AN INTERPRETATION OF ANNUAL RINGS OF DOUGLAS FIR

BY

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Approved:

Redacted for privacy
Professor of Forestry
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7. Sunspot Cycles, Growth Cycles, Precipitation Cycles, 1850 to 1945
INTRODUCTION

This study of tree rings began in the winter of 1946-47 when the writer became interested in meteorological effects on the growth of trees.

During the past thirty or forty years the importance of climatic factors on the radial growth of trees has been studied in various ways, and conclusive evidence now shows that precipitation and temperature determine the growth habit of Douglas-fir (Pseudotsugae taxifolia), as well as its relative position in a stand.

The purpose of this study was two-fold: first, to find out the correlation between climatic and physiographic factors on the growth of trees as indicated by tree rings; second, from the results of the study together with results from other studies, to show past cycles and possibilities of what to expect in tree growth in the future, and how cycles of growth and climate can be applied to forestry of the future.

Since forestry today is becoming more of a science than just a matter of cutting trees, it is necessary to gain more knowledge of the factors which affect the growth of the various commercial species.

Because trees are directly influenced by precipitation and temperature, the cycles of these factors have a direct bearing on the growth of trees and even determine the particular species which will grow in each area.
Today, yield tables which determine our future cuttings are based on increments taken on past growth. The rate of growth may vary with climatic changes and consequently cuttings which are predicted may not be correct as to volume.

Man's existence is dependent on changes. Thus there is a need to develop some means of long-range forecasting of weather cycles in order that a definite idea of what to expect in tree growth can be gained.

**WORK DONE IN OTHER STUDIES**

Dendrochronology work is by no means new. Four hundred years ago Leonardo Da Vinci stated that width of rings was related to wet and dry years. (17).

The first study on record in this country dates back to 1859 when Mr. J. Keuchler determined that variations in the width of oak rings were caused by precipitation. (17)

However, the founder of the science of dendrochronology is Dr. A. E. Douglass (3), astronomer and archaeologist, of the University of Arizona. His studies, which commenced about 1904 in southwestern United States, have today placed him among the leading authorities on tree rings. As an astronomer, he found that the activity on the surface of the sun (sunspots) caused fluctuations in weather, and determined that this activity should show up in the growth of trees. (9). By cross-dating the rings of ponderosa pine in Arizona, Dr. Douglass was able to date
prehistoric records of Pueblo ruins as far back as A.D. 11. Further studies made by Dr. Douglass indicate that weather changes are reflected in coniferous species in both wet and dry areas. Samples of radial growth which represent the wet areas were taken from the Oregon coast, California, Pennsylvania, England, and Germany, while the drier areas were represented by Idaho, Colorado, Arizona and New Mexico.

Keen's work in eastern Oregon (19) during the late 20's and early 30's was an application of tree ring analysis to climatic cycles and tree growth. The study, stimulated by the encroachment of the desert on the pine forest, revealed that there are epochs of dry and wet periods, but that there is no definite pattern of cycles. However, he pointed out that growth of ponderosa pine depends a great deal on precipitation and that a large number of samples is necessary to show the effects of climatic factors on growth.

Florence Hawley's work in the Mississippi area (17) from 1934 to 1940 points to a definite correlation between tree growth and precipitation, and closely parallels the findings of Douglass.

SOURCE OF DATA

This study was made during the summer of 1947 on the upper Illinois River of the Siskiyou National Forest located in Josephine County in southwestern Oregon. See
This homogeneous climatic unit has mild winters and summers with few extremes in temperatures. The average annual rainfall is 50 inches with the growing season ranging from 150 to 180 days.

The low mountainous area with elevations ranging from 1200 to 5000 feet support the growth of Douglas fir (*Pseudotsugae taxifolia*), ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), and several species of true firs.

*Note: Tables and Figures referred to are found in the Appendix.*
MEANING OF TREE RINGS

ANNUAL RINGS
Examination of a cross section of a tree reveals a series of rings varying in width.

Annual growth rings are divided into two sections. The springwood is light colored and porous indicating rapid growth, and the summerwood is darker and more dense indicating that the growth has slackened appreciably. The end of the growing season, which is late August to early September in this area, is quite marked in the ring pattern making it comparatively easy to distinguish each year's growth. See Figure 2.

FALSE AND DOUBLE RINGS
When a tree puts on an early growth of springwood which tapers off into a darker wood because of drought conditions, then adds more springwood which finally tapers off into the characteristic summerwood, an added ring or false ring is formed. This false ring is identified by a band of dark which fades into light on both sides. The gradualness of the change indicates that growth has taken place all in one season. See Figure 2.

Occasionally, due to adverse living conditions, a tree may not grow a ring during a season, or may grow it on only part of the trunk. An increment sample taken here, would have a missing ring. This is a local condition and is
rarely found except in regions of very low rainfall where moisture is the determining factor of growth.

WHAT RINGS TELL

The history of a tree in its struggle in environment is revealed in its rings. The story may tell of a disasterous fire forty years ago, disease and insect infestations, competition with its neighbors, or the influence of climatic factors. If all the elements which control the growth of a tree are favorable, a normal annual growth ring is the outcome. However, if one of these factors should deviate from the normal, a fluctuation in the growth of the tree will result. Rainfall, for example, may show an increase or decrease in the growth of the tree. In order to show this variation a measurement of rings must be made and a graph constructed to show the crests or good times and troughs or bad times.

Trees which are isolated or in an even-aged stand usually have rings which are medium to large near the pith. On the other hand, trees in a two-storied or uneven-aged stand produce rings which are narrow in width near the pith.

Inspection of a graph of the radial growth of a tree shows cycles of narrow and wide development. As all trees in a given stand are exposed to the same climatic conditions it is reasonable to expect patterns of development to be similar. See Figure 3.
The overall trend in radial growth since 1885 showed a decided decrease in annual increment in all groups.

**GRAYBACK GROUP**

Located on a south exposure at an average elevation of 2100 feet, the samples were taken from trees of a residual stand of 1946 timber sale. See Figure 5 and Table I.

**WOODS CREEK GROUP**

Trees sampled in this area were found at an average elevation of 1800 feet and on eastern and western exposures. See Figure 5 and Table II.

**PAGE CREEK GROUP**

The Page Creek group consisted of five codominant trees which are part of the residual stand from the initial cut made in 1946. Samples were taken from trees growing on southwestern exposures at an elevation of 2000 feet. See Figure 5 and Table III.

**DUNN MOUNTAIN GROUP**

The Dunn Mountain Group was located at the highest elevation - 4600 feet - of the experiment. The trees sampled were mature and growing in a saddle with a southwestern exposure. See Figure 5 and Table IV.

**LAKE CREEK GROUP**

The Lake Creek group was taken several hundred feet
above the Oregon Caves Highway on a southwestern exposure at an elevation of 3100 feet. See Figure 5 and Table V.

**REDWOOD HIGHWAY GROUP**

This group was taken several miles south of Cave Junction, Oregon, in a small stand of second growth. The trees were located at an elevation of 1350 feet on a flat adjoining the west fork of the Illinois river. The age of the trees ranged from 40 to 50 years. See Figure 5 and Table VI.

As the age of the trees in the other groups studied were older, and the trend in radial growth showed a steady decrease since 1885, it was necessary to prove that this decrease in radial growth was not due to the age of the trees sampled.

The normal radial growth of Douglas fir is shown in Figure 4. From this graph we can expect trees beyond the age of 50 years to decrease in annual radial growth. Those trees between the ages of 10 and 50 years should increase in radial growth. However, in this case it was not true and the steady decline in rainfall apparently indicates some influence in this trend in radial growth.
METHOD OF TAKING SAMPLES

In obtaining samples the most convenient way, and a way by which the living tree would not be damaged, was to use a 12 inch Swedish increment borer, a hollow auger instrument. The age of the tree was not desired, therefore, a complete increment to the pith was not taken.

Weather conditions for the area dated back to 1890, and as this study was concerned only with a correlation of the tree growth to past known weather conditions, an increment was taken only back to that date.

Samples were taken from trees at breast height. It was found that trees growing on exposed sites have more growth on the lee side while eccentric growth is proportional to steepness of slope with wide rings on the downhill side. Dense and uniform cover produced trees with rings with maintained their concentric growth.

Site quality is manifested by the prevailing shape of the stem at the root collar. A good site will produce trees with a root collar less pronounced and with an annual growth more regular, while adverse site conditions cause excessive root bulging. All these factors had to be considered when taking a sample from a tree in order to get a specimen which gave a true picture of the growth record.

MEASUREMENT OF ANNUAL GROWTH

The lack of precision instruments made it necessary
to make measurements of the radial growth of the samples in periods of five years rather than one. The use of a millimeter scale and hand lens aided in making the measurement.

Previous experiments (9), (17), (19) in this field have used more accurate instruments to record the radial growth in one year periods. It is believed that general tendencies will not be lost by the use of the five year periods. Accuracy of results attained were within 0.20 of a millimeter.

As the data collected from these measurements are the basis of the conclusions drawn from the experiment, it was necessary that each ring be identified as to the correct year of growth and that an accurate measurement be taken.

It has been mentioned that there are sometimes false rings found in the growth of trees due to climatic fluctuations. However, in a climate such as western Oregon, these ring variations are few and usually only found where trees are located on a very poor site with shallow soil.

Daubling the samples with kerosene accentuates the difference in spring and summerwood while a sharp razor blade is useful in preparing a surface for more accurate measurements (17).

**TYPES OF RINGS FOUND IN SAMPLES**

Two types of rings are found in trees. (13) Those which show small variation from year to year are termed
complacent while those which have greater variations are called sensitive rings. The latter are better samples for correlation studies. It was found that trees which grew individually some distance from stand influences and on ridge tops where fluctuations in available soil moisture are greater, produce a ring which was quite sensitive with greater variations in width of rings. Trees which grew along streams where the annual water supply was assured produced rings of a greater width and uniformity than trees on dry sites.

IDENTIFYING TREE RINGS

Matching the patterns of rings, or crossdating, in the samples taken is important in trees producing false and missing rings because of the necessity of knowing exactly what year each ring of growth was produced.

The method involved originated from Dr. Douglass' early experiments in Arizona. (4) It consists of developing a pattern of ring widths associated with each year from a wide selection of trees. These patterns in each tree vary according to the sensitivity of the tree to environmental changes.

In order to determine the exact year of each ring, it was necessary to count from the bark toward the pith. The first ring next to the bark being the year the sample was taken.
METHOD OF ANALYSIS

In order to make correlations, graphs were made of the average growth per five year period for each area. From this data an average of all areas was computed and a graph of the percent of deviation from average growth was constructed. This was necessary as weather records were obtained from several stations and precipitation and length of growing season could be shown only graphically as deviations from the average.

*Weather records were obtained from the "Climatic Summary For Western Oregon" for Redwood Ranger Station at Cave Junction, Buckhorn Farm at Kerby, Waldo at Page Creek Guard Station, Mountain Ranch, and Grants Pass. See Figure 1 for location of these stations.
TREE SELECTION

SPECIES

Douglas fir, being the commercial species in this area, was selected for the study. The rings of this species are well marked, free from variations which might cause errors and from fluctuations in ring width due to environment.

SIZE AND AGE

The size and age of trees from which samples were taken was given some consideration. Because the annual growth of a tree decreases appreciably as it matures, the samples were taken mainly from trees which were actively growing. In order to segregate the fluctuations due to climatic factors, it was necessary to select trees in a wide range of ages. (22) To reduce the effects of competition trees were sampled twelve or more feet apart.

ELEVATION AND EXPOSURE

Sampling of the area included six groups at different elevations and exposures. Within each group individual trees were chosen at different elevations in order that the effect of available soil moisture might be observed.

NUMBER OF SAMPLES PER GROUP

A minimum of five widely separated samples in a uniform area is necessary in order to eliminate chance in the results, and positive conclusions can be made. (9) In
this experiment up to 20 samples for each area were taken, but only the five most sensitive for each group were used.
CORRELATION OF CLIMATE TO GROWTH

GENERAL

Dr. Douglass has said:

"If many widely separated trees in a uniform area show the same variations in the same years continuously (that is for hundreds of years), then these variations are climatic in nature, for climate is the common continuous factor in the life of the forest tree." (4)

The limitation of a forest unit may obviously show the climatic factor involved. For example, in the ponderosa pine region of eastern Oregon, rainfall is the limiting factor and we find the desert encroaching on the forest. In a cycle of wet years the forest has penetrated the desert while the reverse is true during a cycle of dry years.

Another example would be the limitation of growth due to extreme cold temperatures at high elevations or latitudes.

RAINFALL

In considering rainfall as directly affecting the growth of a forest we first have to estimate how much of this rainfall will be available for plant life. In regions of little rainfall the moisture may pass off through evaporation because of higher temperatures. In other regions the rainfall may be high but great quantities lost in runoff.

Precipitation is not directly available for the tree at any time. Previous studies show that the amount made
available is influenced by surface runoff which in turn
is ascertained by the degree of slope and type of soil.

E. E. Bogue found from his studies on maples in the
east that the previous year's rainfall may affect the
following year's growth.

Rainfall records for southwestern Oregon show cycles
of wet and dry periods, and radial growth of the Douglas
fir in this area is closely correlated as shown by Figure 6.

Precipitation which is well distributed throughout
the year will help to maintain a high yield of annual
increment. A great amount of surface runoff occurs during
years of high rainfall which comes in a two or three month
period. With little precipitation for the remainder of
that year the following year's growth will likely be de-
creased providing other conditions remain unchanged. From
this then it is concluded that in years of average rainfall
well distributed throughout all twelve months, radial
growth will be at its maximum.

This close correlation between rainfall and radial
growth increases as the conditions for growth become ad-
verse. A tree located within a stand where conditions for
growth are stable will not show as much change in radial
growth due to increase precipitation as a tree at the
edge of stand where conditions are at a higher degree of
fluctuation.
TEMPERATURE

The following statement comes from R. Zon (23):

"A great part of the living tree is buried deep in the ground and it is the temperature of the soil, not of the air, that affects the activity functioning of roots."

"It is evident, therefore, that weather data alone cannot be translated directly into terms of vegetational processes."

From a study of the weather reports available for this area, it was found that precipitation and length of growing season were closely correlated. See Figure 6. Generally speaking, in years of extreme dryness the growing season was shorter while wet years produced a longer growing period. This factor would help to produce a greater amount of growth during epochs of wet cycles.

The temperature of the air plays an important part in conserving the water supply in the ground. Increasing temperatures with decreasing relative humidity causes greater loss of moisture through transpiration of the plants as well as loss by evaporation from the soil.

During the spring of the year when the average maximum temperature is 62°F. and a great number of days are clear to partly cloudy, growth is at its maximum. During the summer there are a greater number of clear days than in the spring with the result that the average temperature, 79°F., is higher and the relative humidity, 58%, is lower. This change in conditions is shown in the annual growth by a change from spring to summerwood.
SOLAR RADIATION

The temperature is directly affected by the amount of solar radiation which reaches the surface of the earth. Thus in an area where the sun shines a great number of days out of the year the increased temperature will increase the growth until the maximum growing temperature is reached. Beyond the maximum the growth will decline with increasing heat. Regions which have few days of sunshine throughout the year have lower temperatures and the optimum conditions for growing are not obtained.

Consequently, in southwestern Oregon where the average number of clear days is 150 to 180, the conditions for growing will be good, providing daily temperatures are not beyond the maximum for optimum growth.

The occurrence of sunspots also have a definite effect on growth. Dr. Douglass found that a history of sunspot variations was reflected in the annual rings of trees. (10)

Growth cycles which are portrayed in trees sensitive to fluctuations of climate, principally precipitation, correspond to cycles of sunspots. It is believed that these solar disturbances are the cause of enough changes in our climate to produce fluctuations in growth.

Sunspots come in cycles with the 11.4 year cycle being the most important. Other cycles are the 22.6 year cycle and the longer 73 year secular cycle. See Figure 7.

During years of maximum sunspot activity terrestrial storms are more frequent with the result of higher
precipitation. Note correlation of precipitation to number of sunspots in Figure 7.
CLIMATIC CYCLES AND TREE GROWTH

CYCLES: A BASIS FOR PREDICTIONS

The limiting factor when correlating climate to the growth of trees is the lack of weather records for the specific area in question. In this case it was necessary to go as far as 20 miles from the place of research in order to get the necessary weather records.

The hold-over effect from year to year of precipitation and other environmental factors have made it hard to determine the exact cause of growth fluctuations.

Cycles of growth and climate in the past show a definite correlation as to periods of dryness and wetness. These periods show no set pattern by which we could predict the future trend in the climate. However, when placed alongside the cycles of growth and precipitation, then predictions of the future have a better foundation.

During periods when several of the sunspot cycles are at a minimum severe conditions will result. From Figure 7 it can be seen that during the years 1890, 1899, and 1925 when the number of sunspots in all three cycles were below average that extreme drought conditions prevailed. During the years 1893-94 and 1921 a similar condition existed except that sunspot numbers were more than average and flood conditions existed.

VALUE OF CLIMATIC CYCLES

The value of a knowledge of climatic cycles to forestry
is threefold: First is fire protection. During unusually dry periods, fire conditions are quite severe. A knowledge of when these dry periods are coming will be a guide to fire protection plans. Second is the management of our forests. Past experiments show that usually a residual stand will increase in growth due to release from competition for sunlight and moisture. However, in an exceptionally dry period the effects of thinning or partial cutting may be more detrimental to the residual stand because of the opening up process which would allow more desiccation to take place. Therefore, it may be necessary for forest managers to make adjustments to these periods of wetness and dryness in regard to good forestry practices. Third is the possible fluctuations in growth. As there is constant changing in annual increment, yield tables made in the past cannot accurately be used in the future unless conditions remain the same.
SUMMARY

A knowledge of meteorological factors and to what extent tree growth is affected by them is valuable for ecological work and silvicultural practice.

In a given area where all trees are exposed to the same conditions of weather and climate annual increment reflects the predominant factors of growth in wide and narrow rings.

Correlations between climatic factors on the growth of trees as indicated by tree rings are definitely positive. The difficulty in making correlations is the lack of weather records for long periods of time which have been taken close to experimental areas.

The value gained by such a study is in the possibility of long range forecasting of climatic cycles and obtaining a better inter-relationship between solar and terrestrial activities by the aid of the history found in the rings of trees.
BIBLIOGRAPHY


TABLE I

FIVE YEAR PERIODIC GROWTH DATA

FOR

GRAYBACK GROUP

6 TREES

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Note: Growth was measured for the period 1881-85, 1886-90, 1891-95, etc.
# TABLE II

**FIVE YEAR PERIODIC GROWTH DATA**

**FOR**

**WOODS CREEK GROUP**

**5 TREES**

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### TABLE III

**FIVE YEAR PERIODIC GROWTH DATA**

**FOR**

**PAGE CREEK GROUP**

**5 TREES**

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5 TREES

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TABLE VI
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REDWOOD HIGHWAY GROUP
5 TREES

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Measurement of Growth in Centimeters

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- 12": 1.60 1.65 1.15 1.28 1.15 1.20 1.05 0.95 1.45
- 14": 1.55 1.80 2.05 1.18 1.15 1.08 0.78 0.64
- 28": 1.65 1.34 1.70 1.28 1.05 1.05 1.04 1.75
- 22": 1.34 1.24 1.10 1.30 0.95 0.87 0.62 0.59 0.75
- TOTAL: 6.14 7.88 8.35 6.72 6.16 5.55 4.73 4.34 5.99
- MEAN: 1.535 1.576 1.670 1.344 1.232 1.11 .946 .868 1.198
TABLE VII
MEAN PERIODIC GROWTH FOR ALL GROUPS SHOWING PERCENT OF DEVIATION FROM THE MEAN BASED ON GROWTH OF 31 TREES

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Figure 2

Cross sectional view of a tree showing annual growth rings.
A Springwood
B Summerwood
C Double or false ring
D Annual ring
E Absent or missing ring
RADIAL GROWTH IN RELATION TO AGE

Recovery from Suppression

Competition with Neighbors

Effect of Thinning

Gradual Loss of Vigor with Age

Time in Years - Age

Figure 3
PERIODIC GROWTH AND TREND IN GROWTH
FROM 1885 TO 1945

Figure 5

Periodic Growth
Trend Line

Year
1890 1895 1900 1910 1920 1930 1940

Woods Creek
Page Creek
Dunn Mtn.
Lake Creek
PERIODIC GROWTH AND TREND IN GROWTH
FROM 1885 TO 1945

5 Year Periodic Radial Growth in Centimeters

Year
1890 1900 1910 1920 1930 1940

Periodic Growth
Trend Line

Grayback
Redwood Hwy

Figure 5a
CORRELATION GRAPH OF RADIAL GROWTH, RAINFALL, SUNSPOTS, AND GROWING SEASON.

Figure 6
CORRELATION GRAPH OF RADIAL GROWTH, RAINFALL, AND SUNSPOT CYCLES


Figure 7