

MEASUREMENT OF TREE GROWTH IN TROPICAL FORESTS

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The title of my paper --Measurement of Tree Growth in Tropical Forests-- is somewhat misleading. Because tree and forest growth determination are essentially the same anywhere, most of what I have to say is as applicable in British Columbia, Japan, or New Zealand as it is in Ecuador or the Philippines.

Select Specific Problem

The first step in any growth study should be selecting a specific problem. About 20 years ago our Institute became interested in the growth of forests in the limestone hills along the north coast. Therefore a plot of 30 acres was established, supporting 5000 trees, and covering from the base to ridge of a hill, on both windward and leeward sides. Over a 15-year period each of the 5000 trees was measured and remeasured 6 times, with individual records kept of each tree at each measurement.

Recently we wanted to compare the growth at the base and ridge and on the windward and leeward slopes. Species composition varied, of course, and we know growth varies with species, so we checked through the data of all 5000 trees of 74 species to obtain the records of the species occurring on all sites. We had four species with a total of 200 trees.

My point is this. Exactly the same amount of useful information could have been obtained by measuring 200 trees as was obtained by

measuring 5000 trees; of every \$100 spent, \$90 were wasted. Unless the original study is planned to answer a specific question, you will waste labor, you will waste money, you will waste time.

Design Test to Answer Problem
With Minimum Number of Measurements

Once a growth problem is selected for solution, design a study to solve the problem with a minimum number of measurements.

For example, when a comparison in growth rates between species is desired, a comparison between individual trees is more sensitive --and much more economical-- than between plots. Obviously the same thing is true when comparing genetic strains. These latter comparisons are usually in plantations and may be designed to provide very sensitive comparisons from only a few stems of each strain.

Similarly comparisons between sites are most efficiently made on an individual tree basis. Care must be taken, in natural forests especially, to eliminate or account for differences in species effect when comparing sites. No one would compare growth of a pine plantation on a ridge to maria growth in a valley, then claim the ridge site to be more sensitive because the pine outgrew the maria. But in natural forests, even though the difference in species composition may be just as important, site comparisons which ignore species are common.

On the other hand, in routine forest inventory for management guidance, differences between individual trees are of little or no practical significance. The interest lies with developments on an area basis; that is, on plots. In such cases precise measurements of individual trees and the maintenance of individual tree records are frequently superfluous.

It is also worth pointing out that a plot value based on measurement of 30 trees is usually about as reliable as one based on 100 trees, even when used strictly under an area concept. When plots are to be

stratified before analysis, by site, composition, age, past treatment, etc., small plots are of course, easier to locate properly and are more likely to be classified correctly because each plot occupies less area and is less varied.

Briefly, the nature of the problem under study determines the type and precision of measurements desirable, and stand characteristics and statistical probabilities should be considered in determining the number of measurements necessary.

Tree Measurement

Now let us consider actual measurement of trees, since growth --as considered here-- is assumed to be the difference between repeated measurements.

Diameter-Girth

The measurement of diameter (or girth) in growth studies was almost universal until about 10 years ago. The introduction of relascopes (or angle gauges) has modified this situation only slightly. The technique, and tool, used varies somewhat with the frequency of measurement planned.

Weekly. To determine seasonality of growth measurements are commonly made at intervals of a week or less, and the calipers or tape normally used by foresters are not sufficiently precise when used in the accustomed manner. A number of solutions have been adopted.

1. Multilevel measurement. Dawkins (1956) reported that when tree girth is measured to the nearest 0.1-inch at ten levels, with the tape carefully placed on painted bands, the mean, carried to two decimal places, is sufficiently precise and progresses consistently enough for measurement of growth over periods of one week or less. This method requires a great deal of labor per tree measurement, but it calls for almost no capital outlay and is practically vandal-proof.

2. Vernier bands. The use of vernier growth bands, as suggested by Hall (1944), has become widespread in the United States. As commonly prepared they yield accurate readings of circumference to the nearest 0.01-inch. This is sufficiently precise to follow the daily fluctuations in girth which accompany the transpiration cycle. The preparation of the rings requires a jig, which is moderately expensive (usually about \$50 in the US), and aluminum tape and springs. Installation is quick and easy, and the number of readings per man-day is limited almost entirely by travel time. On the debit side the tapes are fairly conspicuous on the tree and subject to vandalism. On large trees, especially, thermal expansion and contraction of the tape may cause seasonal fluctuations in the readings in temperate regions.

3. Dial-gauge micrometer. One of the earlier tools used for precise measurements of radial growth was the dial-gauge micrometer, which is placed on a small platform mounted on lag screws set well into the xylem. This shows less thermal effect and is relatively resistant to vandalism. However, micrometers are too expensive to mount on each tree, even if theft were no problem, and obtaining perfectly consistent results each time one is set in position is somewhat difficult. In addition, of course, only one radius can be measured per mounting, and the lag screws must be set well away from the point of measurement if the results are not to be affected by the formation of callous tissue.

4. Dendrograph. When continuous measurements are desired on one or a very few trees, a recording dendrograph is used. Although girth measurement is possible, all installations I have seen measured a single radius only. Their high price and susceptibility to theft and vandalism strongly restricts possible applications.

2

Yearly. When diameter growth is to be determined for periods of a year or more, consistent results can be obtained by careful use of a diameter tape. We use a steel tape placed on a painted line and read diameter to the completed tenth-inch. Although measurement on a ring painted completely around the tree is theoretically more consistent than when the paint covers only one-eighth to one-fourth of the circumference, we have been unable to demonstrate any improvement under our working conditions, so we no longer use complete rings. We measure to completed units rather than the nearest unit in order to reduce bias in favor of preferred species; for the same reason the measurer is never allowed to know the previous measurement before he remeasures, and if the second measurement appears incompatible with the first he is told only to check his remeasurement. Without these precautions we found that vigorous-appearing trees of preferred species almost always slumped sharply in growth after the initial period of measurement.

It may be worth mentioning that growth in most of the tropics is seasonal, and time of measurement should be planned accordingly.

Periodic. Measurement of diameter growth for periods of five years or longer can be obtained easily with a tape and are reasonably consistent even with calipers. If studies are planned with sufficient foresight to permit measuring trees at the beginning as well as the end of a growth period, the lack of easily counted annual growth rings is of little importance.

However, if the need be sufficiently urgent rings of many tropical forest trees can be counted, at least in regions of marked seasonal fluctuations in rainfall. Even where rainfall exceeds 150 inches per year in Puerto Rico some species form relatively clear annual growth

rings. The use of 3-10 millimeter increment cores, stains, microscopic cross-sections, and rainfall records help when near-perfect counts are necessary.

Height

Techniques and tools for measuring height vary primarily with the height of the trees to be measured.

Short. Trees less than 12-15 feet tall are most easily measured with a 1-piece or jointed rod. Precise measurements of trees more than 6 feet tall usually require care to avoid parallax errors.

Medium. Trees of medium height may be measured with various hypsometers or extension poles.

When many trees close together are to be measured, and when ground conditions permit, an extension pole is about as accurate and is faster to use than hypsometers. Readings must always be made by an observer some distance from the base of the tree under measurement.

Any number of hypsometers are sufficiently precise for most purposes. Probably the most widely used is the Abney, which incorporates a spirit-level. However, several of the new pendulum hypsometers are faster and easier to read, and are also less expensive. Both the Haga and Blume-Leiss have several scales always available; the Sumro can be read most quickly of all but has only percentage and degree scales.

Tall. Heights of trees more than 50 feet tall are almost universally determined with the aid of hypsometers. Any of the standard makes are capable of more precision than a forester can obtain under normal field conditions, especially when measuring round-topped trees. Accuracy of such measurements is increased by measuring from a point as far as possible from the base of the trees, and consistency is improved by

marking the point from which sights are taken on the tree so that subsequent measurements can be taken from the same spot.

Most errors in height determination of trees with a distinct, easily seen tip and base are due to inexact measurement of the tree-to-observer distance or incorrect use of the hypsometer. Sightings with the Haga, especially, are sometimes made before the pendulum has settled to its final position.

Basal Area per Acre

At times the unit of growth to be considered is basal area per acre, (or other unit of area). This is an especially common unit for use as a guide in the extensive management of large acreages. We have found that when a plot contains more than about 25 trees the measurement of each tree diameter to 0.1-inch precision, converting to individual tree basal area, and summing the lot yields a figure of no more utility than tallying the number of trees in each 1-inch diameter class, and converting to basal area by class instead of by tree. The savings in arithmetic using dbh classes rather than individual trees are appreciable, and the larger class permits the use of cumulative tally sheets, which save even more time.

When no information on stand structure is necessary and undergrowth is not excessive plot basal area can be measured with some form of relascope; we prefer the wedge prism because of its convenience in use and extreme portability. By selection of the appropriate gauge of relascope virtually any desired degree of reliability may be attained; a 10-factor relascope is about equal to fifth-acre plots in stands of one-foot mean diameter and is superior in larger stands. All are tremendously faster than any other means of measuring stand basal area.

Summary

In summary, before beginning a growth study in tropic or temperate regions a specific problem should be selected for solution. Once the problem is selected use all available information on the forest in particular and statistical probabilities in general to reduce the number of measurements necessary and increase the reliability of those made. These two steps can tremendously reduce the costs of and increase the useful information from growth studies.

Unless labor is very cheap, weekly diameter measurements are probably best made with vernier bands. Longer-term measurements can be made satisfactorily with a steel tape; every effort should be made to eliminate personal or systematic bias in measuring.

Height of short trees can be measured with a graduated rod, but taller trees usually require a hypsometer. Measuring conditions ordinarily affect results much more than the particular hypsometer used.

Basal area is easily and quickly measured with a relascope when the nature of the study permits.

July 21, 1961.