ESTIMATING INCREMENT FOR INDIVIDUAL TREES ON THE U.S. FOREST SURVEY

(The Place of Individual Tree Growth Estimation in an Extensive National Forest Survey)

Benjamin SPADA, Robert B. POPE

Introduction

The Forest Survey, a nationwide inventory of forest resources conducted by the U.S. Forest Service, is continually refining its objectives and modifying its procedures to better meet its goals. To this end the field plot was redesigned nearly 10 years ago, and the Forest Survey is about to begin a cycle of remeasuring these plots. One of the principal objectives of this remeasurement is to estimate timber growth.

Before starting on the remeasurement cycle, an effort is being made to anticipate problems in estimating growth, and to devise solutions to these. A review of the literature reveals that, although much has been written about estimating timber growth, detailed procedures for solving some of these problems are still lacking. Thus, it is necessary to devise tentative solutions until such time as research results provide more definitive answers.

The purpose of this paper is to illustrate the needs of one nationwide forest inventory for estimates of timber growth, and to point out some of the problems expected in estimating individual tree increment from plot remeasurements, some tentative solutions to these problems, and the need for more research to develop improved methods of estimating individual tree increment and related stand growth.

Growth Requirements

Like most forest inventories, one of the objectives of the U.S. Forest Survey is to estimate the total amount of timber growth on the area inventoried. However, in order to achieve other specified goals, growth estimates must meet two other requirements: they must provide realistic estimates of the net growth i.e. the increase in volume of a specified size class for a specific year, at each field plot location, and these estimates must be in terms of "trend level" current annual growth rather than periodic annual growth. That is, the estimates of current annual growth should be free from the annual and short-term variations of climate and mortality. Instead they should reflect the long-term trends of these influences--hence, the use of the qualifying words "trend level".

Estimates of growth on individual plots are needed in order to appraise the productive condition of the land and timber. An analysis of the present growth relative to current stand conditions forms the basis for judging what kind of management treatments can be used to increase net growth or redistribute it to the most desirable species, age classes, or quality classes.

The two principal uses for growth estimates are for evaluating the productive condition of the forest land and for projecting the existing timber growth and growing stock into the future. Periodic growth, the growth that has occurred during some past period, is not as suitable for these purposes as current annual growth, the growth currently being put on by the existing inventory.

Projections of the existing growth and growing stock volume is currently accomplished through the use of Forest Survey's stand projection program[2/] This program projects changes in timber volume in response to net growth and timber removals. This procedure is used to update inventories to a common date for periodic national compilations of the Nation's timber resource statistics, to help analyze and interpret changes in the timber resources between surveys, and to project future timber supplies under various management assumptions.

Growth Estimation Problems

At present the U.S. Forest Survey is still in a period of changing over from several kinds of fixed or variable radius field plots to a standard cluster of 10 variable radius plots. Thus, growth estimates must be based on remeasuring a set of trees on one kind of plot, while the current inventory is based on measuring a different set of trees on a new kind of plot. Under these conditions it has been possible to obtain unbiased estimates of total net growth. However, efforts to obtain an estimate of growth for a particular plot, which is realistically related to the inventory and other conditions existing on that plot, have not been as successful.

This task should become easier in the near future when inventory, growth, and conditions affecting growth such as mortality are all obtained from the same sample plot location. However, it is evident that plot remeasurement by itself is not going to solve the problems associated with obtaining estimates of trend level current annual growth by plot.

2/ Larson, Robert W. and Goforth, Marcus H. 1970. TRAS A Computer Program for the Projection of Timber Volume. USDA Agriculture Handbook No. 377. 24 pp, illus.

Estimating Periodic Change

The estimation of net volume increment for an individual tree requires measuring or estimating the change in the basic dimensions of the tree. These are generally considered to be: (1) diameter at breast height (d.b.h.), (2) total height, (3) form, (4) bark thickness, and (5) defect or merchantability percent. In attempting to measure periodic change in these dimensions, problems arise from two causes: changes in some of the tree dimensions cannot be directly measured, and other dimensions are so expensive to measure that it is feasible to do so only on a subsample of the inventory tally trees.

Periodic change in d.b.h. is the simplest dimension to measure, and it is easy enough so that it can be done on every tally tree. However, even in the case of measuring periodic change in d.b.h. there are problems. The principal problem seems to be the identification and correction of past measurement errors. Overestimates of past d.b.h. are likely to be detected because they tend to result in zero or negative diameter growth. On the other hand, underestimates of past d.b.h. will be detected only if the error is large. No matter what rules are set up for questioning past d.b.h. measurements, it seems evident that most of the errors that are detected and corrected will be of one type, and that the estimates of diameter growth from remeasurement will therefore be biased on the high side. One can only hope that this bias will be small and that it will tend to disappear completely on succeding remeasurements.

In parts of the country where trees are short, the periodic change in total height can be estimated by remeasurement, using extendible graduated poles or hypsometers. However, with tall trees the error in measurement is likely to exceed the height growth, and some sort of indirect procedure must be used. A possible approach which appears reasonable is to make use of the available families of site curves. By using such curves it is possible to estimate the periodic height growth of a tree based on its current height and the length of the period.

Although it is physically possible to measure periodic change in form and bark thickness, it is an expensive process, and on an extensive inventory like the Forest Survey it is usually necessary to confine these measurements to a subsample of the trees tallied on the field plots. Hence, estimates of the change in these dimensions for the remaining trees must be inferred indirectly. Fortunately, there is a logical procedure for doing this that seems to answer the problem satisfactorily.

For many species there is a substantial amount of data available on the relationship between bark thickness and diameter outside bark. This relationship is usually consistent enough so that bark thickness can be reasonably inferred from diameter. Moreover, it is feasible to develop a gross volume table from detailed measurements made with a dendrometer or optical caliper on sample trees. Such a table will incorporate in it the amount of change in form and bark thickness that is associated with given amounts of change in d.b.h. and total height.

Predicting the change in volume for forked or otherwise non-normal trees that may not be included in the measurement subsample is a particularly perplexing problem. Perhaps the best thing that can be done is to develop a special gross volume table for such trees.

The periodic change in merchantability percent associated with defect is the one volume dimension that cannot be measured, even on sample trees. In order to determine the net inventory volume on a plot-by-plot basis, it is necessary to estimate the defect in each tree tallied. However, this is essentially a subjective process, unless destructive sampling techniques are used. Since in most cases this type of sampling cannot be used if a set of permanent plots is to maintained, one must settle for subjective estimates. The difference between two such subjective estimates on a particular tree at two different occasions in time cannot be considered a reasonable estimate of the real change in defect over time. Consequently, this change can only be arrived at indirectly. The best hope would appear to be the development of families of curves of defect over age or over diameter so that change in defect could be inferred from the estimate of current defect and the change in age or diameter. These curves could be developed from the defect estimates obtained at the most recent remeasurement, or from special studies using destructive sampling.

Estimating Trend Level Current Annual Net Growth

The change in tree volume dimensions obtained by remeasurement are periodic changes. What is needed to satisfy Forest Survey's demand for estimates of current annual growth are the trend level current rates of change in these dimensions. Since d.b.h. is the only dimension for which change is measured directly, the problem boils down to one of selecting a suitable method for obtaining an estimate of current annual diameter growth from a measured periodic diameter growth.

Remeasurement of a tree gives d.b.h. at the present occasion and d.b.h. at the past occasion. What is needed is a reasonable assumption about the shape of the curve of d.b.h. change over time. The most logical assumption appears to be that basal area increment is constant over time. Over long periods of time this probably doesn't hold true, but for relatively short time periods it seems to be reasonable. Application of the principle is simple. From the measurements of d.b.h. past and present, the periodic annual basal area increment is calculated, and this is assumed to also represent the current annual rate. From this it is possible to calculate the current rate of diameter growth which is associated with this rate of basal area increment.

In an extensive forest inventory, like the U.S. Forest Survey, change in the remaining tree dimensions is generally estimated indirectly rather than measured directly. Indirect estimators of dimension changes will produce growth estimates for each plot that differ from reality because of pooling. However, this simplifies the task of estimating the current annual rates of change. If change in total height is obtained from a family of site curves, it is easy to estimate the current rate of height growth for a tree of given height and age. If change in form and bark thickness are built into the gross volume table, then changes in these dimensions are associated with changes in d.b.h. and height. When current rates of d.b.h. and height growth are used with such a volume table to estimate gross volume increment, current rates of change in form and bark thickness are also implicitly used. The resulting gross volume increment is therefore also a current rate. Since rates of change in defect or merchantability percent are also estimated indirectly by association with changes in other tree dimensions, the use of current rates for these dimensions will result in estimates of current rates of change in defect.

As yet the U.S. Forest Survey has no plans for trying to adjust the estimates of individual tree increment for short-term variations in climate. Estimates of stand net growth are sometimes adjusted downward or upward when it appears evident that past periodic mortality has been abnormally high or low when compared to long term trends. However, the growth of individual trees, as calculated by the procedures outlines, will be accepted as trend level.

Estimating Growth on Individual Plots

The growth procedures just discussed are aimed at producing estimates of net increment for each surviving tree tallied on the inventory plot. If these principles are extended to the remaining trees--those that die, are cut, become culls, or ingrowth--then a reasonable estimate of mortality, gross growth, net growth, and timber removals for each plot should be obtained. However, there are two other problems that must be resolved before this goal is satisfactorily met.

Occasionally a plot will have been severely disturbed shortly before measurement, perhaps by thinning or other cultural treatment, or by heavy mortality. In such cases the periodic change in tree dimensions is not a satisfactory basis for estimating the current rates of change. Perhaps boring the trees to obtain current rates of diameter growth is the only solution to this situation.

Another problem crops up when an attempt is made to insure that the estimated growth on a plot is related to the inventory and other conditions tallied on that plot. Individual tree increment is determined by remeasurement only for those trees tallied at both occasions. However, with variable radius plots there will be trees tallied on the second occasion that were not tallied on the previous occasion. These trees will contribute to the estimate of plot volume and current conditions, but not to the estimate of current growth. There would appear to be two

possible solutions to this problem: bore these trees for current diameter growth rates, or predict their current growth using multiple regression equations with various individual tree and stand characteristics as independent variables.

Conclusion

In conclusion it seems essential that we be able to estimate the individual plot net growth associated with changes in tree dimensions resulting from changing plot characteristics.

Better procedures for measuring the components of net growth and relating them to unique stand and site characteristics are needed when available they will produce better growth predictions and also the means to evaluate past forest management activities and future management alternatives.

The U.S. Forest Survey has made much progress toward achieving these goals. Remeasurement of identical plots will further improve the situation. However, it is still recognized that the necessity of having to use aggregated data for changes in individual tree height, defect, and form class underestimates true differences in net growth plot-by-plot and better methods to directly measure these changes tree by tree are still needed.

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Benjamin Spada, Robert B. Pope

Summary

The Forest Survey, a periodic inventory of all forest lands in the United States, is about to begin a cycle of plot remeasurement. One of the principal objectives is to estimate the trend level of current annual net growth for each plot so that it can be related to the forest conditions on that plot. Periodic growth in tree diameter can be measured directly, but change in height, form, bark thickness and merchantability percent must be estimated indirectly. Tentative procedures for converting periodic diameter growth to current annual diameter growth, and for indirectly estimating the current annual change in the other tree dimensions, have been adopted. However, additional studies are needed to improve these methods so that the estimation of increment for individual trees better meet Forest Survey objectives. Also needed are better procedures for measuring or predicting the individual tree components of net growth and relating them to unique stand and site characteristics.

ZUWACHSBESTIMMUNG FÜR EINZELBÄUME BEI DER U. S. WALDINVENTUR

(Die Position der Zuwachsbestimmung von Einzelbäumen in einer umfassenden nationalen Waldinventur)

Benjamin Spada, Robert B. Pope

Zusammenfassung

Die Waldinventur, eine periodische Inventur aller Waldflächen in den Vereinigten Staaten, kommt in die Phase der Wiederholungsaufnahme der Probeflächen. Eines der Hauptziele ist es das Trendniveau des jährlichen laufenden Nettozuwachses jeder Probefläche zu bestimmen, so daß dieser in Beziehung zum Waldzustand auf der Probefläche gebracht werden kann. Der periodische Zuwachs der Baumdurchmesser kann direkt gemessen werden, wogegen die Veränderungen der Höhe, der Form, der Rindenstärke und des Prozentsatzes des vermarktungsfähigen Holzes indirekt bestimmt werden müssen. Versuchsverfahren zur Überführung des periodischen Durchmesserzuwachses in den jährlich laufenden Durchmesserzuwachs und für die indirekte Schätzung der laufenden jährlichen Veränderungen der anderen drei Baummerkmale wurden eingeführt. Es sind jedoch weitere Untersuchungen erforderlich um diese Methoden zu verbessern, so daß die Bestimmung des Zuwachses von Einzelbäumen den Bedürfnissen der Waldinventur besser entspricht. Es werden überdies bessere Verfahren zur Messung oder Vorhersage der Netto- Zuwachskomponenten der Einzelbäume benötigt, die zu den jeweiligen Bestandes- und Standortsmerkmale in Beziehung zu setzen sind.

Übersetzt von J. Pollanschütz

PROJECTIONS DE LA CROISSANCE INDIVIDUELLE DES ARBRES DU RAPPORT DU SERVICE FORESTIER DES ETATS UNIS

(La place de la croissance projectée de l'arbre individuelle dans un rapport extensif du Service Forestier National)

Benjamin Spada, Robert B. Pope

Résumé

La Rapport Forestier, un inventaire periodique de tous les terrains couverts de forêts aux Etats Unis, est en train de commencer un nouveau cycle d'arpentage des terrains. L'un des principaux objectifs est d'estimer le niveau relatif de la croissance annuelle nette pour chaque terrain de façon à le rapporter aux conditions de la forêt sur ce terrain. La croissance periodique de la section des arbres peut être mesurée directement, mais le changement en hauteur, forme, épaisseur du liège et en pourcentage de la valeur commerciale doivent être estimés indirectement. Des procédès tentatifs pour convertir la croissance periodique de la section en croissance annuelle courante de la section, et pour estimer indirectement le changement, annuell courant dans les autres dimensions de l'arbre, ont été adoptés. Cependant, des études additionnelles sont nécessaires pour améliorer ces méthodes de façon à ce-que l'estimation de l'augmentation des arbres individuelles sont plus compatibles avec les objectifs du Rapport Forestier. Des meilleurs procédés sont également nécessaires pour mesurer et prédire les constituantes de la croissance nette de chaque arbre et d'établir leur rapport vis a vis leur position unique et les charactiéristiques de leur site.

EL ESTIMACION DE CRECIMIENTO PARA LOS ARBOLES INDIVIDUALS EN EL RECONOCIMIENTO FORESTAL DE LOS ESTADOS UNIDOS

(El Parte del Estimación de Crecimiento de los Arboles Individuales en un Extensivo Reconocimiento Forestal Nacional)

Benjamin Spada, Robert B. Pope

Resumen

El Reconocimiento Forestal, un inventario periódico de todos los bosques en los Estados Unidos, va a empezar otra vez un ciclo de mediciónes de las parcelas. Para estimar el dirección periódico del crecimiento neto anual corriente para puede relacionarse con los condiciónes forestales por la misma parcela es uno de los objectivos principales. Es posible medir directemente el crecimiento periódico en diametro del arbol pero hay que estimar indirectemente los cambios para altura, clase mórfica, espesor de corteza, y porciento que es comerciable. Han sido eligado los procedimientos tentativos para convertir el crecimiento periódico de diametro hasta crecimiento anual corriente de diametro y para estimar indirectemente el cambio anual corriente por los otros dimensiónes del arbol. Sin embargo, necesitan los estudios adicionales para mejorar estos métodos para que el estimación del incremento por los arboles individuales pueden realizar mas los objectivos del Reconcimiento Forestal. Tambien necesitan unos procedimientos mejores para individuales y asociarlos con característicos únicos del rodal y el estación.