THE STATUS OF GROWTH MODELLING OF RADIATA PINE IN NEW ZEALAND

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ABSTRACT

The history of growth modelling in New Zealand and a new method of data collection which will allow more reliable growth models to be produced are described.

INTRODUCTION

The third generation of New Zealand growth models is under development. These models will be more reliable and more flexible than previous models. Additional information on the distribution of tree sizes will be provided to meet the increased demands of more sophisticated users.

FIRST GENERATION

The first generation of growth models in New Zealand culminated in the model of Beekhuis (1966). Previous models such as Lewis (1954) had relied on graphical techniques and been restricted to unthinned stands. Beekhuis' model was a variable density yield model for *Pinus radiata*, based on a comparatively narrow data range. The model was constructed after intensive examination of data, with a considerable emphasis on the intuitive development of functions which appeared to represent growth processes, and included the concept of a height-driven growth model. The functions developed are easily examined graphically, and contain few parameters. The parameters were estimated by simple linear regression and *ad hoc* techniques.

The model seems to provide acceptable predictions within the range of the data used to develop it, but does not perform well when applied to heavy early thinnings and low final crop stockings.

SECOND GENERATION

During the 1970s more advanced statistical knowledge and the introduction of computers led to an increase in growth modelling. Available data were examined extensively with tools such

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as multiple stepwise regression. Elliott and Goulding (1976) developed a growth model for Kaingaroa which led to a proliferation of similar models. The comparative ease with which growth models could be developed resulted in a host of local versions, all unpublished, and with a wide range in accuracy and the extent to which validation was carried out. The models were developed with an emphasis on statistical significance, and with less concern for biological realities. As these models were available on local computers, they received widespread use, and an increasing degree of criticism as users carried out their own validation. Goulding (1979) discussed validation techniques and aptly warned against the adoption of models without adequate validation.

THIRD GENERATION

The experience of the seventies demonstrated that growth modellers in New Zealand had moved away from biology to statistical methodology. The widespread availability of models led to increased demands for better growth models. The experience of first and second generation modellers was called upon in the development of a third generation of models.

The third generation of models has been developed without the sense of urgency which led to the models of the seventies. As there were existing models, time could be devoted to theory. Concepts which distinguish the emerging growth models include constraining the individual components of a model while attempting to capture the dynamic nature of a forest through feedback between components, and attempting to reflect biological constraints within the limitations of a classical growth model (as distinguished from proposed physiological "mechanistic" growth models).

Garcia (1979) described the development of a system of differential equations with consistent simultaneous maximum likelihood parameter estimates. This system allows the change in status of a stand to be modelled over time. Parameter estimates have been calculated for Southland and Golden Downs (Nelson) data (O. Garcia, pers. comm.). The system of equations provides a method of estimating growth which is flexible and yet realistically constrained. Parameter estimates will be calculated for all regions where suitable data are available.

Growth models in New Zealand have been predominantly stand models *(i.e.,* they have projected the growth of a stand, and not the individual trees within a stand), although Clutter and Allison (1974) developed a diameter distribution model. Work has also been carried out on the modelling of individual tree growth. Manley (1981) and Tennent (1982) have developed respectively distance-independent and distance-dependent growth models (see Munro, 1974), for radiata pine in Kaingaroa Forest. Both models require further development and validation, but will predict the growth of individual trees within a stand, allowing for the effects of management and stand conditions.

DATA REQUIREMENTS FOR GROWTH MODELLING

Growth modellers to a great extent have used the data contained in the N.Z. Forest Service Permanent Sample Plot (PSP) System (McEwen, 1976). This extensive data set contains a wide variety of plots from many different sources. Some plots are from designed experiments, and some plots are conservancies' growth plots. The number of measurements range from 1 to over 12 with some plots measured for over 30 years.

The data set contains many accurately measured plots although many contain inaccuracies. Eliminating these inaccuracies and overcoming the problems associated with an unbalanced data set are necessary for effective parameter estimation. In a recent example several months were required to prepare and correct a data set, while subsequently one week only was required to produce a provisional model.

Although every growth modeller would appreciate a large number of good observations, it is better to have a small reliable set of data than a large unreliable data set. With this in mind a new plot system has been devised for collecting data specifically for growth modelling. Such data will be of limited use to foresters, but will be of great use to growth modellers. The new plot system will be an enhancement of the existing PSP system, and all previous PSP use will still be available.

The new plot system consists of circular plots with the intensity of data collection reducing outward from the centre. A peg is placed to locate plot centre. The distance and magnetic compass bearing to each tree are recorded, all trees are numbered and bands painted at breast height. Diameter at breast height, total height, green crown height, and pruned height are recorded for all trees within 5 m of the centre peg. The height of the tallest tree within each compass quadrant of radius 11.3 m is measured to provide an estimate of predominant mean height. The diameters of all trees are measured within a maximum radius as given in Table 1. Additional heights are measured to allow a height-diameter regression to be calculated.

TABLE 1: PLOT SIZE BY AGE

Stand Age (yr)	*Plot radius (m)*	*Plot area (ha)*
0-5	11.3	0.040
>5-10	15	0.071
>10-15	20	0.126
>15	23	0.166

Plots are measured annually for three years, unless the plot is disturbed by tending, when annual measurements are to continue a further three years after tending. As plots are measured for their final year they are replaced with a new plot in a different stand. Plots are established in stands at ages 5, 10, 15, 20, 25, 30, and 35 years, evenly distributed over site index and stocking at each age. Plots are to be measured annually between May and September, with each plot measured close to the same date each year.

The plots will provide data suitable for individual tree or stand growth models. Supplementary data may be collected to suit an individual researcher. With a limited number of observations, problems of correlated error (*e.g.*, see Davis and West, 1981) will be reduced. The turnover will prevent the data base being a monument to past silvicultural practices. Long-term growth-monitoring plots will still be required, and these may be continuations of one of the modelling plots, or separate plots. However, only a limited number of such plots will be required by growth modellers, mainly for validation purposes.

CONCLUSION

As New Zealand forest management shifted from untended stands through conservative thinning schemes to the current heavy early thinning regimes, growth modelling has evolved through to the third generation of models.

The third generation of New Zealand growth models will be based on sound statistics with attention given to biological growth processes. A specialised data set is being constructed which will enable growth modellers to obtain more precise parameter estimates. Future growth models will be more accurate and more flexible than current growth models. They will be supplanted in turn by growth models reflecting physiological modelling discoveries.

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