



CO-OP REDWOOD YIELD RESEARCH PROJECT

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Research Note No. 14

June 1, 1980

CONCEPTS, DESIGN, AND USES OF COASTAL GROWTH MODELS

by

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ABSTRACT

This research note describes the concepts, design, anticipated use, and current status of the coastal growth models developed through the Cooperative Redwood Yield Research Project.

I. INTRODUCTION

The major focal point of the Cooperative Redwood Yield Research Project has been the development of models to predict both stand growth and the impact of various management practices, which are largely in the form of partial harvests. These models will then be imbedded in computer programs to facilitate the handling of large amounts of input data, to perform the necessary computations and predictions, and to present results in a usable form. As most computer programs invariably get tagged with some form of a name, we have chosen "CRYPTOS" (Cooperative Redwood Yield Project Timber Output Simulator) as an appropriate acronym.

This note provides a general overview of how these models can be used to provide information to forest managers.

II. CONCEPTS

The general guiding philosophy that has been followed in the development of coastal growth and yield models can be summarized by the following points:

- (1) The models should be flexible enough to adequately portray differences in stand development due to species mix, structure and size distribution by species.
- (2) The models should be capable of predicting stand response to a variety of possible harvest prescriptions.
- (3) The models should be capable of accepting a wide range of input data.
- (4) When actual historical growth data is available, it should be possible to "calibrate" the models to a specific stand.

The basic design concept employed in the construction and anticipated use of the coastal growth models represents a departure from the "traditional" managed stand yield table model. In the traditional model, growth, yield, and harvest data are presented based on a stand that is assumed to be optimally stocked from its inception or at least from a point in development corresponding to the initial tabular description in a conventional yield table. The resultant yield table and harvest report are subsequently presumed to represent an optimum relative to some management goal.

The coastal growth models however were developed from a pragmatic user-oriented viewpoint. Relative to the "traditional" yield model, our design concept is characterized by

two fundamental departures:

- (1) The models are intended to be applied to stands as they actually exist. From a practical point of view, stocking in most young-growth coastal stands is a result of past natural processes. Most of these stands are probably not considered to be optimally stocked by the managers in charge. Hence, the intended use of the models is to provide some indication of how specific unmanaged stands should best be managed. This distinction in design is necessary to make the models of practical use.
- (2) There is no specific management goal incorporated in the models. The management aspects of growth prediction are incorporated by the manager as a sequence of harvest prescriptions. Consequently, the manager may compare harvest and yield forecasts resulting from several possible harvests prescriptions and select the one that best meets the goals of management.

The preceding design concept essentially places the burden of prescribing the optimal management regime for a particular stand on the manager. In other words, the manager must iteratively search through several regimes with the role of the growth models being an almost instantaneous mechanism for estimating the consequences. While it is certainly possible to develop a computerized optimization algorithm which incorporates the growth models programmed to find the most optimal regime relative to a specific management goal, this aspect is currently not being pursued. The basic reason is that very few managers have the same management goals. Secondly, several managers in the coastal region have indicated that they have different management objectives for different stands.

III. MECHANICS

To accomplish the first point listed above, the approach taken is generally classified as a distance independent tree model approach to stand development. In this approach, stand increment is estimated as the sum of the increments on individual trees minus estimates of mortality.

To accomplish this, an inventory plot record or a "modified stand summary is used to characterize a particular "stand". This record contains the following items for each tree:

- a) species code
- b) DBH in inches
- c) total height in feet

d) live crown ratio

e) tree expansion factor to a one acre basis

In conjunction with a DBH/total height volume equation, this record can be used to provide estimates of current volumes per acre, basal area, and other stand characteristics. Next, each tree record is subjected to the following procedure:

- (1) Five year changes in DBH, total height, and crown size are estimated by species specific increment functions. The entire plot record is used to develop predictor variables such as density (eg. basal area) and relative size (see Research Note No. 15 for a detailed description of the increment functions) for each tree. The only other information required is site index.
- (2) Another set of species-specific prediction equations are used to estimate the probability that the tree will die. The tree expansion factor is subsequently reduced by this amount.
- (3) Increments are then added to DBH, height, and crown size to provide an estimate of what the inventory record would look like if it were measured five years later. Subjecting this "projected" record to the inventory summation process provides estimates of stand yield. Differences between successive yield summaries produce growth estimates.

IV. HARVESTS

After any of the five year 'growth' cycles, the stand record can be subjected to a simulated harvest. There are innumerable harvest possibilities since an entire tree by tree representation of the plot or stand is available for modification. A tree harvest is implemented by the reduction in the tree expansion factor.

The current version of CRYPTOS has one harvesting routine that will allow the user to remove percentages of trees in different diameter classes by species. Research Note No. 16 has a detailed description of this procedure. It is emphasized that while the current harvesting routine is quite flexible, it by no means exhausts all possibilities. For example, one might wish to mimic an actual marking procedure and remove trees additionally on the basis of live crown ratios. After some experience with the model is gained, such additional features may also be incorporated.

V. INPUT DATA REQUIREMENTS

CRYPTOS contains over 50 models, all of which are based on the tree record specifications listed previously. Inventory and growth plot data are not necessarily collected to these specifications. Hence two choices exist:

- (1) Construct sets of models for every possible set of inventory specifications.
- (2) Provide the means of converting inventory data collected under different specifications to the data required to run the program.

We have made the second choice largely because the first presents a somewhat overwhelming task.

To begin with, if height measurements are made on the basis of numbers of logs, Research Note No. 9 provides models that can be used to estimate unmeasured tips. If crown sizes are not collected, Research Note No. 15 provides models that can be used to estimate height to the crown base given DBH and height. If no height data other than site tree information is available, Research Notes No. 8 and 12 can be used to estimate the entire height distribution by species.

Lastly, we have the "synthetic" situation where (for even-aged stands only) all we have are site indices, ages, and numbers of stems by species. Using both this data and the models described in Research Note No. 11, diameter distributions can be generated for each species component. Previously described sources can then be used to estimate heights and crown sizes. Research Note No. 17 is a writeup of a computer program that uses all of these models to "generate" a stand of trees and create the appropriate tree records for use in CRYPTOS.

VI. CALIBRATION FEATURES

The system of models developed for growth prediction purposes utilizes data collected throughout the entire north coast region of California. This fact coupled with the somewhat erratic nature of mortality, annual fluctuations in stand growth relative to much longer periodic trends, and the somewhat unique nature of each individual stand of trees, makes the likelihood that the growth models will exactly portray the development of a specific "on-the-ground" stand of timber somewhat remote.

While there is apparently little that can be done to account for short term fluctuations in predicting future stand development, there may be some situations where the

overall growth trend predicted by the models may warrant adjustment for a specific stand. Two basis for model adjustment or "calibration" are available:

- (1) Subjective adjustment based on the manager's experience.
- (2) A methodological adjustment based on a comparison of actual past stand growth data with model predictions.

Allowance for the first type of adjustment is founded on the premise that the growth models by no means are considered to be an absolute "hewn in stone" prediction for all possible coastal stands subjected to all possible harvest prescriptions. While considerable care has been exercised in the selection of appropriate design logic, statistical methodologies, and data in model construction and validation, there are some situations where these models will be used which have no empirical data base for support. Indeed, these situations are the fundamental reasons for which the Cooperative was established - to provide information on young-growth forest management in a region where young-growth forest management is relatively in its infancy. Consequently, if managers for any reason wish to alter the absolute level of the yield predictions, a methodology is available.

The second type of adjustment utilizes a different kind of reasoning to calibrate the models. In this case, the actual past performance of the stands themselves are used as the bases for determining the predictive validity of the growth models. If differences between actual and predicted performance are significant, adjustments can be made so that the overall yield prediction is currently "right on".

The entire mechanics of calibration is still in the process of being worked out although preliminary methods based on relatively simple correction procedures have indicated substantial increases in predictive capabilities.

VII. USE

The basic core of models that constitute the Redwood Yield model provides a versatile means of supplying information on growth, yield, and response to harvests for specific stands. To make maximal use of the coastal growth models requires users to have access to a computer and the programming capabilities to implement specialized user specific modifications. It is realized that not all anticipated users have computer access or for that matter, not all possible uses require continual computer access. Hence, the following user/use categories are recognized:

- (1) No computer access
 - a) general yield tables
- (2) Computer access
 - a) standard computer programs
 - b) user specialized programs

General Yield Tables

As one of the final documents of this project, a collection of "managed stand" yield tables will be published and distributed. These tables will utilize the stand generator program to provide a standard initial description of stands with varying species mixes and densities. Yield projections will be made for each of these stands under a general assortment of harvest prescriptions. While a document of this nature was implied in the original objectives of this project, we feel that this is probably a limited use of the entire yield projection system. These tables provide some basis for generally comparing management impacts on a certain general class of forest stands. However, when one considers all of the different possible species mixes, densities, stand structures, and management possibilities, these tables may not be totally adequate.

Standard Computer Programs

Standard computer programs are to become available so that potential users may install them on their own computer systems with relatively minor modifications. In addition, CRYPTOS will remain available on the UC computer system at least until July 1, 1981. In either case, CRYPTOS can be used in an interactive mode or a batch mode.

Interactive Mode

The interactive mode is currently installed on the University's PDP 11/70 computer system. It is operated from a computer terminal by responding to "prompts" generated by the program. Full operating instructions for the interactive version of CRYPTOS are given in Research Note No. 15.

This mode uses a representative stand table or a single plot record tailored to the specifications previously described as input. The stand generator program (see Research Note No. 17) can be used to create an input file for even-aged stands based on broad stand characteristics (age, species composition, site index, and number of trees). This mode has several uses which include:

- (1) Setting general harvesting guidelines for stands of different characteristics.

- (2) Inputting early stocking levels to be used in conjunction with precommercial thinning prescriptions.
- (3) Rapidly exploring growth and yield responses to changes in stand characteristics.
- (4) Identifying possible limitations and inconsistencies in the models.

Ideally, the fourth use of this model would eventually vanish. However, when we consider that the models are supposed to describe the growth and yield of the "universe" of coastal stands (barring virgin old growth), perfection at this stage is somewhat of a heroic hope.

Batch Mode

The batch mode of CRYPTOS uses the same models as the interactive mode, but the entire "input stream" must be specified in advance. This mode is currently implemented on the University's CDC 6400 computer system, and is considerably faster and less expensive to operate for large data sets. Thus the analysis of whole inventories are best done using the batch mode.

In an actual production framework, we envision the following situation. An estimate of growth and yield for a particular tract of timber is desired. A sample of inventory plots are measured. A batch processor program would then make growth and yield estimates for each plot, simulate harvests on them if they met certain requirements, and aggregate the plot growth and yield estimates to get an overall estimate for the entire tract.

It is true that one might initially aggregate all plots to get a representative per acre stand record and use the interactive model or a simpler "one plot" batch processor to accomplish the same thing. However, this procedure is not recommended for the following reasons:

- (1) Loss of information - inventory data is used for a variety of purposes. Plot data is frequently segregated by a variety of characteristics to compile statistics for several possible management uses. Aggregating plot data into a single "stand table" precludes this process. The batch program can essentially create an estimate of a future raw data inventory file.
- (2) In actual harvest operations, we usually heavily thin the dense portion of the stand and use some moderation in lightly stocked areas. These within stand density differences are depicted by the density distribution of sample plots. Using the batch mode, some of these plots will be passed over or lightly harvested while

others will be heavily thinned. Using an aggregate stand table, the same harvest prescription applied to single plots might produce a radically different "leave stand". Hence, we feel that the batch mode applied to individual plots provides a more realistic picture of what might actually happen in a harvest.

- (3) In heterogeneous tracts, we feel that the single aggregate stand table projection may be inaccurate. As an extreme case, consider a tract composed half of non-stocked areas and half of densely stocked stands. The aggregate approach would consider this as a single uniform moderately stocked stand. It is rather obvious that the aggregate stand table approach would produce a radically different yield estimate than the plot by plot approach which we feel is more accurate.

User Specialized Programs

Some users may wish to modify the standard programs or create their own version so as to be more compatible with existing inventory and data systems. To facilitate this type of use, an analyst/programmer's guide (Research Note No. 19) is being prepared which documents the logic and linkage of all of the component growth models in the yield projection system.

Inventory Update

As another possible use of these models, we note that the design, groundwork, and data processing required to do conventional inventories is a costly undertaking. The models presented here offer an alternative to this usual procedure. On stands that have prior inventories and have not been subjected to radical harvests, the growth models offer a relatively inexpensive means of estimating an updated raw inventory data file. An analysis of the relative costs and precision of this type of procedure compared with conventional inventory updates is one of the major logical extensions of growth model development.