Draft Report to FRAMES Committee

Yield equations for regrowth forests regenerated from fire on the southeast coast of New South Wales

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Introduction

Regrowth forests constitute a substantial proportion of the forest estate under the management of State Forests in south-east N.S.W.. They are managed for multiple use, with wood production and biological conservation being the most important management objectives. Managing these forests for multiple use has greatly increased the demand for accurate growth and yield information on forest management. To provide forest managers the ability to determine the growth and yield of these forests, research has been carried out to develop growth and yield models for the regrowth forests in south-east N.S.W. (Bi 1994, Bi and Jurskis 1996). In addition, forest inventory is providing for each management unit stand level attributes such as nominal stand age (year of logging or fire), number of retained old trees per hectare, regrowth stand density and diameter class (as determined from the crow size of trees on aerial-photos). These stand characteristics from inventory can be inputted in growth and yield models to predict future stand growth and yield of the regrowth forests.

The forest management system has undergone a considerable change since the inception of integrated harvesting in 1969 (Bridges 1983). The management regime for a particular regrowth stand depends on its productivity and site conditions. Some stands are never to be thinned, while others can be thinned more than once before harvesting. This paper concerns the development of growth and yield models for unthinned stands regenerated from fire in the coastal area of south-east NSW.

Study area

The south-east regrowth forests of N.S.W. lie within latitude 36°21' to 37°28' south and longitude 149°01' to 150°50' east. The region can be broadly divided into a tableland area and a coastal area, each with a diversity of forest types. The coastal forests consist mostly of dry sclerophyll forests where *E. sieberi* is the predominant commercial species. It can grow in pure stands, but is often found in association with *E. obliqua*, *E. cypellocarpa, E. fraxinoides, E. dalrympleana, E. muellerana, E. radiata, E. dives, E. longifolia, E. globoidea* and *E. viminalis*. The coastal area is warmer and receives less rainfall than the tableland area. The mean annual rainfall ranges from 700mm to 1000mm. The mean annual temperature is between 13 and 15°C and the mean minimum temperature in the coldest month is in the range of 5-8°C. The elevation of these areas varies from 20m to 650m above sea level. The parent material in many of these areas is either Devonian or Ordovician sediments (Kelly and Turner 1978).

Wild fire has had a pronounced effect on the regeneration and age structure of the coastal forests (Bridges 1983). High intensity fire can destroy all trees and induce dense even-aged regrowth stands. Stand densities of 85000 trees/ha within six months after fire, of 30,000 trees/ha at age 9 and of 3300 trees/ha at age 32 have been reported (Bridges 1983, Jurskis, unpublished report).

Methods

Data

The data used for developing the yield functions consisted of growth plots established in the early 70's in 1939, 1952 and 1964 fire regrowth stands, control plots from four thinning trials and control plots from fertilizing trials. These plots are distributed over a range of site conditions in four state forests: Nadgee, East Boyd, Bruce Creek and Mumbulla. Measurements of these plots normally include DBH of all trees and the height of a few dominant trees in each plot. Occasionally height was measured for all trees or not measured at all. Measurements have been carried out at irregular time intervals. Many plots were measured annually in the 70's. In more recent years most plots have been measured every 3-5 years.

Since fire is a frequent event in this region many plots have been affected by fire to some extent. Fire disturbances have brought a great deal of 'noise' into the growth data making data analysis very difficult. A previous analysis of the data by Bruskin and Horne (1990) found a number of shortcomings which reflected the quality of the growth data from these plots. In this study, plot measurements taken after fire were not used since the data represented the coppice growth only, but not the growth of the original stands.

Stand volume estimation

Underbark stem volume was calculated for regrowth trees in each stand using volume equations developed by Bi (1996, unpublished report) for eucalypt species in the study area. For trees without height measurements, height was predicted using height-diameter equations developed by Bi (1997, unpublished report). Then the predicted height was multiplied with the mean ratio of observed height and predicted height of trees with height measurement in each plot to reduce bias of prediction. The sum of individual stem volumes of regrowth trees was taken as the volume of the regrowth stand.

Density of upper canopy trees

In stead of stand density, density of upper canopy trees (dominant and co-dominant trees) was used as a variable in the yield equations developed in this study. Ingrowth induced by minor fire disturbance such as fire hazard reduction burning influenced the changes in stand density to a large extent, but it had only a minor influence on stand volume growth. Measurement of ingrowth trees was not always accurate and consistent, which reduced the accuracy of data on stand density which was largely driven by the changes in the number of smaller trees in a stand over time. These small trees were not a major component of stand volume growth. In comparison, density of upper canopy tree was more important in determining the growth and stand dynamics of the regrowth stands. Also, density of upper canopy trees can be more easily and accurately obtained from aerial-photos in forest inventory for incorporation into the yield equations to increase prediction accuracy.

Site productivity index

The methods of calculating site productivity index were similar to the approach used by Bi and Jurskis (1996). A maximum height-age curve was derived from all height and age data.

$$H_{\max} = 35.9833(1 - e^{-0.1789\,Age})^{2.6778}$$

The 50 largest trees/ha was selected from each plot as site trees. However, the size of some plots was too small for selecting even a single site tree from the plots using this criteria. In such cases, a minimum of two site trees was taken. For each site tree, a ratio of observed tree height over the maximum height at the same age was calculated. The mean ratio of site trees from each stand was taken as the site productivity index of that stand. For stands with more than one measurements, the average value of the index was used. Different from the conventional site index which predicts stand height at an index age, this index provides a relative measure of site productivity given the height and age of the selected site trees. It varied from 0.41 to 0.96 among the 92 sample stands.

Regression analysis

Results

The estimated yield equations are

$\ln N = 7.504 + 44.902\ S\ T^{-1} - 0.011 N_o - 3.064\ S$ $n=124$ $R^2=0.87$ (1)

$\ln V = 1.751 - 24.857\ T^{-1} + 3.360\ S - 0.006\ N_o + 0.292 \ln N$ $n=124$ $R^2=0.85$ (2)

where N is the density of upper canopy trees in trees/ha;
S is site productivity index;
T is stand age in years;
N_o is density of old trees in trees/ha;
V is stand volume in m^3/ha.

For any unthinned fire regrowth stand with a given value of site productivity index and a specific old tree density, the yield equations can generate a set of curves showing changes in density of upper canopy trees, stand volume and MAI with age. The following examples show the pattern, scale and size of model modelled responses.

Fig. 1. Predicted changes in density of upper canopy trees with age for the most productive, average and least productive sites (from left to right) within the range of observed site productivity. The three curves within the same graph show from top down three levels of old tree density: 0, 10, 20 trees/ha respectively.

Fig. 2. Predicted changes in regrowth stand volume with age for sites corresponding to Figure 1.

Fig. 3. Predicted changes in MAI with age for sites corresponding to figure 1.

References

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Fig. 3. Predicted changes in MAI with age for sites corresponding to figure 1.

Fig. 4. Predicted changes in density of upper canopy trees, stand volume and MAI with age for a hypothetical best stand when site productivity index equals 1. The maximum value of site productivity index among stands used to develop the yield functions is 0.85. The data did not include control plots from Mumbulla thinning trial due to confusion of plot size. These plots might be the most productive stands among our sample plots.

Note:

1. These curves are shown as examples. For any particular value of site productivity index and old tree density, the yield equations will generate a set of curves showing changes in density of upper canopy trees, stand volume and MAI with age. So technically the yield equations can generate a family of infinite number of curves.

2. The effects of old tree density may be less convincing because I feel that there are not enough number of plots with a range of old tree densities among the plots in fire regrowth forests.