GROPE: A STANDARDIZED GROWTH PROJECTION METHOD FOR TROPICAL RAIN FOREST

by

D. ALDER, T.J. SYNNOTT and J.P. SMITH

ABSTRACT

Describes a computer program, GROPE, currently under development which utilizes flexible multivariate models for tree growth, mortality, and ingrowth to project growth on permanent plots in tropical rain forest. The data consist of tree characters, remeasured at intervals, and optional quadrat characters as stand density indices. Simulation is stochastic, with Monte Carlo generation of random normal deviates from the fitted regressions. The printed results consist of stand tables comprising observed and forecast numbers of trees, basal areas and volumes on the plots.

1. INTRODUCTION

The work described here evolved from earlier studies in tropical rain forest growth simulation by SYNNOTT and SMITH, using a program called GROWTH, originally written by I.A. ANDREW*. In GROWTH, diameter increment is predicted from diameter for each tree, and the increment used to update the stored diameter for the next growth cycle. The parameters for the regression of increment on diameter are estimated for species groups. The residual error of the regression is used as the basis for the generation of normally distributed random deviates which are added to the predicted increments to give a stochastic growth model. Apart from diameter growth, GROWTH incorporates mortality and ingrowth, both on a stochastic basis. Mortality is based upon a mean rate derived from the data, and a mean diameter for dying trees. The number of trees predicted to die in a growth cycle is removed from the simulation, the actual selection being made from those trees closest to the average diameter for dying trees. Ingrowth is likewise predicted as an average rate, with a stochastic function to assign to ingrowing trees diameters similar to the mean for observed ingrowth.

* now senior Biometrician, Forest Research Institute, Rotorua, New Zealand

GROPE** was designed as an extension of GROWTH to incorporate the additional variables that have been measured on many permanent plots, in addition to diameter, into the predictive equations for tree growth, mortality, and ingrowth. Such variables may be, for example, codes for crown position and crown form, height, and basal area and stem numbers on the quadrat in which the tree is situated. The principal was adopted of specifying the simulation in terms of a general model that was independent of the actual tree or quadrat parameters measured in a given case; the latter are defined by the user of the program on data cards.

An additional extension that is planned once the initial program has been tested fully is to incorporate stand treatments by specifying a variety of cutting effects to alter the competitive status and relative canopy position of trees; and to allow alterations in species competition through selective enrichment or cutting practices.

2. THE GENERAL MATHEMATICAL MODEL

An equation of the form given below provides the basis for stochastic prediction of changes in the values of tree and quadrat parameters, for mortality, and for ingrowth for each cycle of simulated time. The model is linear in the mathematical sense in that it can be fitted by non-iterative least squares analysis to obtain reasonable estimates of the coefficients. The random error terms are derived from a normal distribution with a mean of zero and standard deviation derived from the regression analysis.

The equation is: -

$$Pi = ri \left\{ fi \left[b_{iok} + \sum_{j=1}^{Mi} b_{ijk} \cdot g_{ij} + N(S_{ik}) \right] \right\} \qquad (1)$$

where:

Pi is the predicted value, which may be rate of change of diameter, crown position, height etc. for individual tree growth; basal area for aggregate quadrat growth; stem numbers for ingrowth to the class of measured trees; first observed values for ingrowth trees or a zero-one mortality predictor.

** GROPE is an acronym for Generalized Rainforest Out-turn Projection Evaluator.

i is a model serial number, used to refer to the parameter being predicted.

r_i is a rounding and truncation function. Some values, such as crown position may be limited to, for example, integer numbers in the range 1-5. Appropriate setting of r takes account of such effects.

f_i is a transformation function to allow the logarithm, exponent, or reciprocal of the predicted variable to be used. This allows a flexible variety of curvilinear relationships when combined with the possible g_{ij}.

j is an index denoting the coefficient number in the equation.

k is an index referring to a particular species group. The regression coefficients and error terms b and S will vary for each species group.

g_{ij} refers to a variable which is constructed according to data supplied by the user, from the set of available tree and/or quadrat parameters. In equations for ingrowth, only quadrat parameters may be used. The various parameters may be used to create a given g_{ij} by: -

(1) simple substitution i.e. g_{ij} may represent diameter, crown form, etc.

(2) multiplicative or additive interaction e.g. g_{ij} may be (height x basal area), or (crown position - crown form)

(3) transformation e.g. g_{ij} may be log (diameter).

N refers to a normal distribution function with mean zero and standard deviation S_{ik} unique to each species group.

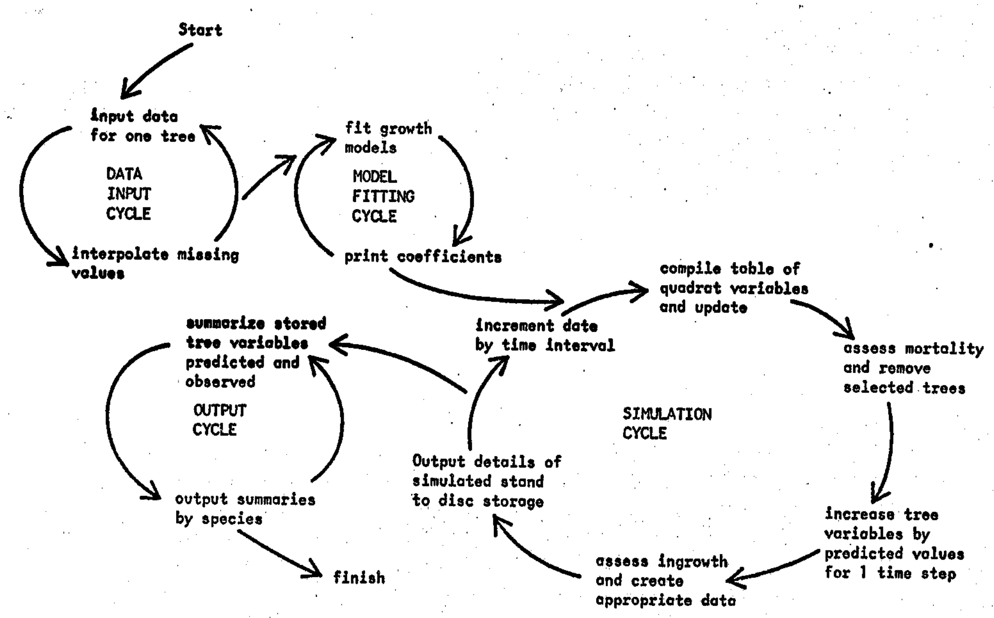
3. STAGES OF PROGRAM OPERATION

The main stages in operation of the simulation program are shown in figure 1. The plot data consist of any set of data referring to tree measurements; the actual factors measured must include diameter, and optionally any other factor. The plot may be subdivided into quadrats, in which case quadrat variables may also be included as measures of competitive status or as relevant to ingrowth. Experiments may be simulated by regarding the whole experiment as a single plot and the treatment replicates as quadrats. The program is designed especially for those plot layouts in which

not all trees on a plot or quadrat are measured; it can however cope as well with those cases where there is complete coverage of all stems. The program is also designed to deal with cases where not all trees are measured in each assessment. In these instances, an interpolation routine inserts the missing values, as the data are read by the program.

The model specifications refer to the construction of the g_{ij} from the various available tree and quadrat parameters. It is necessary to specify one model for the growth or change of each tree and quadrat parameter with time. These models may be very simple e.g. averages of observed changes, or very complex curvilinear models involving several interacting parameters. The program prints the models given in an easily comprehended form.

Figure 1: Main stages of GROPE



The models are then fitted to the data. The program has a facility for reserving some of the data for comparison purposes only. The b coefficients in equation (1) are fitted by linear regression to each species group. At this stage, if a species group contains insufficient observations to fit a model (i.e. the number of b coefficients is greater than or equal to the number of observations) the species groups are merged, commencing with the least abundant group and proceeding until a model can be fitted.

The program then enters the simulation phase. The actual time intervals used are specified as a series of dates given by the user commencing with the dates of data measurement. Simulation proceeds in steps of one year, by firstly computing the changes in each tree or quadrat variable, and the likelihood of a given tree dying during the period. Secondly the number of new trees is computed, and for each new tree, a set of parameters achieved from the models fitted to the observed ingrowth. During the year for which a date of measurement or projection is given, the simulation is adjusted to give a proportional fraction of all observed changes, and the entire set of tree parameters is stored for that date, for recovery in the final phase.

The final phase of the program involves retrieval of the stored data, and the simulated tree parameters, and their output as a series of stand tables, broken down by diameter classes and dates for each species group and for the whole stand. The stand tables are arranged to show predicted and observed values and their differences for dates for which data are available; and then the predicted values only for the later dates for which data are not given.

4. DISCUSSION: GROPE AND MAB

GROWTH and GROPE have demonstrated the feasibility of using conventional permanent plots as the basis for the construction of systems models to predict yields from tropical rain forest. GROWTH suffered from the weakness that for many species and situations, the correlation between increment and diameter was very low indeed; nor could treatments be incorporated into the model. GROPE allows such obviously significant factors as crown position to be included in the growth equations, and measures of competition derived from quadrat parameters. As such it can be expected to provide the basis for significant advances in yield prediction studies in tropical rain forest.

There are deficiencies in GROPE that principally arise from a lack of feedback between competitive and growth processes. This shortcoming is necessary because of the basis of tree selection on many TRF permanent plots. The selection of measurement trees is usually based upon technological or marketing factors. A tree may disappear from a series of measurements (and therefore constitute "mortality") because, for example, it has broken at half height as a result of a typhoon. In its place another tree will be selected, constituting "ingrowth". Yet the first tree is still an important ecological entity that may compete with or contribute to the growth of other trees.

It is hoped that plots established under the Man and the Biosphere program will provide data that are more complete in that all trees on a plot will be measured. In such cases, it will be possible to augment GROPE by incorporating feedback between competition indices and tree growth and to compare the utility of results from such situations with other sources of TRF permanent plot data. Needless to say, such studies cannot be attempted until at least two remeasurements are available from a plot. Analysis and elucidation of results from the treatment experiments on MAB plots will be greatly facilitated by GROPE and similar systems models.