# APPROACHES TO PRUNED RESOURCE EVALUATION

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## ABSTRACT

*Large volumes of potentially valuable pruned radiata pine logs are about to come on stream in New Zealand. Procedures are required to evaluate pruned log quality in terms of product recovery and potential value. These must consider log volumes, external and internal log characteristics, performance under various primary processes, and the market environment.*

*Three approaches to pruned resource evaluation are discussed. An approach based entirely on prediction is used for long-term strategy planning; measurement is impossible, estimates and approximations are all that can be achieved. A second approach addresses short-term planning for a maturing resource; accuracy is improved with the inclusion of preharvest inventory and a clearer knowledge of market conditions. The third approach is aimed at providing information for log sales and is necessary when internal log description cannot be predicted without risk of large error. Very detailed log descriptions are obtained from direct measurement and these can be fed into computer simulation models that predict log processing performance.*

## INTRODUCTION

The 1985 New Zealand radiata pine estate is about 1 000 000 hectares. Approximately half of this has been butt-log pruned. The proportion of pruned logs in the state wood supply is currently quite small; for 1985-86, 76 500 m$^3$ of the 5 299 000 m$^3$ potential total sawlog supply will be large pruned logs. However, both the log supply and the proportion of pruned logs will increase quite dramatically over the next 2½ decades; in 2010-11, 1 984 000 m$^3$ (17.8%) of the 11 131 000 m$^3$ of potential total sawlog supply will be large pruned logs.†.

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Pruning may be carried out for a variety of reasons; the predominant intent in pruning New Zealand radiata pine is to add value by producing clearwood. The simplest perception of this is a clearwood sheath over a knotty core. However, pruning often produces equivalent or greater volumes of clearwood inside this sheath owing to irregular shaped and/or centrally displaced knotty cores. In a well-pruned, well-managed stand, the pruned butt logs may be worth the aggregate value of all other logs in the stand. On the other hand, belated pruning may do little more than add defects in the form of occlusion scars.

High variation in pruned log quality is known to exist in the stands to be harvested over the next decade. These stands, collectively termed the "transition crop", were planted from the late 1940s through to the early 1960s. They received a variety of silviculture schedules with differences in the timing of pruning, numbers of stems pruned, number of pruning lifts, final pruned heights, the timing and numbers of thinnings, and final crop stockings. Within a pruned stand only a portion of the final crop may have been pruned and this pruning was often to varying heights. Variations on the way silviculture was applied within a single stand were also not uncommon. The consequences of a range of attitudes to stem selection, and varying incidence and severity of stem damage incurred at pruning and thinning, have further increased the variety of the pruned transition crop. Histories of silviculture may provide indicators to pruned log quality, but initial experiences with the transition crop histories have shown these are often inaccurate and tend towards optimism. Frequently the silviculture prescription only has been recorded, not the actual timing of operations or any assessment of how well targets were achieved.

Diameters over pruned branch stubs and final log sizes are determined by site, silviculture, and rotation length. Influences on other important pruned log characteristics are less easily identified. Some of these additional log features can be categorised by external assessment, *e.g.*, sweep buttressing, fluting, and ovality; but others remain hidden inside the stem, *e.g.*, resin pockets, dead adventitious shoots, pith centrality and sinuosity, stem damage, density, and ring width. All may affect log quality. For all these considerations the pruned element of crops (*i.e.*, the pruned resource) warrants special attention.

To fully appreciate the complexities in evaluating pruned logs, it must be realised that each characteristic can assume a different importance under a different primary process path (primary processes in this paper refer to sawing, peeling, and slicing only). For instance centrality of the pith is extremely important in peeling pruned logs, but not critical in sawing, unless inflexible sawpatterns are adopted. Therefore, pruned resource evaluations are incomplete unless performance under various primary processes are considered.

Pruned resource evaluations are not limited to providing data for pending log sales. Examples of other objectives can be found in long-range planning and comparisons of theoretical regimes. The amount of effort required and level of precision possible depends on the information available and the purpose of the evaluation. This paper examines three different approaches to pruned resource evaluation.

## THE BASICS OF PRUNED RESOURCE EVALUATION

Any evaluation of a pruned resource should have four basic phases:

(1) *Log volumes and external properties:* Assessment of piece size and quantity per hectare by pruned log types.
(2) *Internal log properties:* Assessment of internal pruned log features.
(3) *Market environment:* Definition or forecasts of market prices, requirements, and preferences.
(4) *Interpretation:* Interpretation or prediction of the combined effects of phases (1), (2), and (3) on subsequent primary processing, grade outturn, and log value.

The degree to which the results of each phase can be found by prediction rather than by sampling and direct measurement depends on the resources development and recorded history and also on the context of the evaluation. Whether or not detailed measurements with their attendant costs are warranted is determined by the risks associated (for both grower and merchant) with inadequate pruned log quality definition and the price differentials between all log types.

It is suggested that a pruned resource may be evaluated at three distinct levels of resolution. Each level is appropriate for different uses and reflects a different emphasis on actual measurement versus prediction for the four phases of the evaluation. At the first level, for long-term planning, each phase is based on prediction. The second level addresses short-term planning problems and differs from the first by the inclusion of pre-harvest inventory and an existing rather than a predicted market environment. The third level is appropriate for specific pruned log sales. Volumes, piece sizes, and log descriptions in terms of both internal and external properties are determined by measurement. Prediction of results from primary processes is based on individual log process simulation models using detailed log descriptions.

A diagrammatic view of the four phases of pruned log evaluation at the three different levels of resolution is shown in Fig. 1.

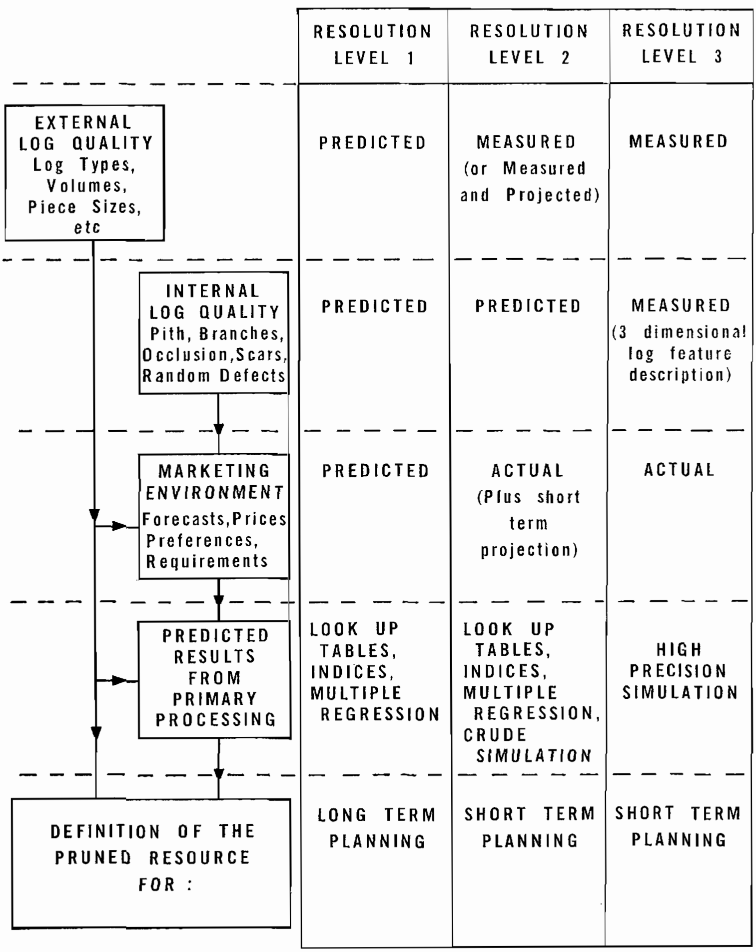



FIG. 1: *The four phases of pruned resource evaluation at the three different levels of resolution.*

## THREE LEVELS OF RESOLUTION

*Level 1*

All four phases of resource evaluation are prediction based.

(1) *Log volumes and external properties:* Yields and stock tables are predicted, *e.g.,* using both growth models (Mensuration Project Team, 1978) and the stand volume generator (Goulding and Shirley, 1979).

(2) *Internal log properties:* Branch stubs and associated occlusions are represented by parameters. These parameters are predicted using the regressions described by Knowles *et al.* (in prep.) and by Park (1982). Other relevant environmental data may be included to anticipate contingencies such as resin pockets.

(3) *Market environment:* Predicted by long-range forecasting.

(4) *Interpretation:* Predictions of grade outturn and pruned log value are made via "look-up tables", simple functions, *e.g.,* Grade Index (Park, 1980), or the multiple regressions of Whiteside (1982) incorporated into SILMOD (Whiteside and Sutton, 1983).

The resolution of information at Level 1 is appropriate for long-term planning to determine yield flow over time and to select appropriate silvicultural regimes. It is necessary to provide estimates of volume and to subdivide this volume into broad log classes suited to various primary processes with some idea of processing results and profitability. Markets are forecast so that the real situation at rotation's end remains largely unknown. Log quality can only be predicted using functions or indicator parameters and may do little more than rank a crop or portions of it by expected relative value. Interpretation of quality through detailed process simulation and comparison of results for various primary processes is inappropriate. A high degree of accuracy is unlikely to be achieved for a specific stand because of the total reliance on cumulative predictions. In the case of bare land or very young stands, even the silviculture to be applied must be predicted.

Examples of projects at Resolution Level 1 are:

(a) The Harvesting and Marketing Strategy recently adopted by the New Zealand Forest Service to determine the level of cut by region by year over the period 1984 to 2011.

(b) Comparisons of rates of afforestation and the properties and profitabilities of various theoretical silviculture regimes for the Maraetai Block (Fenton, 1972; Fenton and Dick, 1972).

(c) Regime evaluation by the Radiata Pine Task Force silviculture stand model, SILMOD (Whiteside and Sutton, 1983). This models a stand on a per hectare basis, predicts external and internal log properties, and then, for a range of sawing options, predicts timber grade outturn and profitability.

As the technique is appropriate for long-term planning, such predicted values for pruned logs must be regarded as indicative only. When sales proposals are being considered for a specific resource close to the time of harvesting, this level of resolution is not adequate. In one recent example, stand records and growth model were used to define the volume and piece sizes in a sale of pruned logs. The predicted yield of large pruned logs (>30 cm s.e.d.) was 147 $m^3$/ha and it was assumed most of this would be peeler quality. When the stand was eventually assessed it was found the stand records were seriously in error in terms of stocking and the proportion of pruned stems. The assessed total pruned logs volume was 70 $m^3$/ha and because of an excessive incidence of sweep, the assessed pruned peeler volume was only 26 $m^3$/ha.

*Level 2*

At this level only two of the four phases of pruned resource evaluation remain totally reliant on prediction.

(1) *Log volumes and external properties:* Standing volume, distributions of piece size and pruned log types based on external characteristics are derived from measurements taken in a pre-harvest inventory, *e.g.*, MARVL (Deadman and Goulding, 1979). External features such as ovality of the log and surface defects may assist in differentiating pruned log types. Short-term projections of inventory results will be necessary when the proposed clearfelling date is a few years in the future.

(2) *Internal log properties:* As at Level 1, branch stubs and occlusions are represented by predicted parameters. On occasions these predictions might be formulated using reliable records of timing of silviculture operations, and assisted by known site index, final crop stocking, basal area and height to reconstruct the past growth of the stand to the time of pruning.

(3) *Market environment:* Current market information is relevant. Short-term projections may be required.

(4) *Interpretation:* The same "look-up table" or function approach used at Level 1 also applies at this level because internal log characteristics have remained as predictions and assumptions. However, the additional information on actual log types and sizes, from inventory, increases the capability to predict conversions. All forms of grade and value predictions at Level 2 may be subject to large errors, because internal characteristics remain hidden and unmeasured and the predictions should be considered as indicative only.

Level 2 applies to medium/short-term planning, A few years before harvesting, a stand will be considered in a marketing plan with a view to either allocating its products to existing sales agreements or including it in new sales. Descriptions of the quantity and quality of pruned log types will be required together with indications of how well each might satisfy the demands of various primary processes. A distinction should be made here between indicating expected performance and attempting to deduce absolute values. The latter are not necessary at this level and may result in embarrassing errors.

Evaluations at Level 2 may provide results adequate for purposes where the risks and penalties associated with errors in predicting quality are low. They may also be considered as precursors to more detailed exercises at Level 3.

Pruned log sales over the next 10 years are expected to be relatively small and often made up of many stands. Recent proposals for the sale of 300 000 m$^3$ of radiata, over a 5-year period, from Tairua Forest is an example of how complex the problem can become. Basic information is given in Table 1. The sale involves 37 stands ranging in area from 2.1 to 48.4 ha. Twenty-three of these stands have been pruned, but within these there is a range of final crop stockings, piece size, and pruned heights. The timing of thinning and pruning varied, as did the number of pruning lifts. It is obviously impractical to attempt a thorough evaluation of the internal properties of the pruned logs in each stand by sampling. A pruned resource evaluation, carried out by the four phases defined for Level 2, would effectively stratify the stands in the sale, define volumes, and provide indications of quality. It would also provide a sound basis for decisions as to whether more detailed exercises at Resolution Level 3 are warranted and, if so, what sampling strategy to use.

TABLE 1: BASE PROPOSAL FOR TAIRUA FOREST LOG SALE — 1984

| *Description* | *Piece Size* | *Pruning* | *Area (ha)* | *Stands (No.)* |
|---|---|---|---|---|
| Young | Small | High | 66.6 | 4 |
| Poor | Small | Low | 68.0 | 2 |
| | | High | 79.1 | 5 |
| | | Unpruned | 32.3 | 5 |
| Medium | Moderate | Low | 100.4 | 3 |
| | | High | 61.6 | 5 |
| | | Unpruned | 57.8 | 4 |
| Good | Large | Low | 49.1 | 2 |
| | | High | 14.2 | 2 |
| Poor Low stocking | | Unpruned | 66.3 | 5 |
| | Totals | | 595.4 | 37 |

Average stand area — 16 ha
Range — 2.1–48.8 ha
Time period — 5 years
Total volume — 300 000

An example of the application of Level 2 techniques is given below:

> A forward sale of logs from East Coast forests was concluded in 1983. Included in this sale were pruned logs from 8 stands in Patunamu Forest. Prior to the sale the Patunamu stands were divided into two crop types; Type 1, hauler country, high stocking; Type 2, tractor country, production thinned, low stocking. MARVL inventories were completed and stand histories were consulted. These data were used to adjust SILMOD in a retrospective fashion and so enable predictions of log value and sawn grade outturn for each crop type. Projections to various possible felling ages were also included.

The justification for surpassing Level 2 and embarking on time-consuming and expensive detailed analyses depends on the risks associated with inadequate pruned log quality definition and the price differentials expected between log types. As stated earlier, stand histories for the crop to be harvested over the next 10 to 15 years may often be misleading. Operational records do not always effectively represent crop conditions, or accurately document past silvicultural actions. Differences may be caused by unrecorded operations, recordings based on prescriptions rather than measured parameters, natural losses, or errors (especially for site quality) at the time of quality control. This makes confident prediction of basic variables, such as diameter over pruned stubs, most difficult. Even when stands on similar sites have had identical silviculture, very significant variation in quality may persist. Experience from over 500 pruned logs examined in 18 sawing studies, 5 peeling studies and 6 cross-sectional studies have shown that pruned logs may be seriously downgraded by any one or by combinations of the following: resin pockets, eccentric pith, wandering pith, atypical occlusion (usually associated with poor pruning techniques), dead and concealed adventitious shoots, production thinning damage. To date, little progress has been made on identifying any of these by external observations on trees or in predicting their presence.

To provide an example, two logs classed as the same by pruning history and external characteristics, have been reconstructed in Fig. 2. They came from different forests and were extracted from the data pool of logs sawn in a series of studies on "nominally straight" pruned butt logs (see Park, 1986; Park and Parker, 1983). Nominally straight, in those studies, has been defined as logs with less than 11 mm/m of sweep. Pruning histories, diameter over branch stubs (D.O.S.), and external log features, with the exception of 4 mm/m difference in sweep, were virtually identical in the two logs shown. Log 648 produced the percentage of clears expected. However, the combination of an expanded defect core size due to sinuosity of the pith and a serious incidence of resin pockets had a very significant effect on clears produced from log 210; total clears were more than halved and the outturn in No. 1 Clears was reduced to a fifth of the percentage expected.

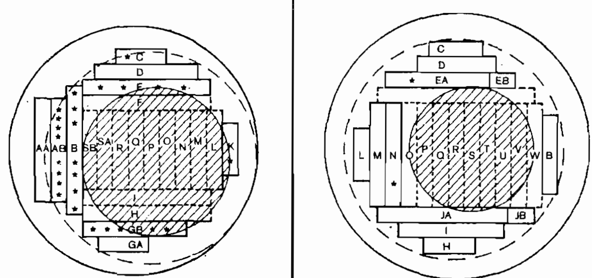
*Level 3*

At Resolution Level 3, all four phases of pruned resource evaluation are based on actual data.

(1) *Log volumes and external properties:* Derived from preharvest inventory (as at Level 2).

(2) *Internal log properties:* Internal features are determined by stem analysis. A random sample of trees are located and felled. The pruned logs are dismantled to give an accurate three-dimensional description of both internal and external features. At present there are three possible methods for carrying out this log dismantling and stem analysis, namely, a cross-sectional analysis system (Somerville, 1985); a sawing study method

| | LOG 210 RANKLEBURN (Cpt. 5) | LOG 648 PATUNAMU (Cpt. 3) |
|---|---|---|




| | LOG 210 RANKLEBURN (Cpt. 5) | LOG 648 PATUNAMU (Cpt. 3) |
|---|---|---|
| number of lifts | 2 | 2 |
| pruning schedule | age 6 to 2·7m<br>age 8 to 5·5m | age 6 to 3·0m<br>age 9 to 5·5m |
| dbh (o b) | 51·7 cm | 50·5 cm |
| sed (i b) | 40·2 cm | 41·5 cm |
| length | 5·5 m | 5·5 m |
| sweep | 9 mm/m | 5 mm/m |
| dos | 168 mm | 176 mm |
| defect core | 297 mm | 243 mm |
| resin pockets in clearwood zone; (a) total observed | 26 | 2 |
| (b) frequency | 1·59/m² | 0·10/m² |
| percentage of log volume outturned as; (a) No 1 Clears | 5·5 % | 26·4 % |
| (b) No 2 Clears | 5·5 % | 0 % |
| Total Clears | 11·0 % | 26·4 % |

- CLEARS
- 'CLEARS' BUT FOR RESIN POCKETS
- ***... NUMBER OF RESIN POCKETS OBSERVED
- OTHER GRADES
- LARGE END DIAMETER
- SMALL END DIAMETER
- DEFECT CORE

FIG. 2: *Comparison of two logs classed as the "same" by external appearance and pruning.*

(Park and Leman, 1983); a peeling study method (Park, *et al.* 1983).

(3) *Market environment:* Evaluations are carried out for existing market conditions.

(4) *Interpretation:* The purpose of gaining detailed descriptions of actual logs is to provide input for individual log computer simulation medols to predict the conversion and grade outturn from a range of different processing paths. (Two such models, X-PEEL (Somerville, in prep.) and SEESAW (Park, 1986; Garcia, 1986) have been developed by the N.Z. Forest Service, Forest Research Institute.) If log descriptions have been derived through a sawing study, the first interpretation is obviously based on the actual results from that study. Such actual results are limited to the sawpatterns used, other study decisions and the variables of the mill used to convert logs. Simulation offers the opportunity to thoroughly evaluate the same logs under a range of sawing options and a range of mill variables, and then to evaluate these logs through a range of variations on other primary processes.

It is anticipated that simulation based on three-dimensional log feature description will be quite accurate. The prime objectives will be to express the potential of logs, but mechanisms will be included to accommodate various levels of process efficiency. Most of the resource evaluation error will be governed by adequacy of field sampling. Errors associated with sample size and selection may be examined and controlled as part of an ongoing sampling strategy.

Two examples of evaluations carried out at Level 3 are:

(a) "Regional validation studies of pruned radiata pine butt logs sawn to boards" (Park and Parker, 1983). Because sampling was restricted to "nominally straight" logs, these studies applied to only part of the pruned resource.

(b) The 1984 sale of pruned logs from Ngaumu State Forest. A total of 38 pruned logs were randomly sampled across the four populations of trees comprising the sale. These logs were cross-sectionally analysed and their three-dimensional log feature descriptions were used to indicate and represent the quality of logs in the sale. The Forest Service made available to prospective buyers, scale plottings of the three-dimensional log descriptions (Somerville and McGregor, 1985), predicted timber grade results under two sawing patterns (Park and

Parker, 1983; Whiteside and Sutton, 1983) and simulated peeling results using XPEEL.

## DISCUSSION

The choice of approach to pruned resource evaluation should depend on the purpose of that evaluation. Long-term planning exercises are usually unable to obtain detailed or precise standing resource description because the crops are immature. Corresponding log values and performance at primary processing can only be predicted with results regarded as indicative. As planning horizons shorten, the need for more specific and precise evaluations of existing crops becomes apparent. Measured information on internal quality can be obtained by stem analyses. The alternative is to use predicted parameters to represent internal log characteristics. To adopt results generated from predicted parameters is to assume that these parameters are correct, adequate, and that their distributions and interactions are known and understood. These assumpions are likely to be incorrect owing to our general lack of experience in dealing with pruned logs and the hidden complex nature of internal log characteristics. When stands are approaching maturity, the shortcomings of using predicted parameters must be balanced against the costs of gaining actual data through detailed stem analysis. This is particularly relevant to the immediate problems with the "transition crop".

Ongoing improvements to stand record systems and the taking of additional measurements immediately after silvicultural operations, together with expected advancements in knowledge, will combine to strengthen predictions on future crops.

Physical sampling a population of pruned logs for evaluation purposes necessitates a consideration of sample size. It is theoretically possible to measure the many individual internal parameters and define their distribution and interactions on a total log population basis. However, the sample size requirement is likely to be prohibitively large. The alternative is to consider a random sample of logs and use either the sawing study method or the cross-sectional analysis system to reveal and quantify both internal and external properties. Although log descriptions may be complex and differing, the merit of each sample log under a particular primary process can be quite similar. When this occurs sample size requirements may be small. The evaluation of a log's processing performance can be determined either by entering log parameters into predictive functions or by using detailed three-dimensional log descriptions in process simulation models. The latter have potential advantages in both accuracy and in flexibility for examining modifications to a process path.

The evaluation of an existing pruned resource for log sales is an operational planning problem. A fair price for any commodity depends on an accurate description of the goods sold. This is not the current situation in the trading of pruned logs. Internal log properties are likely to be ill-defined. Unless accurately inventoried, prediction of volumes by log type are frequently in error. Pre-harvest inventory of the standing resource, coupled with prediction of internal log quality, can indicate potential value and will serve to differentiate between those stands likely to have disappointing returns on pruning and those with the potential for high value.

Pruned logs are new to many processors, so a period of learning must prevail. Inadequate information and inexperience combine to create an atmosphere of risk and uncertainty, which must in turn be reflected in conservative log prices. One method is seen as appropriate to evaluate a potentially valuable pruned resource with the confidence to avoid severe penalties for error. This entails pre-harvest inventory, dismantling a representative sample of pruned logs, completing detailed three-dimensional log feature descriptions, and then using high precision individual log simulation models to predict the results for the various primary processing paths.

## REFERENCES

Deadman, M. W.; Goulding, C. J., 1979. A method for the assessment of recoverable volume by log types. *N.Z. Jl For. Sci., 9* (2): 225-39.

Fenton, R. T., 1972. (a) Economics of radiata pine for sawlog production. (b) Economics of sawlog silviculture which includes production thinning. (c) Import costs and overseas earnings of sawlog and export log afforestation. (d) Implications of radiata pine afforestation studies. *N.Z. Jl For. Sci., 2* (3): 289-312.

Fenton, R. T.; Dick, M. M., 1972. Profitability of 'normal' afforestation for the overseas log trade. *N.Z. Jl For. Sci., 2* (3): 289-312.

Garcia, O., 1986. SEESAW, a visual sawing simulator. Part 2. The SEESAW computer program. *Proc. Conversion Planning Project Team Gen. Mtg — April 1986* (in press).

Goulding, C. J.; Shirley, J. W., 1979. A method to predict the yield of log assortments for long-term planning. *In* Mensuration for Management Planning of Exotic Forest Plantations. *N.Z. For. Serv., For. Res. Inst. Symp. No. 20:* 301-14.

Knowles, R. L.; West, G. G.; Koehler, A. R. Predicting "diameter-over-stubs" in pruned stands of radiata pine. *N.Z. For. Serv., For. Res. Inst. Bull.* (in prep.).

Mensuration Project Team, 1978. *Stand Growth Models — User Manual. Computer Systems for Forest Management.* N.Z. For. Serv., Wellington.

Park, J. C., 1980. A grade index for pruned butt logs. *N.Z. Jl For. Sci., 10* (2): 419-38.

——— 1982. Occlusion and the defect core in pruned radiata pine. *N.Z. For. Serv., For. Res. Inst. Bull. No. 2.*

——— 1986. SEESAW, a visual sawing simulator. Part 1. Data, methods and program evaluation. *Proc. Conversion Planning Project Team Gen. Mtg — April 1986* (in press).

Park, J. C.; Firth, J.; van Dijk, W. A. J., 1983. Part 1. A peeling study method for pruned logs. Part 2. Grading veneers from photographs. *N.Z. For. Serv., For. Res. Inst. Bull. No. 52.*

Park, J. C.; Leman, C S. E., 1983. A sawing study method for evaluating timber from pruned logs. *N.Z. For. Serv., For. Res. Inst. Bull. No. 47.*

Park, J. C.; Parker, C. E., 1983. Regional validation studies of pruned radiata pine butt logs sawn to boards. *N.Z. For. Serv., For. Res. Inst. Bull. No. 51.*

Somerville, A., 1985. The field procedure for the cross-sectional analysis of a pruned radiata log. *N.Z. For. Serv., For. Res. Inst. Bull. No. 101.*

——— in prep. XPEEL. A rotary peeled veneer simulation model.

Somerville, A.; McGregor, M., 1985. XPLOT: Imagery for pruned log sales. *N.Z. Jl For., 30* (2): 232-6.

Whiteside, I. D., 1982. Predicting radiata pine gross sawlog values and timber grades from log variables. *N.Z. For. Serv., For. Res. Inst. Bull. No. 4.*

Whiteside, I. D.; Sutton, W. R. J., 1983. A silviculture stand model: implications for radiata pine management. *N.Z. Jl For., 28* (3): 300-13.