*The Indirect Determination of Forest Stand Variables from Vertical Aerial Photographs**

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ABSTRACT: *A study was recently made of the possibility of determining several forest tree and stand factors from aerial photographs in an indirect manner. Values such as age, or growth rate of trees naturally cannot be measured directly on vertical aerial photographs. There is a possibility, however, that these factors can be determined indirectly from variables that can be measured, such as tree height or crown diameter. This is a discussion of the methods employed in this study.*

INTRODUCTION

VERTICAL aerial photographs have been of incalculable value to the forest manager as a source of vital information. They are used in almost every phase of work involved in the management of large areas of timber land. Perhaps the greatest single forestry activity to which aerial photographs have been applied is inventory. The intensity with which photographs are applied in forest inventory varies considerably. Under some conditions they can be and are used for volume determination with a minimum amount of supplementary field work, but under other conditions they serve only as a guide for the instruction or movement of field crews.

A knowledge of the existing timber volume is of prime importance to the forest manager, but there are other factors that must be known as well if the area is to be managed properly. At the present time these additional factors regarding a forest stand, such as average age, average d.b.h.,[1] average growth rate, reproduction and silvicultural conditions, must be determined by ground surveys. These necessary additional factors cannot be seen on vertical aerial photographs either because of scale limitations, the vertical view presented, or simply because of the nature of a forest stand.

There are, however, a number of stand variables that can be counted or measured on aerial photographs. Among these are: tree height, crown diameter, crown density and number of trees per acre. These factors are of little value in themselves, but may be useful in determining other factors that cannot be seen or measured. The forest stand factors that cannot be seen are perhaps related to or controlled by the same environmntal factor, or controlled by one or more of the factors that can be measured directly. If there can be determined the relationships that exist between the factors that can be measured directly and the factors that cannot be seen, then it may be possible to estimate these latter factors in an indirect manner.

[1] Diameter breast high.

OBJECTIVES

A study as above described was recently conducted for the longleaf pine type (*Pinus palustris* Mill.) in northeast Florida. This was primarily a statistical study of ecological relationships but it has been established on a practical photographic interpretation basis.

This was not a study to determine the cause or effect, but rather a study to determine the trends of existing relationships and their extent. Neither was it the intent of the study to determine relationships that may exist in the longleaf pine type in other areas or in other types, but only to determine the relationships that may exist for a specific type. While the resulting relationships may not be applied directly to other forest types, the method employed in this study could be followed to determine similar relationships. This method may also suggest a possible solution to similar problem areas that exist in other fields of photo interpretation.

* Based on a portion of a thesis submitted to the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy, July 1956.

Procedure

The field work consisted of the measurement of 13 tree and stand variables on 65 one-tenth acre sample plots located in 13 stands of the longleaf pine type. During the process of collection of field data and preliminary analysis, the number of variables was reduced to eight. These remaining variables were those that showed indications of being of value in this study.

The eight variables were then divided into two groups. One group—those variables that can be measured directly on aerial photographs—consisted of: tree height, crown diameter, crown density and number of trees per acre. The other group —those variables that cannot be seen or measured on aerial photographs—consisted of: age, growth rate, d.b.h. and volume.

A multiple regression analysis was made to determine the possible linear or curvilinear relationships that existed between each of the non-measurable factors and four measurable factors. The measurable factors that were found to be significantly related to the non-measurable factor were then used to derive a formula for estimating values of each of the non-measurable factors.

Results

The formulae were the primary product of the study. However, since the method of procedure is of greater importance, from a photographic interpretation standpoint, it seems advisable that only the expected accuracy of estimation be discussed. It should be here stated that, for the limits of the original data, all relationships were found to be linear. Even though curvilinear relationships perhaps exist in nature, all subsequent discussion is on a basis of linearity.

Several assumptions must be made and several conditions must be met before any statement of accuracy can be made regarding the estimate of a non-measurable factor from these formulae. It must be assumed that the accuracy obtainable in the determination of the measurable factors is:

Height	ten foot classes
Crown density	ten per cent classes
Crown diameter	three foot classes
Number of trees	within twenty per cent of actual

It must be further assumed that the variance in radial growth, age, d.bh. and volume, which is not accounted for by the significantly related measurable factor, is without bias. If these two assumptions can be made, and if the condition can be met that the values of the measurable factors that are applied to the formulae are within the limits of the original data and near the means of the original data, then the number of photographic plots needed to produce the desired accuracy in the estimation of the non-measurable factors can be determined. The limits of the original data are:

Average tree height	34 to 60 feet
Crown density	6 to 72 per cent
Average crown diameter	7 to 20 feet
Number of trees	4 to 42 per $\frac{1}{10}$ acre

The accuracy of estimation obtainable in a homogeneous stand when the above conditions exist is:

Radial Growth	$\pm$.044 inches of actual average growth rate at d.b.h. with 44 photographic sample plots, 95 times out of one hundred.
Age	$\pm$2.5 years of actual average age at d.b.h. with 12 photographic plots, 95 times out of one hundred.
D.B.H.	$\pm$.74 inches of actual average d.b.h., with two photographic plots, 95 times out of one hundred.
or	$\pm$.37 inches of actual average d.b.h., with seven photographic plots, 95 times out of one hundred.
Volume	$\pm$9.6 cubic feet of actual average volume with 29 photographic plots, 95 times out of one hundred.

The above stated relationships and expected accuracy apply only to the longleaf pine type found in the study area. The relationships found to exist in this area may not be applied directly to other areas or other species, but similar relationships may be found to exist.

By using an approach such as here described, it is possible for the photo interpreter to make estimates of values in forestry or similar activities that can be determined from aerial photographs in no other way.