with climatic records. Summer precipitation had little influence on the ring diameters of these trees. Good information for October-June precipitation was obtained at the growth sites. Factors

such as release from suppression, insect injuries, soil changes, effect of fire or lightning, and distance from weather stations tend to prevent a high correlation between rainfall and tree-ring growth.

Douglass (1919) observed that sunspot cycles were associated with other dominant cycles affecting the growth rate of trees located near the forest edge. Tree-ring growth of 1,000 years ago was not greatly different from that of today in the same region. However, there were pulsations of climatic cycles, and a great drought has occurred every third century in the southwestern part of the United States. He concluded (1931) that tree ring studies in that area indicated the occurrence of sunspot cycles with intervals of 10, 11, and 20 years, and also 7, 14, 21, and 28 years.

Avery, Creighton, and Hock (1940) studied the annual rings of hemlock as related to environmental factors in Connecticut. Five trees were located near a brook and ten were on a dry, rocky ledge. Although growth rates varied between the two locations, a remarkable degree in cyclic fluctuation appeared. Fall and winter rain did not give any different correlation between climatic environment and tree growth than rain from March to July in that area.

Lyon (1936) found a good agreement between the growth rate of 47 hemlock trees in six areas in Vermont and New Hampshire and a historic diary dated from 1727 to 1780. The oldest tree had 391 rings.

Glock (1937) found that some tree rings may be absent from the lower part of a tree trunk when seasonal rainfall is very low.

Campbell (1949) reported that one of the early comparisons of climate and tree growth was made near Fredricksburg, Texas, by Kuechler in 1859 on three post oak trees varying in age from slightly more than 100 to 134 years. The tree-ring record indicated that there were 12 extremely dry years, 11 very dry years, 19 dry years, 22 average years, 11 wet years and 59 very wet years in that area from 1725 to 1858.

Sellards, Tharp, and Hill (1923) studied the age and diameter of trees along Red River in connection with the Oklahoma-Texas boundary dispute in southwest Oklahoma. The trees studied were principally elm, cottonwood, hackberry, and pecan. The oldest tree was a pecan. It was 175 years old and 33 inches in diameter. One chittamwood was 105 years old. Cottonwoods were about 100 years old and two elms were 158 years old.

Thornthwaite (1941) studied climatic variations in Oklahoma from 1900 to 1939. The average climate in east central Oklahoma is moist subhumid. However, 31 percent of the years during this period were dry subhumid in the north part of this area. Only 18 percent of the years were dry subhumid in the south part of this area. Whereas, 35 percent of the years in south central Oklahoma were humid as compared with 16 percent in north central Oklahoma. Two years were classified as semiarid. Effective warm season rainfall was quite variable for the different years in both the moist subhumid and the dry subhumid portion of the State.

Experimental Studies

In December 1957, a study of tree-rings was undertaken in south central Oklahoma to provide more historic information on the climatic pattern for this area than was available from U. S. Weather Bureau reports. Sections from ten post oak trees *(Quercus stellata)* and one black oak *(Quercus nigra)* were obtained from the Leon Daube ranch, and one section from a recently cut post oak stump from the Fitzgerald ranch. Both ranches are located north of Mannsville in Johnston County. Sections

from five post oak trees were obtained from sandy land near Perkins in Payne County, and one section was cut from a bur oak tree *(Quercus macrocarpa)* east of Morrison in Pawnee County in August, 1959.

The tree-rings were measured and dated from the outside of the trunk, beginning with the year the tree was cut. The first 55 rings of each tree from Johnston County, Oklahoma, were compared with rainfall records collected at Tishomingo, Oklahoma, from 1903 to 1957. No appreciable difference in elevation occurred between the area where the trees grew and the point where the rainfall data were obtained. The first 65 rings of each tree from Payne County, Oklahoma, were compared with rainfall records obtained at Stillwater from 1895 to 1930 and from the Oklahoma Agricultural Experiment Station Perkins farm from 1931 to 1959. The width of each tree-ring was compared with rainfall for a 12-month period from October 1 to September 30 of the year for which ring measurement was made.

The average age of the ten post oak trees from south central Oklahoma was 180 years with the oldest being 273 years. The average age of the six trees that were used in the tree-ring study from upland soils in north central Oklahoma was 182 years, with the oldest being 231 years.

Annual rings were narrow in post oak trees from Johnston County when seasonal rainfall from October 1 to September 30 was less than 30 inches. One exception occurred in 1909 when more than one half of the trees did not show a reduction in ring thickness when seasonal rainfall was only 23.1 inches. Rainfall for the previous season had been 62.9 inches. The average seasonal rainfall (October 1 to September 30) at Tishomingo, Oklahoma, for the 55-year period from 1903 to 1957 was 37.4 inches. Average rainfall for the 65-year period from 1895 to 1959 at Stillwater, Oklahoma, was 34.4 inches. Narrow tree-rings did not appear until seasonal rainfall was 28 inches or less in the Payne County comparisons. Four years of abundant rainfall in Payne County had a greater residual influence on tree growth the fifth year when rainfall was low than similar years in Johnston County. This condition apparently was related to the sandier character of the Payne County soil. Narrow tree-rings formed during periods of suppression were not used in the estimation of drought frequency.

Figure 1 contains information on the years from 1710 to 1959 when the rings of post oak trees were narrow. The solid lines indicate a good agreement between all trees for those years. From two thirds to three fourths of the trees had narrow rings for the years designated by broken lines. These data show that seasonal rainfall was much below the average in central Oklahoma during 20 to 25 percent of the years from 1710 to 1959. The period from 1910 to 1919 was less favorable for tree growth than any of the other 10-year periods. One of the longest periods of favorable rainfall occurred between 1940 and 1951. There were nine intervals when rainfall was favorable for tree growth for more than five years, five intervals of six years, two intervals of seven years, two of eight years and one each of ten, eleven and twelve years. A minimum of 25 drought years occurred from 1710 to 1835 and 30 drought years were observed from 1835 to 1959. More drought years occurred from 1810 to 1859 and 1910 to 1959 than for the other 50-year periods.

A higher correlation was obtained between tree-ring width and rainfall in Johnston County than for similar measurements in Payne County. A higher correlation occurred between tree-ring width and the drought years than between tree-ring width and seasons of average or above average rainfall. When years for which weather data were available were divided into low, moderate, high, and very high rainfall groups, the correlation coefficient between growth rate and seasonal rainfall for one tree in Johnston County was increased from .55 to .73 by dropping the

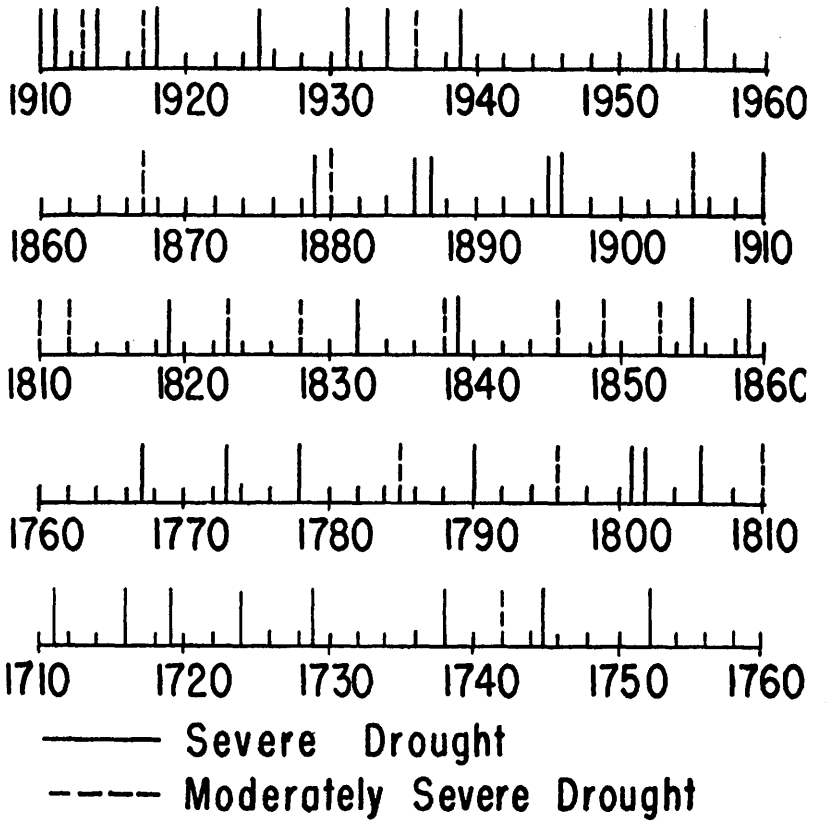

Figure 1. Years from 1710 to 1959 in central Oklahoma when annual rings of post oak trees were narrow, indicating much below average rainfall from October 1 to September 30 of the following year.

very high rainfall years from the comparison. A similar result was obtained in Payne County. The average tree-ring width per inch of rain for the four post oak trees in Johnston County that had the highest correlation between ring width and seasonal rainfall was as follows: low rainfall years, .057 inches; moderate rainfall years, .058 inches; high rainfall years, .058 inches; and very high rainfall years, .047 inches for the period 1903 to 1959. The average tree-ring width per inch of rainfall for the trees in Payne County were: low rainfall group, .054 inches; moderate rainfall, .048 inches; high rainfall, .046 inches; and very high rainfall, .036 inches.

Drought did not affect the growth rate of a large number of bur oak trees in several stream valleys in north central Oklahoma that were harvested as saw logs in 1959. Most of these trees were about 100 years old. A large hickory tree, 130 years old, and a large pecan tree, 175 years old, that grew on the flood plain of Black Bear Creek in Pawnee County had annual rings of relatively even widths during early, middle and late growth periods. These trees provided no information on climatic variations that have occurred in this area.

A low annual precipitation-evaporation index as proposed by Thornthwaite (1941) was correlated with low annual rainfall and narrow tree-rings, but it frequently did not correlate with low crop production. Quantity of rainfall when corn is tasselling has an important influence on the yield of this crop. A warm winter combined with low rainfall in early spring is often unfavorable for the production of fall-planted small grain. Average August temperature also has a significant effect on the yield of cotton. Consequently, the number of narrow tree-rings found over a 250-year period only indicates the minimum number of unfavorable seasons for plant development.

SUMMARY

A study of the variation in the annual width of rings in post oak trees revealed that the climatic pattern in central Oklahoma has not changed appreciably during the past 250 years. Narrow tree-rings indicate that a minimum of 25 drought years occurred during the first half of this period and 30 drought years during the last half of this period. Severe droughts usually were observed as single years between seasons of more favorable rainfall. However eighteen of the 55 low rainfall years occurred as nine pairs of dry years. No evidence was found to support a theory that a recurring cycle of dry seasons was interspersed between wetter periods.

Although an average of one out of every four or five years was dry according to tree-ring measurements, there were nine intervals when rainfall was favorable for tree growth for more than five years, four intervals of six years, two intervals of seven years, two of eight years, and one each of ten, eleven, and twelve years. The period from 1910 to 1919 had more narrow tree-rings than any other ten-year interval. Drought years were more frequent from 1910 to 1959 than from 1860 to 1909.

The quantity of rain falling in a 12-month period from October 1 to September 30 was closely related to tree-ring width. The yield of cultivated crops is often low when total annual rainfall is low. However, low yields of warm season crops were obtained during some seasons because of severe summer drought when the total seasonal rainfall was favorable for the growth of post oak trees.

REFERENCES

Avery, G. S. J., H. B. Creighton and C. M. Hock. 1940. Annual rings in hemlocks and their relation to environmental factors. Am. J. Botan. 27: 825-831.

Bogue, E. E. 1905. Annual rings of tree growth. Monthly Weather Review. 33: 250-251.

Campbell, T. N. 1949. The pioneer tree-ring work of Jacob Kuechler. Tree Ring Bull. 15: 16-20. Laboratory of Tree-Ring Research. University of Arizona.

Douglass, A. E. 1919. Climatic cycles and tree growth. Carnegie Inst. Pub. 289. Washington, D. C.

Douglass, A. E. 1931. Tree rings and their relation to solar variations and chronology. Ann. Rept. Smithsonian Inst. 304-312.

Glock, W. S. 1937. Principles and methods of tree ring analysis. Carnegie Inst. Wash., D. C. 100 pp.

Hawley, F. 1941. Tree ring analysis and dating in the Mississippi drainage. Univ. Chicago Press.

Johnston, J. P. 1941. Height growth periods of oak and pine reproduction in the Missouri Ozarks. J. Forestry 39: 67-68.

Lyon, C. J. 1936. Tree ring width as an index of physiological dryness in New England. Ecol. 17: 457-478.

Robbins, W. J. 1921. Precipitation and the growth of oaks at Columbia, Missouri. Missouri Agr. Expt. Sta. Res. Bull. 44.

Schulman, Edmund. 1942. Centuries-long tree indices of precipitation in the Southwest. Am. Meteor. Soc. Bull. 23: 148-161 and 204-217.

Sellards, E. H., B. D. Tharp and R. T. Hill. 1923. Investigations on the Red River made in connection with the Oklahoma-Texas boundary suit. Uni. Texas Bull. 2327: 133.

Thornthwaite, C. W. 1941. Atlas of climatic types in the United States. 1900-1939. U.S.D.A. Misc. Pub. 421.

Weakly, H. E. 1943. A tree ring record of precipitation in western Nebraska J. Forestry 41: 816-819.

Will, G. F. 1946. Tree ring studies in North Dakota. N. Dakota Agr. Expt. Sta. Bull. 338.