F.R.I. PROJECT RECORD

NO. 2857

PSP FUTURE STRATEGY COMMITTEE REPORT

W. HAYWARD
C. GOULDING
B. RAWLEY
G. WEST

REPORT NO. 22 JUNE 1991

Note : Confidential to Participants of the Stand Growth Modelling Programme
: This is an unpublished report and must not be cited as a literature reference.

EXECUTIVE SUMMARY

The PSP Future Strategy committee was set up to formulate a strategy for efficiently sampling the forest resource in order to supply data for growth and yield modelling.

The committee has drawn up recommendations on the basis of three specific terms of reference:

- to report on appropriate future growth modelling data requirements for permanent sample plots;
- to review the most appropriate methods for nationally sampling the forest resource;
- to review appropriate field trial designs.

The report recommends that the Minimum Standards manual be amended to include measurements of green crown height, predominant mean height and seedlot number as an attribute of the plot.

A framework is to be established for sampling the forest resource, which must take into account the following parameters; age; initial stocking; timing and intensity of pruning/thinning; genetic breed; site productivity. It is intended to cover the range of desirable treatment combinations of initial stocking, residual stocking and thinning timing with a 'core' framework of plots. This will be augmented with well designed trials which evaluate the other factors and treatments.

It is suggested that there are a series of 'levels' of experimental design characterised by the blocking of treatments and on the location of replications. These 'levels' are:

- when the trial must be concentrated on one site;
- when treatments can be replicated across locations;
- when a quantifiable index of site quality is used as a main effect;
- individual growth 'monitoring' plots;
- permanently located grid plots.

The sub-committee acknowledges that the Stand Growth Modelling Cooperative must take the responsibility for the planning and coordination of the establishment and remeasurement of permanent sample plots, thus ensuring a National overview.

STAND GROWTH MODELLING CO-OPERATIVE

P.S.P. FUTURE STRATEGY COMMITTEE REPORT

SUMMARY OF RECOMMENDATIONS

The following is a suitable strategy for efficiently sampling the forest resource in order to supply data for growth and yield modelling:

- for each identified forest site ensure that the "core" framework described in this paper is adequately covered with plots. This core database defines a growth response surface suitable for modelling the changes in forest growth with respect to changes in density;

- ensure that there are sufficient pruning trials established in order to test and quantify the hypothesis that pruning affects tree and stand growth;

- ensure that, where necessary, appropriate fertiliser trials are established to test and quantify the hypothesis that fertiliser application affects tree and stand growth;

- ensure that the currently established national set of genetically-improved radiata pine trials are augmented in a planned fashion in order that growth and yield gains for improved seedlots are able to be quantified.

Note: Due to the everchanging nature of genetic improvement, it is important that any future silvicultural trials are established in the latest genetically improved material.

The Stand Growth Modelling Co-operative (SGMC) has accepted that a Nationally co-ordinated strategy for permanent sample plot establishment and re-measurement is essential. To achieve this objective a PSP sub-committee has been formed and its terms of reference for this task are as follows:

SPECIFIC TERMS OF REFERENCE

A. To report on appropriate future growth modelling data requirements for permanent sample plots, including, as examples, plot and stem characteristics to be measured, frequency of re-measurement and measurement standards.

B. To review and recommend the most appropriate methods for nationally sampling the forest resource. For instance, guidelines on the numbers of plots and their location are needed.

C. To review and recommend appropriate field trial designs for the establishment of PSPs.

The advantages from a Nationally co-ordinated strategy lie in the "planned" coverage of the range of site and silvicultural interactions in the most efficient way enabling the maximisation of growth information collected per dollar cost. The SGMC has as its major objective the prediction of stand growth and quality for all defined forest sites within New Zealand. The PSP system provides the data necessary for this predictive process and consequently, a satisfactory plot establishment strategy will ultimately yield better growth models.

(A) Future Growth Modelling Data Requirements for PSPs

The "Minimum Standards for the Establishment of Permanent Sample Plots" manual, published by the SGMC has proven to be a workable document indicating, among other things, required measurements for plot and stem characteristics, frequency of re-measurement and measurement standards. However, the following amendments to the Minimum Standards manual are recommended.

Proposed Amendments to Minimum Standards for Collection of Growth Data

1. Green crown height should be included as a required measurement in all plots at all measurements

(a) Up to 18 m MTH.
(b) Where there is incomplete crown closure after 18 m MTH.

The rationale for allowing the inclusion of green crown height is that crown length has been demonstrated to be a useful predictor of stand growth, it is used in some existing models and is likely to be incorporated in future models if it is available.

2. Predominant mean height should be included as a minimum measurement

Currently, sample height trees are specified as a minimum measurement requirement without the requirement that from them the PMH be able to be calculated. There are two main uses for height measurements:

Calculation of PMH or MTH for building predictive functions for height growth. For this PMH is preferred because it is better defined for a plot than MTH is.

Calculating tree volumes. For this application a sample of heights across the diameter range is needed.

With little or no increase in measurement workload beyond the measurement of the sample height trees already specified PMH can be made available.

3. Seedlot number should be recorded as an attribute of the plot

The rationale for needing an indication of the parentage is that recent and anticipated rapid changes in the tree improvement field will lead to considerable variation between the plots available for the next round of growth modelling. As it seems reasonable to infer some growth improvement from tree improvement we should be acting now to record the variation so that it can be allowed for in growth modelling.

The seedlot number is more useful than the GF ranking i.e. you can go from the former to the latter but not vice versa. If we only record GF ranking then we will not have the ability to use alternate ranking systems as they are devised.

(B) Framework for Sampling the Forest Resource

Any strategy purporting to provide an information framework for coverage of a forest resource must take into account the following parameters:

- Age
- Initial stocking
- Timing and intensity of thinning
- Timing and intensity of pruning
- Genetic breed
- Site productivity.

Where site productivity may in turn be defined in terms of

- soil structure and productivity
- Nutrient status
- Rainfall
- Temperature
- Disease susceptibility.

It is assumed that site productivity can be classified into groupings which are satisfactory for growth modelling purposes. For example, the currently defined growth modelling regions can be considered as aggregations of forests which have similar site qualities, reflected in their similarity of growth pattern. Site class can be defined as a similarity of growth rate within any aggregation of forests of similar growth pattern.

The following framework describes a PSP database which is intended to provide the "core" information for growth modelling for each defined site class. This framework describes various thinning intensities and thinning timings, over a range of initial stockings, for plots in which any pruning which may have occurred has not affected growth over the years of measurement. The aim of this core dataset is to provide growth data for modelling purposes which is largely unconfounded by any pruning effects.

Framework for a "Core" PSP Growth Database

INITIAL STOCKING RANGE <500

		THINNING MCH RANGE (m)			
		<9	9-17	17>	UNTHINNED
Residual	<150	X	X	X	
Stocking	150-225	X	X	X	
Range	225-275		X	X	
(Stems per Hectare)	275-350			X	
	350-500				X
	500-900				
	900-1800				
	1800				

INITIAL STOCKING RANGE <500-900

		THINNING MCH RANGE (m)			
		<9	9-17	17>	UNTHINNED
Residual	<150	X	X	X	
Stocking	150-225	X	X	X	
Range	225-275	X	X	X	
(Stems per Hectare)	275-350	X	X	X	
	350-500	X	X	X	
	500-900				X
	900-1800				
	1800>				

INITIAL STOCKING RANGE 900-1800

		THINNING MCH RANGE (m)			
		<9	9-17	17>	UNTHINNED
Residual	<150				
Stocking	150-225		X	X	
Range	225-275				
(Stems per Hectare)	275-350		X	X	
	350-500				
	500-900				
	900-1800				X
	1800>				

INITIAL STOCKING RANGE 1800

		THINNING MCH RANGE (m)			
		<9	9-17	17>	UNTHINNED
Residual	<150				
Stocking	150-225				
Range	225-275				
(Stems per Hectare)	275-350		X	X	
	350-500				
	500-900				
	900-1800				
	1800>				X

A complete coverage of this matrix with plots, for each site, will provide data for forming a robust growth modelling response surface which concentrates data about "expected" treatment ranges, but which also, extends the range of treatments well outside the accepted norm. A recommended minimum number of plots per cell per site is three, yielding 102 plots as a minimum core number of plots per site. Care must be taken to ensure that replication over time is incorporated and that consequently, the plot age measurement range spans and extends the rotation length.

A growth model which estimates yield based on changes in stand density only is obviously incomplete and in order to cater for the effects on yield of pruning, fertiliser application and an ever changing genetic base, a series of additional trials are recommended to augment the core database. Whereas the core growth database can be composed of plots which maybe individually established monitoring plots or established as part of a designed experiment, quantifying the effects of alternative treatments requires carefully designed and maintained experiments, again established on a site class basis.

Experimental trials usually require more intensive tree measurements and control of measurement timing and standards. No one experimental design will fully provide all the information required for yield estimation, research into growth prediction and silviculture, or into understanding the fundamental processes of tree growth and development.

Recommendations on appropriate trial designs are given in section (C) of this paper. However, it is essential that a series of trials are established by site, yielding information to quantify the additional growth and yield effects due to tree pruning, incorporating varying levels of final crop stocking and followers, fertiliser applications and genetic breed, and their interactions.

One grandiose design incorporating all relevant treatment effects (site, thinning, pruning, fertiliser, genetics...) would prove highly impractical and impossible to manage. The intention here has been to fully span and extend the range of desirable treatment combinations with a "core" framework of growth plots and then to augment this database with well designed trials which evaluate any other relevant additional growth and yield effects.

Additional Trial Requirements

The emphasis here should be on the testing of relevant hypotheses concerning the growth and yield of our forest crops. Given that the "core" database effectively summarises the growth and yield of a forest crop with respect to changes in density, we are now concerned with quantifying any additional changes in growth when other silvicultural practices are incorporated.

(a) Testing the Effects of Pruning and Early Thinning

These trials are seen as essential additions to the "core" framework in order to quantify changes in tree growth with pruning. The factors involved in these trials are:

- green crown remaining;
- dominance of pruned stems
- dominance of unpruned followers
- final crop stocking
- pruned height
- thinning timing.

Efficient trial designs are available that will test both single factor variation and any factor interactions.

(b) Testing the Effects of Fertiliser Application

For those sites known to be nutrient deficient, these trials are also seen as an essential addition, i.e., phosphorus deficient clay soils etc. There are many standardised trial designs available and could include factors such as:

- Nitrogen (N)
- Phosphorous (P)
- N + P
- N + P + other nutrients
- Control.

(c) Testing the Effects of Genetic Improvement

It is fortunate that the Stand Growth Modelling Co-operative, in collaboration with the Genetics and Tree Improvement of the FRI, have established a large and important set of trials specifically designed to quantify growth and yield gains from genetically-improved radiata pine.

Some of these trails were superimposed on existing trials but more recently, precise information will be available from the large numbers of planted trials established throughout New Zealand. These planted trials are carefully designed and all incorporate "benchmark" seedlots from which genetic gains can be estimated.

After the 1991 establishment program, the intensity of trial establishment is expected to decrease. Initially,a "large" number of plots/trials was necessary to test hypothesis such as whether there were breed by stocking or breed by site interactions.

Also, future gains are not expected to rival the quantum leaps experienced by going from a climbing select seed source to the "first orchard" to the "second orchard" (then control pollinated); gains are expected to be more predictable and interpolation possible.

The SGMC with a close liaison with the Genetics and Tree Improvement Group must be entrusted with the "watchdog" task of ensuring that the necessary trial establishment is implemented so that an adequate coverage of genetic change is affected.

(C) Appropriate Field Trial Designs for PSPs

No one design or series will fully provide all the information required for yield prediction, research into growth prediction and silviculture, or into understanding the fundamental processes of tree growth and development.

It is suggested that there are a series of "levels" of experimental design dependent on the objectives of the experiment, the practicality of carrying out the treatments, and on the situation at the time. The "levels" are characterised by the blocking of treatments, and on the location of replications.

As a general principle, there should be several (preferably three or more) replications per treatment, and replication should occur through time. However it may not be necessary to have more than one replication in one trial location, and the replication may be obtained by repeating the trial in subsequent years.

(a) Where the Trial Must Be Concentrated On One Site

These are the more traditional sorts of experiments in forests. Practical considerations force a complete experiment to be located in one place, for example where the treatment involves planting the trees, as in the co-op's genetic gain series of trials, where control of the treatments is complicated and difficult and can be managed only at one location, or where an important objective is to demonstrate treatment differences to management.

There must be several replications at the site, and blocking of treatments should be used to minimise within block variation. The site must be as uniform as possible, which can usually only be obtained when the experiment is kept to a reasonable size by limiting the number of treatment combinations. Blocking can be geographical across the area, but it is recommended that when an experiment is imposed on an existing stand, where possible blocking be by initial levels of basal area or stocking (i.e. each plot within a block should have a similar basal area or stocking at the start of the experiment before treatment).

A split-plot design can be used, but in all cases both the plot size and border between plots should be of an adequate size with enough trees after any thinning so that the experiment can be measured throughout its life. Above all the design must be robust, and overly-complex designs avoided so that the inevitable loss of one or two plots or incorrect treatment does not invalidate the experiment.

(b) Where Treatments Can Be Replicated Across Locations

This situation is more common than may be at first thought. The problem with having an experiment in one location only as in (a) above, is that interactions of treatment with site or environmental variables will remain undiscovered. The results of the experiment may only apply to that one location, which in unfortunate and extreme situations may not be typical of the rest of the forest estate. By installing an experiment across several locations, these problems can be minimised.

Only one or two replications need to be installed at each location, but there must be two or more locations. Differences other than site must be minimised between locations (i.e. same age or stand development, same seed stock, same timing of treatments). Even though the trial has the appearance of several sub-experiments, it is still controlled and analysed as one complete experiment. At each location the simplest of possible designs is used, which should minimise the area required for the trial.

However, it is clear that finding several sites to establish the experiment is sometimes more arduous than finding one site. Control of treatments must be feasible across the whole experiment, and particular care is required if timing of treatment is critical to ensure that operations are not different for the same treatment in the different replications or locations.

(c) Where A Quantifiable Index Of Site Quality Is Used As A Main Effect

These designs can often be of the "Response Surface" type, either uniform precision, fully rotatable, or the more conventional ANOVA designs. One of the factors is site quality. Plots of the same site quality are (usually) established at one location, but it is necessary that it is possible to determine and find the desired levels of site quality reasonably accurately when establishing the trial. A trade off can occur between numbers of replications and locations/levels of treatments, sometimes with only one replication of each treatment, but many treatment levels, relying on the high order interactions to provide the error term in a conventional ANOVA.

The advantage of this type of experiments is that it is more likely to get better coverage of the forest estate, avoiding problems with specific location effects and haphazard selection of environmental conditions. It can be extremely economical in the total number of plots required, reducing the area of land required at any one location, and also permitting resources to be spared to try out the more extreme, so-called unlikely, treatments. With a quantifiable site variable, data from these experiments will be more useful in determining the effects of environmental variables, and will more readily link with the sorts of data collected from the physiologically based experiments.

However, these types of experiments are only possible when the control of treatments is sufficiently simple and manageable so that operations can be carried out precisely and on time across the several locations. Often, only one plot in a given location may require treatment at any one time, and a given experiment may require many more visits and considerably more travel than the experiments in (a) and (b) above. There will be less opportunities for economies of scale when carrying out silviculture or measurement, as can often occur with large numbers of plots in one block. Finding suitable stands is difficult and time consuming, and also requires a large area and range of sites from which to make a choice.

(d) Individual "Monitoring" Plots

The monitoring plots are not experimental plots as such in that they are established without any research treatments, without borders and without disturbing the stand. The forest estate is stratified by crop type, and age class within crop type, and one or more plots established in stands within each cell. Plots are established individually or in small clusters, should be large enough to contain an adequate number of trees for many years, and are abandoned and replaced with similar plots when tree numbers decrease too much, see Tennent's growth Modelling plot series.

They will not provide data on conditions outside of the range of current and historical management, which within New Zealand tends to be confounded with time and age of the stands. However, they will provide accurate and timely information about the growth of stands under operational conditions avoiding any problems associated with researchers applying too "careful" a treatment. They are ideal for validating and modifying yield tables or growth predictions for the forest estate provided by growth models.

(e) Permanently Located Grid Plots

These plots monitor long term changes in forest productivity. They have not been established to any degree in New Zealand. For each forest estate or owner, a very small number of plots (20 or 30) should be established on a grid reference (provided by a systematic grid or a stratified random sample), regardless of current stand conditions, but in potentially productive forest land. That is, the plot location could fall amongst trees, in a gap within a stand, or on unstocked land, but not on permanent non-forest land. The plot centres and boundaries are precisely and permanently demarcated (but may be hidden, with buried markers or clearly defined survey points) so that the plots can always be relocated even after felling and replanting, and the plots remeasured. The interval between measurements can be long, 3 to 5 years or longer, and usually but not necessarily the plot is also remeasured when production thinning or clearfelling is carried out. Provided that the set of plots can be viewed as a random sample of the entire forest estate regardless of age class distribution, the data will provide a check against the yield forecasting and regulation system, as well as indicate trends in long term site productivity.

CONCLUSION

It is hoped that this exercise has outlined a strategy which will ensure that growth and yield information will be collected in an efficient, planned fashion. It is also to be hoped that this same strategy can be used to identify any growth data "holes" in the current database and any potential redundancy of plot information. It is important that where redundancy is identified that recommendations are made by the SGMC to abandon future measurements. The end result of such a rationalisation is that any current plot must be seen to be individually important and contributing to our overall understanding of growth and yield development. In this situation the SGMC must take the responsibility for the co-ordination and planning of establishment and remeasurement, thus ensuring a National overview. The actual plot measurements and maintenance must be the responsibility of the respective forest owner and an appropriate "in-kind contribution" mechanism must be agreed upon.

SGMC PSP COMMITTEE

Bill Hayward	-	Tasman Forestry
Brian Rawley	-	NZFP Forests
Dr Chris Goulding	-	FRI
Graham West	-	FRI