ARTICLES

Greater specialisation of improved seedlots in New Zealand: New developments for efficient selection of parents and evaluation of performance

S.D. Carson*

Abstract

Profitability for New Zealand radiata pine forestry could be improved by using seedlots selected to target specific sites or specific end products. Trees selected from the tree improvement programme are being ranked for a number of selection criteria to facilitate selection of seed orchard parents for different mixes of characteristics. Research is progressing towards specifying genetic changes in stem form in planning and prediction models so that log quality of specialised seedlots can be predicted, as is already being done for genetic improvement in growth rate. Ratings for the major selection criteria could be incorporated in the New Zealand Seed Certification System, making selection of specialised seedlots easier and allowing prediction of performance of specific seedlots.

Introduction

Gain resulting from genetic improvement of radiata pine in New Zealand over the last 35 years has been high (Figures 1 and 2).

Figure 1. Large block genetic gain trial in Kaingaroa Forest – GF2 seedlot, bulk collection from a land-race stand.

Control-pollinated seed orchards (Figure 3) have allowed increased genetic gain by making it possible to produce genetically-improved planting stock from crossing among small numbers of parents. Resulting seed can be used directly as production seedlots, or vegetatively multiplied (Figure 4) to extend the plantation area on which it can be planted. Control-pollinated seed orchards make it possible to achieve the high selection intensity required for effective production of "designer seedlots", that is, seedlots selected for specific traits (selection criteria) to maximise profitability for specific sites and/or for specific end uses (Carson, M. 1987, Carson, M. *et al.* 1990, Carson, M. 1991).

Figure 2. Large block genetic gain trial in Kaingaroa Forest – GF2 control-pollinated seedlot.

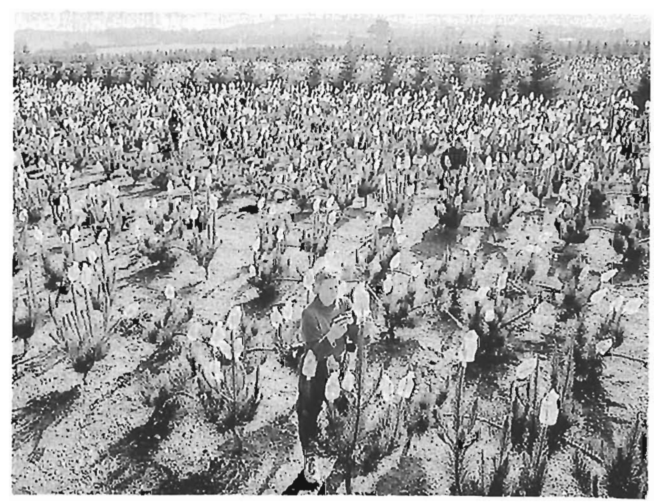

Figure 3. Proseed's commercial meadow orchard at Amberley for production of control-pollinated seed.

Designer seedlots are produced by emphasising a specialised set of selection criteria. For example, a high genetic quality for straightness would be important on an ex-farm site where high fertility results in many crooked stems, but less important on sandy soils where the trees are naturally much straighter. Also, high wood density might be emphasised for the production of structural timber, but may be less critical for pulpwood for making some types of papers. Choice of parents to use for production of designer seedlots will depend on their relative ranking for the

* *The Author: Dr Sue Carson is Scientist, Forest Mensuration and Management Systems, and Programme Manager, Gene Mapping and Fingerprinting, NZ Forest Research Institute, Private Bag 3020, Rotorua.*

selection criteria relevant to the specific problem and/or end use.

Forest managers will want to predict yield and log and wood quality of designer seedlots. Genetic changes in growth rate are already being modelled by modified stand growth models (Carson and Garcia, unpublished), with constantly improving predictions expected over the next 20 years as additional data from genetic gain trials become available. Research is under way aimed at modifying planning models to take genetic changes in stem form traits into account.

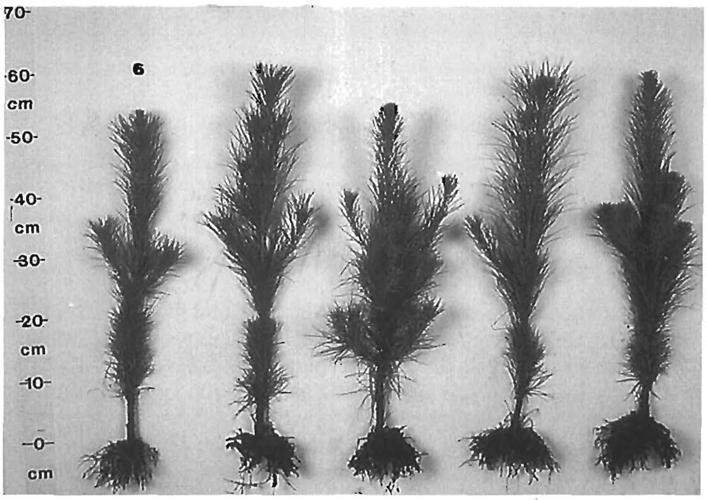

Figure 4. Stool bed cutting of high genetic quality.

Designer Seedlots

History of selection and testing of seed orchard parents

Plus trees have been selected in New Zealand since the 1950s. Each "series" of plus trees was selected within a certain time period for a specific set of selection criteria (Carson, M. 1987 and 1990, Shelbourne *et al.* 1986). For example, the '850 series' was selected in the early 1950s by very intensively searching forest plantations all over New Zealand for outstanding trees. Increased growth, good stem form and light, uniform, wide-angled branching habit were emphasised. In contrast, the '268 series' was selected in 1968 by partitioning stands in northern Kaingaroa Forest into one-hectare blocks and selecting the best tree in each block for similar criteria, with explicit emphasis on multinodality. The '870 series' was selected primarily for extremely long internodes, combined with good growth and stem form. Plus trees have been extensively progeny tested, but almost without exception only in comparison with those in the same series. As a result, parents in a series have been well tested and ranked against one another, but cross-series comparisons are not yet as reliable.

Vegetatively-propagated genetic copies (ramets) of selected trees were established in open-pollinated orchards from the mid-1950s until 1985. Commercial seed was first produced in 1971, with enough seed being produced to plant all New Zealand plantations by the mid 1980s. Trees were selected using rankings based on a mix of selection criteria that reflected perceptions of the relative importance of the selection traits, supported by sensitivity analysis achieved by varying the weights given to the selection criteria (Burdon and Thulin 1966, Carson, M. 1988, Shelbourne 1970, Shelbourne and Low 1980). Relatively large numbers of clones were required in these orchards (Sweet and Krugman 1977). This limited genetic gain, but was done to avoid self-pollination among ramets of the same clone and to ensure a wide representation of parents in the seed produced. Some specialised seedlots were produced from collecting seed from orchard trees with particular characteristics; for example, resistance to *Dothistroma pini.* However, this resulted in relatively small genetic differences among seedlots, because selection was effective only on the female side of the pedigree and pollen contamination from outside the orchard was often very high.

Control-pollinated orchards have greatly increased flexibility for producing designer seedlots. A higher selection intensity is achieved through flexibility in choice of parents and through reduction in the number of parents used to produce a production seedlot (Burdon 1986, Carson, M. 1986 and 1987, Carson, M. *et al.* 1992, Sweet and Krugman 1977). Also, pollen can be collected in one location and applied to female clones at another location, and parent clones can be held in clonal blocks without the risk of selfing or pollen contamination. Resulting genetic gains can be much larger with this approach.

Selection of parents for designer seedlots

Predictions of relative performance of seed-orchard parents appear to be valid for all parts of the country where radiata pine has been tested. Genotype-by-environment interaction does not appear to be large enough in New Zealand to warrant selection for adaptation to local site and climatic conditions. The predicted increase in genetic gain calculated for regionalised vs non-regionalised seed orchard strategies was small (Carson, S. 1991, Johnson and Burdon 1990, Shelbourne and Low 1980) and would require substantial extra cost for progeny testing to capture. It appears instead that designer seedlots produced by varying the mix of selection traits for end-product improvement will increase profitability more than specialisation aimed at increasing adaptation to local climate and site.

The NZ Radiata Pine Breeding Cooperative is developing a separate rating of potential seed-orchard parents for each important selection criterion. These national breeding values predict the average performance in New Zealand plantations. A matrix of national breeding values is being constructed as illustrated in Table 1. Parents in the different series as well as those in the same series are rated relative to one another for each selection trait. These ratings will be more useful for selecting parents for designer seedlots, where choice of selection traits is customised, than were previous rankings of parents based on multiple traits.

Genetic improvements in different selection traits, while often correlated overall, are not closely linked when considering selection of top parents. The very best parents for one trait are not often the very best for other selection criteria. For example, although Dothistroma resistance and growth rate are clearly positively correlated when all parents are considered (Carson S. 1989, Carson and Carson 1991), some of the best parents for growth rate are quite poor for Dothistroma resistance. The data in Table 1 are hypothetical, but illustrate the nature of typical trade-offs among selection criteria.

TABLE 1. Hypothetical national breeding values

Parent	Diameter (mm)	Dothistroma (%)	Breeding Value Straightness[1]	Internode Frequency[1]	Needle Retention[2]
268.A	20	13	6	5	4
268.B	19	5	3	4	3.5
875.C	19	12	6	6	2
850.D	18	0	4	7	2.5
268.E	18	–3	3	4	3.5
880.F	17	14	7	5	4
–	.	.	.	.	.
–	.	.	.	.	.
–	.	.	.	.	.
268.G	0	0	6	2	1.5
880.H	0	5	2	5	2.5
	.	.	.	.	.
	.	.	.	.	.
	.	.	.	.	.
850.I	–18	5	5	6	1.5
850.J	–19	7	2	4	3
875.K	–19	–2	6	2	3.5
268.L	–20	–12	4	3	3

[1] subjective scores from 1 to 9, with 9 being very straight or very multi-nodal.
[2] subjective scores from 1 to 6, with 6 representing full retention of three seasons' needles.

National breeding values tend to be distributed in a bell-shaped normal curve as illustrated in Figure 5. They represent the relative amount of gain contributed by each individual parent when compared to the mean of all parents. The relative worth of a parent contributing to a control-pollinated seedlot is estimated as the weighted average of the parental values. Comparisons of genetic change calculated for different combinations of parents represent valid predictions of gain from potential production seedlots, and thus provide quantification of relative trade-offs between different selection criteria.

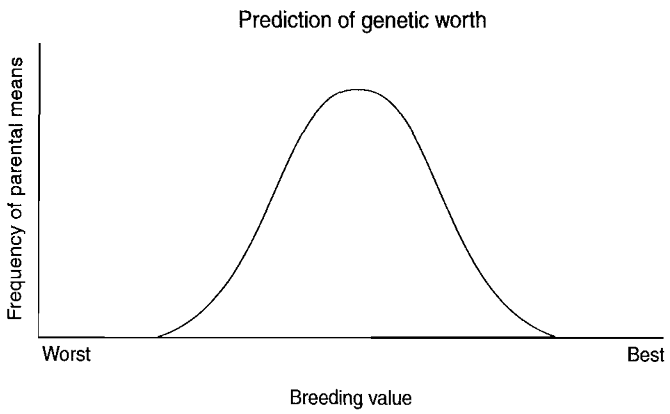

Figure 5. Distribution of national breeding values.

Predicting Yield and Quality of "Designer Seedlots"

Conversion of changes in selection criteria to differences in selection objectives

While national breeding values quantify relative genetic worth very well, they do not predict very accurately the absolute economic value of genetic changes. Tree breeders select trees by measuring specific characteristics related to the economic worth of end products. Because of the long rotation of forest crops, selection needs to take place at young ages rather than when the economic worth of final end products can be directly measured. Therefore, translation of genetic changes in selection criteria into economic gain in selection objectives is required; that is, national breeding values require translation into predictions of yield and log quality.

The impact of selecting for diameter at about age eight can be translated into changes in final stand yield through use of genetic gain multipliers in growth models, as is being done by the Stand Growth Modelling Cooperative (Carson, S. and Garcia, unpublished). The rate of change of the height, stocking and basal area functions is increased with genetic improvement, and has been quantified by measuring genetic gain trials grown on different sites and with different silviculture. Currently, the values of the multipliers are indicated by specifying the 'GF rating' of a seedlot. This is assigned by the New Zealand Seed Certification Service based on breeding values for growth and stem form combined (Vincent 1987). Growth is given twice the weight as stem form, so the GF rating gives a strong indication of genetic worth for growth. A seedlot's genetic worth is thus used along with designation of region, site index, and spacing to predict final stand volume.

Proposal: modify planning models to reflect genetic changes influencing log quality

Planning models, including STANDPAK (West 1993, Whiteside 1990), typically utilise different modules to predict the final characteristics of a stand (Figure 6). For example, growth models predict stand volume, while a branch model is used to predict knot size. Results from all modules are brought together to construct an overall prediction of the volume and quality of different log types

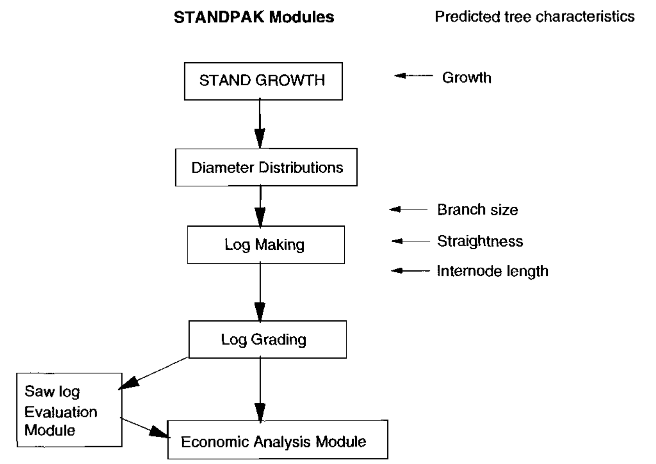

Figure 6. Modules in STANDPAK.

and product mixes. Predictions are used for evaluating different management options, scheduling of pruning and thinning operations, and predicting wood yields by log-quality classes. If the relative genetic worth of a seedlot for quality traits could be specified in the appropriate module of a planning model, predictions of log and wood quality might improve for designer seedlots.

A seedlot's genetic worth relative to other seedlots can be determined by its average breeding value. However, the absolute performance of seedlots will differ from region to region (Figure 7). For example, trees on average are much straighter when grown on the Auckland sands than in the Central North Island, no matter what their genetic make-up. Also, trees grown on sandy soils tend to have finer branches, and shorter internodes than those grown on most other sites. In fact, the large morphological differences in radiata pine grown in different regions provide one of the bases for using breeds with a varying mix of selection traits (Carson, M. 1991).

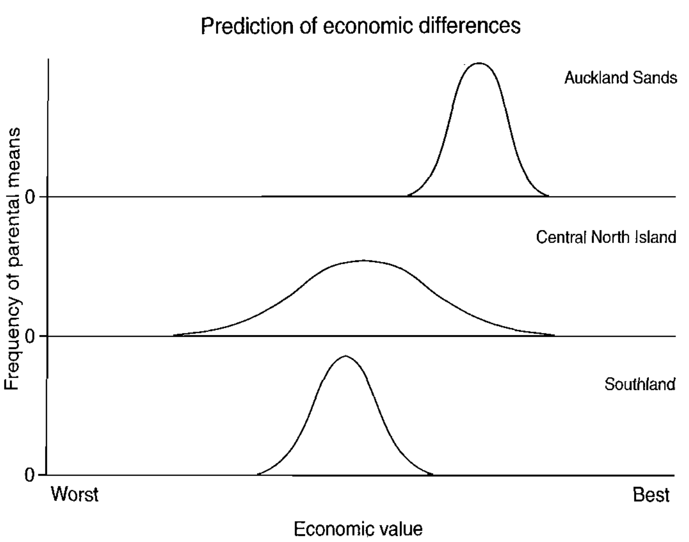

Figure 7. Distribution of economic differences for a single selection trait (hypothetical).

In addition to regional differences in the overall average performance of different seedlots, the magnitude of differences among seedlots will also differ from region to region. This is because genetic variance differs; that is, the magnitude of differences among genetically-improved parents (Figure 7). For example, the difference between the best and the worst parents for straightness will be much greater on Central North Island sites than on the Auckland sands. An actual measurement of internode length on offspring of the same parents in progeny trials planted on both the Auckland Sands and in the Central North Island illustrates these points by showing both a strong regional difference in mean performance and a large difference in variance among parents (Carson, M. and Inglis 1989) (Figure 8).

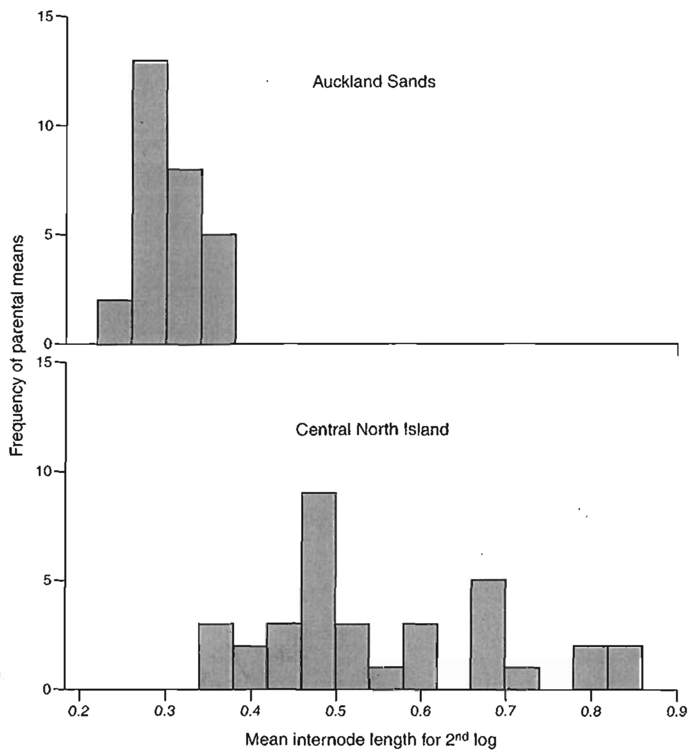

Figure 8. Distribution of average internode length in two contrasting regions.

Performance for various traits, including growth, is also often affected by site quality and silviculture. The New Zealand growth models can be used to obtain good prediction of the effect of region, site index, and stocking on growth. Because national breeding values do not represent actual differences between seedlots grown in specific situations and growth models can calculate these, genetic differences have been quantified in such a way that growth models provide the basic prediction of performance with an adjustment for genetic quality. The existing functions in the growth models predict the basic growth patterns, while differences among seedlots become differences in how fast growth progresses. Realistic predictions appear to result. For example, differences among seedlots in slow-growing standards are predicted to be smaller than in fast-growing stands, which appears to reflect reality.

Research supported by the Forest and Farm Plantation Management Cooperative is determining the value of specifying genetic worth for internode frequency and straightness in planning models. Objective measures closely related to economic worth are being related to national breeding values. In essence, information like that illustrated in Figure 7 is being gathered. Eventually, the appropriate modules in planning models may accept a seedlot's genetic worth for internode frequency and straightness as input in order to improve prediction of the quality and value of a stand.

Determining optimal economic weights of selection traits

When it becomes possible to input a seedlots genetic value for specific selection criteria directly into planning models, designer seedlots can be more accurately compared. Planning models could be used to convert a change in selection criteria (represented by national breeding values) into an improvement in selection objectives, which are specific to a particular site and silviculture. By using values calculated for actual parents, real seedlots would be simulated. Two alternative seedlots could be compared for volume production, log quality, and product outturn. Seedlots could be compared for their predicted performance in different regions and/or with different silviculture, greatly facilitating determination of the appropriate weights for the various selection criteria.

TABLE 2. Radiata Pine Breeds

Breed	Seed Certification Code	Selection Criteria
Growth and Form	GF	GROWTH, straightness, malformation
Dothistroma Resistant	DR	RESISTANCE, GROWTH
Long Internode	LI	LONG INTERNODES, growth
High Density	–	increased density, growth
Pole Production	–	multiple branching, straightness

Future Direction of New Zealand Seed Certification

The New Zealand Seed Certification Service has so far developed three separate rating scales (three separate improvement ratings) for quantifying a seedlot's genetic worth (Table 2). A seedlot can be rated for any of the breeds, and a seedlot will have different ratings for each of them, because each breed emphasises a different set of selection criteria (Table 2). In addition to the Growth and Form Breed (GF), ratings for two special-purpose breeds are available. The Dothistroma-Resistant Breed ranks seedlots to achieve optimum volume growth on high-risk Dothistroma sites. The Long-Internode Breed rating provides a ranking for internode frequency. Certification for special-purpose breeds also includes the rating for the growth and form breed. A wood density breed (emphasising increased density and growth) and a pole breed (emphasising multiple branching and straightness) are available from the tree improvement programme but are not yet rated by the Seed Certification Service.

The New Zealand Seed Certification Service is progressing towards an enhancement of the rating system where, in addition to the improvement ratings now available, individual trait ratings are provided. Trait ratings could be presented on the certificate as "DI22 ST7 IF6 DR18", that is, with diameter (DI), straightness (ST), internode frequency (IF), and Dothistroma resistance (DR) ratings. The first application of these trait ratings will be the use of the diameter rating for the prediction of growth by growth models. A more precise prediction of stand volume should be achieved by using diameter rating to indicate a seedlot's genetic worth instead of GF rating, since the GF rating indicates genetic worth for a combination of growth and stem form traits, rather than just for growth. The Stand Growth Modelling Cooperative is implementing this change.

Extension to Clonal Forestry

True clonal forestry, that is, the use of tested clones, would allow even greater flexibility in the choice of designer plantations. When ranking information is available, a similar system for rating and predicting the performance of tested clones using planning models could be developed in the same way as that proposed here for family forestry. Prediction of performance of a single clone may not be as accurate as for control-pollinated seedlots (for the same reasons that improvement rating for a single control-pollinated family is not as reliable as for a mix of several parents), but may be acceptable for a mix of clones or a group of single clone blocks. Just as with the system being developed for predicting performance of control-pollinated seedlots, a prediction system for clones would require development and testing before its utility can be ascertained.

Conclusions

The increasing use of control-pollinated seed and vegetatively-multiplied cuttings for radiata pine production forests provides a vehicle for forest owners not only to increase gain from tree breeding, but also to customise the emphasis placed on selection criteria, such as growth rate, straightness, internode frequency and disease resistance. This could maximise profitability on sites with particular characteristics (for example, high risk for disease or sand dune sites) or in forest stands destined for specific end uses (for example, poles or pulp).

National breeding values are being developed for each commonly used selection trait. This will facilitate selection of designer seedlots, that is, seedlots intended to maximise genetic gain on specific sites or for specific end uses (see Table 3). National breeding values for internode frequency and straightness are being related to log quality so that genetic changes can be taken into account in planning models. This will allow changes in selection criteria to be translated into changes in selection objectives, which are often specific to site and silviculture. Predicted performance of specific seedlots could be obtained by specifying Seed Certification ratings for separate selection traits and using these to adjust the appropriate modules of planning models to reflect the effects of genetic change.

TABLE 3. Steps being carried out for selection and evaluation of designer seedlots

Development	Pay-off
1. Calculate breeding values for commonly-used selection criteria so that all parents in the New Zealand breeding population can be compared for each trait separately.	Efficient selection of designer seedlots.
2. Relate national breeding values to regional differences in mean performance and magnitude of differences among parents by measuring progeny trials and genetic gain trials in different regions.	Clearer nomination of the optimum mix of selection criteria for designer seedlots.
3. Modify modelling systems to allow input of seedlot ratings for other traits in addition to growth rate.	More accurate prediction of performance of designer seedlots.

Complete implementation will require several years of research and, as such, represents a long-term goal. However, we now have a framework for focusing the incorporation of genetic changes into prediction models. Implementation would enable more efficient selection and better prediction of performance of designer seedlots. The New Zealand Seed Certification Service, and planning models (including STANDPAK) would be the vehicles for technology transfer of this information.

Glossary

breed: a specified set of selection criteria and economic weights aimed at achieving breeding goals appropriate for a particular site type or end use.

breeding objective: the characteristic with a direct effect on profitability which changes as a result of genetic selection. For example, increased volume at rotation age is the breeding objective achieved through selection on diameter measured at age eight years (see **selection criteria**).

breeding population: the set of tree genotypes (called clones or parents) which is considered to represent the best performers intended for crossing and re-selection for the next generation.

breeding value: a number that represents a parent's relative genetic worth compared to other parents. May represent genetic worth for a single trait or for a mix of traits, each with a specific economic weight.

clonal forestry: planting of tested clones in production forests.

designer seedlots: offspring of parents selected for their genetic potential to perform optimally on specific sites or for the production of specific end products.

economic weight: the relative weight given to a unit of variation in a selection criterion reflecting its economic importance compared to the other selection traits.

genetic gain: a change in performance of a stand of trees as a result of genetic selection and breeding.

GF rating: a rating assigned by the New Zealand Seed Certification Service for the Growth and Form Breed, which reflects a seedlot's relative genetic worth for growth and stem form, with growth given twice as much weight as stem form.

improvement rating: a number assigned by the New Zealand Seed Certification Service reflecting a particular seedlot's relative genetic worth for a particular breed, that is, for a specified set of selection criteria, each with a specific economic weight.

production population: the set of tree genotypes (called clones or parents) which is considered to represent the very best performers intended for current seed orchard production.

ramet: a vegetatively-propagated genetic copy of a tree.

selection criterion: the attribute or variable upon which genetic selection is performed, for example, diameter at age eight years (see **breeding objective**).

trait rating: a number assigned by the New Zealand Seed Certification Service which reflects a particular seedlot's relative genetic worth for one specific selection criterion.

Acknowledgements

The author wishes to acknowledge Graham West, Jenny Grace, Mike Carson, Gerry Vincent, Bruce Manley, Paul Jefferson, and James Turner for contributions towards developing the ideas presented in this paper and for contributions to the manuscript as well as constructive review, and Rowland Burdon, Mike Wilcox, Ken Klitscher, Tony Shelbourne and an unnamed reviewer for constructive criticism of the manuscript.

References

Burdon, R.D. 1986: Clonal forestry and breeding strategies – a perspective. Proceedings IUFRO Working Parties on Breeding Theory, Progeny Testing, and Seed Orchards. Williamsberg, Virginia, USA. Oct. 13, 1986. pp 645-659.

Burdon, R.D. (Comp.), and I.J. Thulin (ed.). 1966. The improvement of *Pinus radiata:* a record of a symposium. Forest Research Institute, Rotorua, Nov., 1965. 92p.

Carson, M.J. 1986: Control-pollinated seed orchards of best general combiners – a new strategy for radiata pine improvement. Agronomy Soc. of New Zealand, Special Publication No. 5: 144-1480.

Carson, M.J. 1987: Improving log and wood quality: the role of the radiata pine improvement programme. New Zealand Forestry, February 1987.

Carson M.J. 1988: Long-internode or multinodal radiata pine – a financial analysis. Ministry of Forestry, Forest Research Institute, FRI Bulletin No. 115. 25p.

Carson, M.J. 1989: Comparison of improved radiata pine breeds using STANDPAK. New approaches to spacing and thinning in plantation forestry. FRI Bulletin No. 151. Proc. IUFRO Symposium, Rotorua, New Zealand.

Carson, M.J. 1989: From improved breeds to clonal ideotypes? Pp. 47-50 *In* J.T. Miller (Ed.) Proceedings FRI/NZFP Forests Ltd. Clonal Forestry Workshop. May 1-2, 1989, Rotorua, New Zealand Ministry of Forestry. FRI Bulletin No. 160.

Carson, M.J., R.D. Burdon, S.D. Carson, A. Firth, C.J.A. Shelbourne, and T.G. Vincent. 1990: Realising genetic gains in production forests. Paper 3.1 *in* Breeding and genetic resources: Proceedings, joint meeting of Western Forest Genetics Associates and IUFRO Working Parties S2.02.05, S2.02.06, S2.02.12, and S2.02.14 on Douglas-fir, Contorta pine, Sitka spruce, and Abies spp., Olympia, Washington, August 1990.

Carson, M.J., and C.S. Inglis. 1989: Genotype and location effects on internode length of *Pinus radiata* in New Zealand. N.Z.J. For. Sci. 18(3): 267-279.

Carson, M.J., T.G. Vincent, and A. Firth. 1992: Control-pollinated and meadow seed orchards of radiata pine. Pp 100-109. In Mass Production of Genetically-Improved Trees: Proceedings IUFRO Conference. Bordeaux, France, Sept. 1992.

Carson, S.D. 1989: Selecting radiata pine for resistance to Dothistroma needle blight. N.Z.J. For. Sci. 19(1):3-21.
Carson, S.D. 1991: Genotype x environment interaction and optimal number of progeny test sites for improving *Pinus radiata* in New Zealand. N.Z.J. For. Sci. 21(1):32-49.
Carson, S.D. and M.J. Carson. 1991 Realising gains in resistance to Dothistroma. *In* Dean, C. and C. Hanel. Proc. 11th Research Working Group 1 (Forest Genetics), Australian Forestry Council. March 11-15, 1991. Coonawarra, South Australia. Pp. 71-75.
Johnson, G.R. and R.D. Burdon. 1990: Family-site interaction in *Pinus radiata:* implications for progeny testing strategy and regionalised breeding in New Zealand. Silvae Genetica. 39:55-62.
Shelbourne, C.J.A. 1970. Genetic improvement in different tree characteristics of radiata pine and the consequences for silviculture and utilisation. Pp. 44-58. In Sutton, W.R.J. (Ed.). Pruning and Thinning Practice. Symposium Mar. 16-20. 1970, Rotorua. FRI Symposium No. 12.
Shelbourne, C.J.A., R.D. Burdon, S.D. Carson, A. Firth, and T.G. Vincent. 1986: Development plan for radiata pine breeding. Forest Research Institute, Rotorua. 142 p.
Shelbourne, C.J.A., and C.B. Low. 1980. Multi-trait selection and associated genetic gains of *Pinus radiata* progenies at five sites. N.Z.J. For. Sci. 10(2): 307-324.
Sweet, G.B., and Krugman. 1977. Flowering and seed production problems – and a new concept of seed orchards. Third World Consultation of Forest Tree Breeding, 1977. 8p.
Vincent. 1987: Certification system for forest tree seed and planting stock. NZFRI Bulletin No. 134.
Vincent. 1990: You choose the parents. NZFRI What's New No. 182. 4p.
Vincent. 1987: Which radiata pine seed should you use? NZFRI What's New No. 157. 4p.
West, G.G. 1993: managing stands of radiata pine using PC-STANDPAK. New Zealand Forest Research Institute, What's New in Forest Research No. 229.
Whiteside, I.D. 1990: STANDPAK Modelling system for radiata pine. In James, R.N.; Tarlton, G.L. (Ed.) New Approaches to Spacing and Thinning in Plantation Forestry: Proceedings of a IUFRO Conference held at the Forest Research Institute, Rotorua, April 10-14, 1989. Ministry of Forestry, FRI Bulletin No. 152.

Preferences for scenarios of land-use change in the Mackenzie/Waitaki Basin

John R. Fairweather* and Simon R. Swaffield†

ABSTRACT

Earlier research on the effects of land-use change on a range of landforms in the Mackenzie/Waitaki Basin identified three dominant preference themes: for plantations, for a combination of grazing and trees, and for conservation (Fairweather and Swaffield, 1995). These themes were used to generate five scenarios of land-use change for the area, for each of which the detailed visual, economic, and social effects were modelled (Evision and Swaffield, 1994). This article reports on preferences for these scenarios.

The results suggest that preferences for the effects of land-use change are relatively stable, that detailed information on effects had only minor influence upon the ordering of preferences for scenarios, and that levels of acceptability for the preferred scenarios were high. Overall, there was support for a significant increase in plantations, shelterbelts and improved pasture, but wilding management was considered essential. The diversity of preferences suggests that a widening range of land uses can be expected to occur in the future.

INTRODUCTION

The Forest Research Institute's Planning for Rural Environments research programme has brought a number of research perspectives to bear on rural planning, with the overall aim of developing improved methods for managing land-use change. In particular, the programme has focused on potential land-use changes in the Mackenzie/Waitaki Basin study area, employing a suite of techniques useful for predicting and evaluating the visual, economic and social effects of particular combinations of agriculture and forestry (Evison and Swaffield, 1994). These techniques include GIS research and computer visualisation (Hock *et al.*, 1995; Bennison and Swaffield, 1994), attitude surveys (Fairweather and Swaffield, 1995), socio-economic analysis of forestry/agriculture options, and property-level economic analysis of land-use change. Findings on the effects of land-use change in the study area can be used by farmers and others involved in high-country management, whilst the improved planning procedures contribute generally to the development of decision support systems for rural planners throughout New Zealand.

An essential part of the FRI study has been the presentation of data on predicted effects of land-use change involving forestry to a range of interested parties, in order to assess the acceptability of the options available. The procedure adopted in the early stages of the research in 1993-94 was to disaggregate and simplify the complex of variables potentially involved, in order to present relevant information in a cost-effective and meaningful way. Landform and rainfall were selected as key biophysical variables determining the viability of land-use options. A Geographic Information System (GIS) database was developed for the study area, from which four landform categories were defined and for which the effects of different land-use options were estimated. The landforms were: hills slopes between 16° and 35°, lower slopes between 8° and 16°, and flats less than 8° (all three with greater than 800 mm annual rainfall), and flats less than 8° with less than 800 mm annual rainfall. The analysis highlighted a number of operational issues involved in applying GIS to an extensive study area with complex landforms. As a result, some expert interpretation of anomalies in the data set was needed (for example, to distinguish 'lower' slopes, which were taken to be slopes and debris flows adjacent to the basin floor, from small areas of modest slope angle located at higher elevations). Similarly, given the goal of broad-scale categorisation, small areas of distinct landform with an area of less than 10 ha (for example, small moraines, or flatter hill tops) were aggregated with the adjacent landform type. Detailed explanation of the derivation of these categories is given in Hock *et al.* (1995).

For each landform a set of information cards had been pre-

* *Lincoln University, Agribusiness and Economics Research Unit.*
† *Lincoln University, Landscape Architecture.*