

PSP MATRIX DEVELOPMENT

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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This is an unpublished report and **MUST NOT** be cited as a literature reference.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 SGMC has accepted that:

- 1) a nationally co-ordinated strategy for permanent sample plot (PSP) establishment and re-measurement is essential, and
- 2) the SGMC must take some responsibility to plan and co-ordinate the establishment and re-measurement of PSPs to ensure a national overview.

An on-going issue with the SGMC and *Forest Research* Project 17 is the rationalisation of PSPs in an informed manner to optimise our PSP growth analysis and modelling database. This extends beyond the PSPs in SGMC genetic gain trials to include the broad-base of PSPs required for the entire effort in growth analysis and modelling.

The objective of this Report is:

- to describe the work to-date on the development of a PSP matrix, and
- to describe its application to a portion of the PSP database.

The PSP matrix described in this report establishes a surface across region (Regional Council Boundary), site (300 Index, preliminary), silviculture (Stand Density Index), genetics (GF), and tree-size (Mean Crop Height) to characterise the national coverage of Permanent Sample Plots.

In a test-case of this matrix approach with four regions (Bay of Plenty, Hawkes Bay, West Coast, and Otago), relative similarities and differences among regions became apparent. These similarities and differences in matrices, if obtained on a national basis from combined *Forest Research* and Industry databases, will provide a holistic view towards planning and co-ordinating the establishment and re-measurement of PSPs to help ensure adequate data for growth and yield analyses and modelling.

The next step will be to use the SGMC Email Forum for follow-up discussion on the appropriate manner to continue the work, i.e.,:

- discuss any amendments to the approach and development of the matrix,
- include all the other regions,
- include Industry PSPs not currently on the *Forest Research* database, and
- incorporate an improved 300 Index, which is more stable and incorporates the effects of thinning and pruning.

INTRODUCTION

The SGMC has accepted (SGMC Report No. 22, 1991) that 1) a nationally co-ordinated strategy for permanent sample plot (PSP) establishment and re-measurement is essential, and 2) the SGMC must take some responsibility to plan and co-ordinate the establishment and re-measurement of PSPs to ensure a national overview. An on-going issue with the SGMC and *Forest Research* Project 17 is the rationalisation of PSPs in an informed manner to optimise our PSP growth modelling database. This extends beyond the PSPs in SGMC genetic gain trials to include the broad-base of PSPs required for the entire (SGMC + FRST/PGSF) growth analysis and modelling effort. An Email Forum (April 1999) in the SGMC Focus Group, Database Strategy, provided a positive signal to initiate the work, cognisant of the task's ultimate utility (practical and manageable national overview of our PSPs) and its potential draw on resources (time and money).

OBJECTIVE

The objective of this Report is to describe the work to-date on the development of a PSP matrix, and its application to a portion of the PSP database. Based on this description, a follow-up discussion using the SGMC Email Forum will assist to make informed decisions on the appropriate manner to continue the work.

NOTATION

plot_id	= Permanent Sample Plot (PSP) identifier
forest	= forest identifier
region	= Regional Council Boundary (RCB)
altitude	= elevation (m)
GF_rating	= Growth and Form genetic improvement rating
seedlot	= seedlot identifier
plant_date	= plantation planting date
age	= height adjusted plantation age (decimal years)
MTH	= mean top height (m)
MCH	= mean crop height (m)
site index	= site index at plantation age 20 years (m)
sph_live	= live stems per hectare (sph)
purpose_code	= PSP purpose code identifier
slope	= uphill slope (degrees)
aspect	= azimuth from N, NE, E, SE, S, SW, W, NW, and NA (if flat)
dbh _q	= quadratic mean diameter breast-height of the stand (cm)
SDI	= Stand Density Index (Reineke 1933), sph, as if dbh _q was 25.4 cm
I300	= 300 Index, preliminary (Graham West and Mark Kimberley, pers. com.)

DATA

Data to input into the matrix was extracted from the *Forest Research* PSP system using a Structured Query Language, SQL, (**Appendix 1**). Criteria for inclusion of data included:

- only one species - *Pinus radiata*,
- plot status current or younger than 30 years,
- plot types not nelder or shelterbelt,

- measurements with more than 3 heights and all diameters,
- measurements with age greater than 3, and
- measurements not including root collar diameters.

As a test-case of the matrix approach, 4 of 15 geographic/political regions (described in the Methods section) were selected to provide data:

- Bay of Plenty,
- Hawkes Bay,
- West Coast, and
- Otago.

These regions provided a varied range in geography and radiata pine productivity to test the utility of the matrix.

Variables extracted directly from the PSP System included:

- plot_id,
- forest,
- region,
- altitude,
- GF_rating,
- seedlot,
- plant_date,
- age,
- MTH,
- MCH,
- site index,
- sph_live,
- purpose_code,
- slope, and
- aspect.

Variables subsequently derived (as described in the Methods section) from the extracted PSP data included:

- Stand Density Index (Reineke 1933) and
- 300 Index, preliminary (Graham West and Mark Kimberley, pers. comm.).

METHODS

To keep the national matrix practical and manageable, descriptive matrix variables were kept to a minimum. 'Lumping' was considered unavoidable, as 'splitting' to produce an intensive matrix factorial would result in an impractical and unmanageable matrix. For PSP data not residing on the *Forest Research* computer system, the intention is that the matrix will be distributed to SGMC members to fill-in and to identify Industry's contribution to the national PSP perspective. Combined, the two matrices (*FR's* and Industry's) would provide an overview of the entire existing matrix ('surface') of PSPs (experimental and growth monitoring) controlled by *Forest Research* and Industry.

The adopted matrix approach was to simply, but concisely categorise PSP data at each measurement date according to a combination of solitary descriptive variables relating to:

- national perspective (region),
- site (productivity),
- silviculture (stocking density),
- genetics (improvement rating), and
- tree-size (mean crop height).

Additional descriptive variables, such as, altitude, aspect, and/or rotation number may be useful, but this type of classification would be utilised, as an adjunct to the matrix, rather than an explicit matrix variable.

Results were tabulated using SAS Proc Tabulate (SAS 1999).

National Perspective

To provide a national perspective with respect to site, silviculture, and genetics; Regional Council Boundary (RCB), was selected as a matrix variable (**Figure 1**).

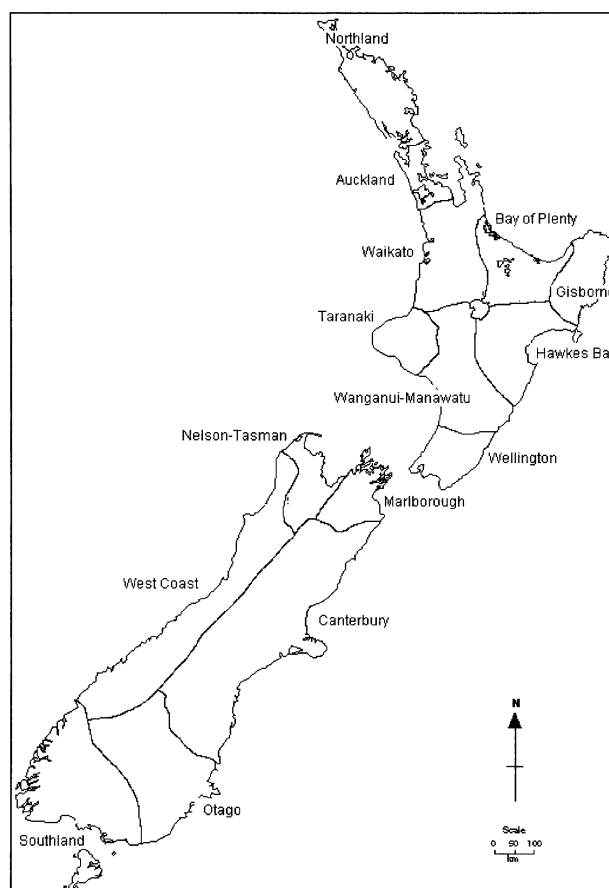


Figure 1. Regional Council Boundaries (15) selected to provide a national perspective with respect to site, silviculture, and genetics: Auckland, Bay of Plenty, Canterbury, Gisborne, Hawkes Bay, Marlborough, Nelson, Northland, Otago, Southland, Taranaki, West Coast, Waikato, Wanganui - Manawatu, and Wellington.

Site

Graham West's and Mark Kimberley's '300 Index' (a measure of radiata productivity based on volume mean annual increment) was selected to characterise site (productivity) as a matrix variable. The development of this index is still on-going, using a broad range of research trials and PSPs across New Zealand, and supported by the Forest and Farm Plantation Management Cooperative and FRST/PGSF. The 300 Index formulation used during the PSP matrix analyses reported herein, has since been superseded by an improved formulation. Nonetheless, the current PSP matrix analyses is still considered useful for the purpose of demonstrating the utility and intent of the 300 Index, as a matrix variable.

The preliminary 300 Index that was used is derived from the classical yield form of the Schumacher equation. The formulation has been reparameterised to predict volume mean annual increment (MAI), adjusted for age and stocking. The index has been standardised to represent volume MAI at age 30 and 300 sph. Thinning and pruning effects were incorporated, but at this stage of the development of the PSP matrix, these effects were ignored by setting to unity relevant portions of the index equation. The reliability of this exclusion of thinning and pruning effects was first tested on a range of data, which demonstrated only minor variation to calculated indices from the inclusion/exclusion of thinning and pruning effects. Thinning and pruning effects were ignored for two basic reasons: 1) the 300 Index formulation and incorporation of thinning and pruning effects were still under review and refinement, and 2) the implementation of the 300 Index equation (inclusive of thinning and pruning) is not a trivial exercise, as historic thinning and pruning events relevant to each PSP's re-measurement dates must be assessed.

Based on a preliminary survey of PSP data, the following 300 Index classes were used:

300 Index Class	Volume MAI (m ³ /ha)
Low	< 20
Medium1	20-28
Medium2	28-35
High	35-50
Extreme	> 50

The "extreme" group is considered an artefact of the 300 Index (preliminary) equation, operating at the upper limits of reliability (i.e., especially stand age < 10 years).

Silviculture

Reineke's Stand Density Index, SDI, (Reineke 1933) was selected to characterise silviculture (stocking density) as a matrix variable. Silviculture largely concerns the manipulation of growing space, which across a national perspective of both stand age and tree size, is best described succinctly as a relative index, rather than an absolute index (e.g., sph). While tree stocking (sph) explicitly characterises silviculture in terms of absolute stand density, stocking on its own does not convey the relative intensity of silviculture, or relative manipulation of growing stock that has occurred.

SDI provides a relative measure of growing space (intra-tree competition), and is a function of quadratic mean dbh (dbh_q) and tree stocking (sph):

$$SDI = 1.0147 * (10)^{[\log_{10} * sph + 1.605 * \log_{10}(dbh_q) - 2.25]}$$

SDI is the number of trees per hectare (sph), *as if*, dbh_q was 25.4 cm; and is independent of species, site quality, and age (Reineke 1933). SDI continues to be regarded as a standard to assess tree size-density relationships (Cao et al. 2000 and Curtis 1982). Based on a preliminary survey of PSP data, the following SDI classes were used:

SDI Class	Stocking, as if dbh_q was 25.4 cm (sph)
Low	< 250
Medium1	250-500
Medium2	500-750
High	> 750

Genetics

GF (growth and form) was selected to characterise the degree of genetic improvement as a matrix variable. If the GF rating was not present on the PSP system database, then assumptions were made from either the seedlot's number or the year of planting.

The following genetic classes were used:

GF Class	GF Rating
Unimproved	1-5
Climbing Select	6-12
Open Pollinated	13-18
Control Pollinated	> 19

Tree size

Mean crop height (MCH) was selected to explicitly characterise tree size as a matrix variable. Stand age was not used because at a given age, stand characteristics vary by site, silviculture, and genetics. Dbh_q was not used because of dependence on site, silviculture, and genetics to a greater degree than tree height.

Based on a preliminary survey of PSP data, the following MCH classes were used:

MCH Class (m)
< 10
10-15
15-20
20-30
> 30

RESULTS

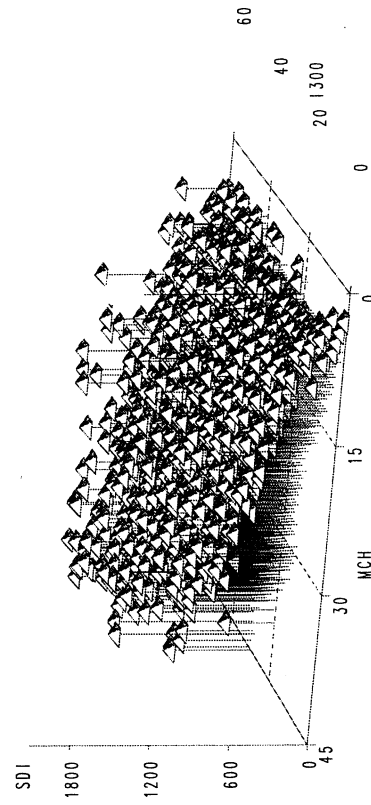
Figure 2 presents three-dimensional graphs (SDI x MCH x I300, preliminary) of the filled matrix (all genetic classes) for each of the four regions. **Figure 3** presents similar information, but the matrix variable, SDI, is replaced with sph. The figures are provided to give a visual impression of the filled matrices, and are not meant to provide detailed information.

The detailed results of filling the matrix (region by site, silviculture, genetics, and tree-size) are presented in **Tables 1 - 2** (all genetic classes) and **Tables 3 - 10** (by genetic class) for the regions:

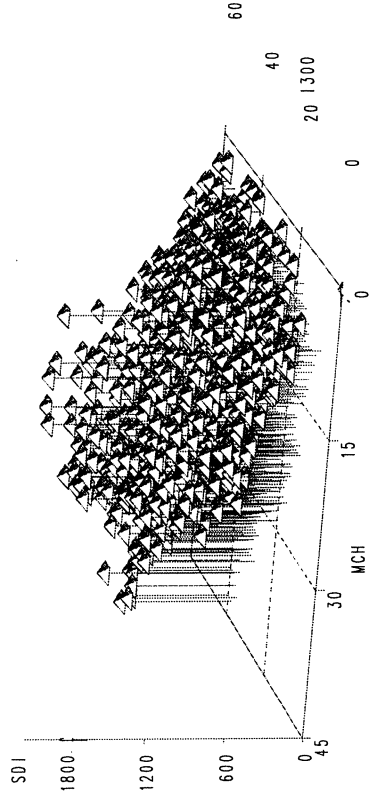
Region	Total Number of ALL Measurement Points
Bay of Plenty	10,378
Hawkes Bay	3,957
West Coast	1,465
Otago	2,043

Entries in the matrix cells identify the percentage (%) of the total number of ALL measurement points for a region. A percentage is used, so that results are comparable across the four regions. Matrix cells without observations are blank and shaded, while cells with "< 1" identify cells having less than 1% of the total number of ALL measurement points. **Table 11** presents the percentage of the total number of ALL measurement points by region for classes of the solitary variables: genetics, SDI, 300 Index (preliminary), MCH, age, and sph.

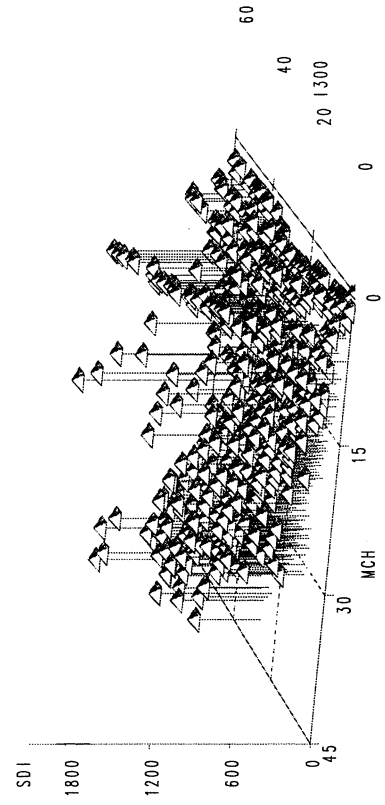
Bay of Plenty
SDI x MCH x I300



Hawkes Bay
SDI x MCH x I300



West Coast
SDI x MCH x I300



Otago
SDI x MCH x I300

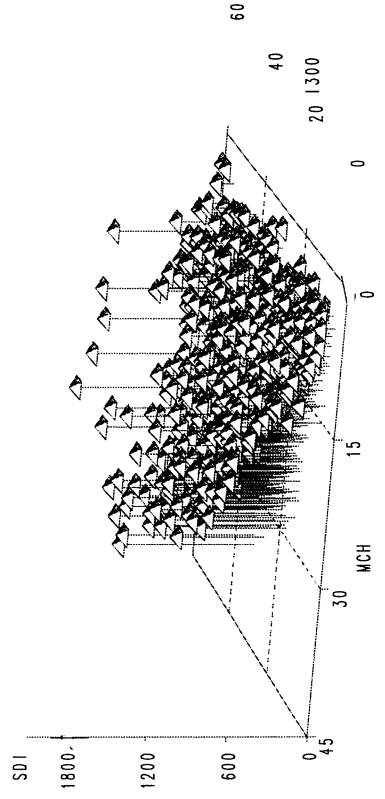
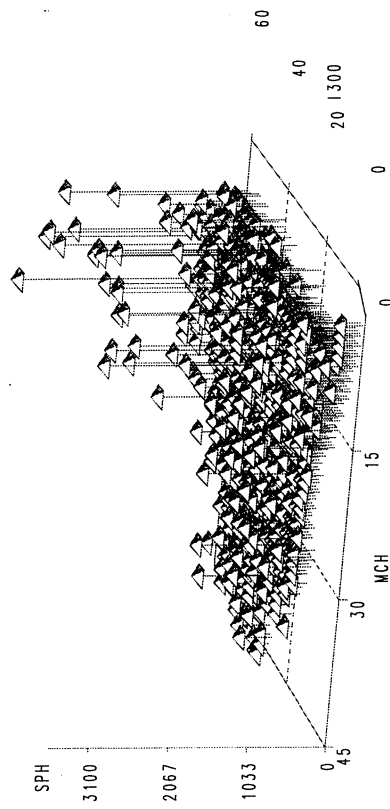
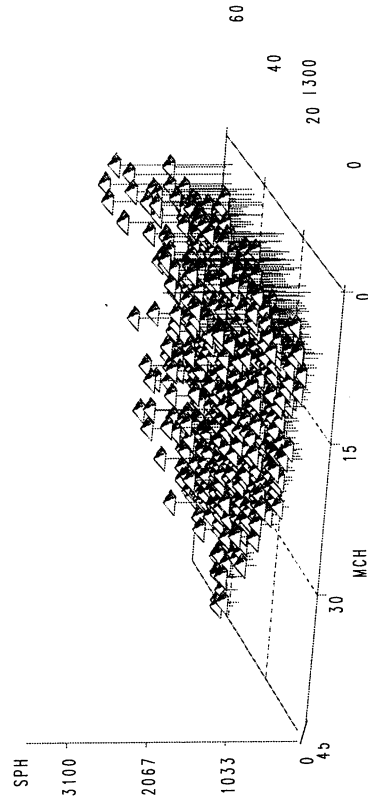


Figure 2. Three dimensional graphs (SDI x MCH x I300) of the filled matrix, all genetic classes for each of four regions.

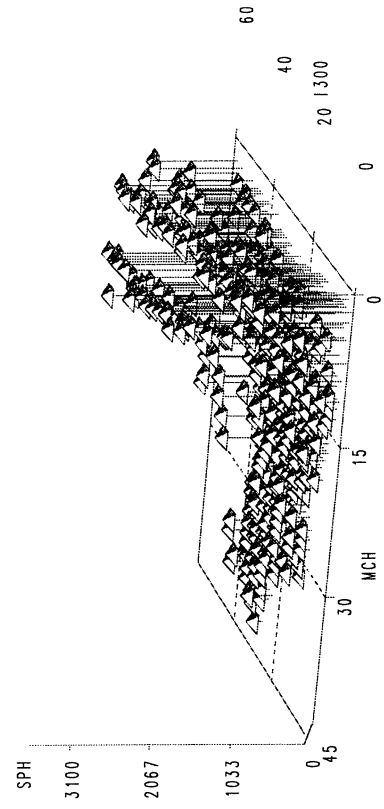
Bay of Plenty
SPH x MCH x I300



Hawkes Bay
SPH x MCH x I300



West Coast
SPH x MCH x I300



Otago
SPH x MCH x I300

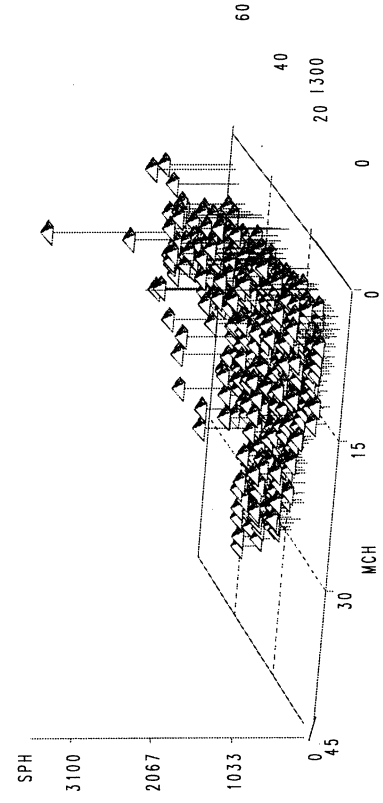


Figure 3. Three dimensional graphs (SPH x MCH x I300) of the filled matrix, all genetic classes for each of four regions.

Bay of Plenty: All Genetic Classes

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Bay of Plenty																			
GENETIC CLASS:		ALL																			
NO. MEASUREMENT POINTS:		10378 (100%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10	2	1	1	1	12	1	1	<1	1	4	<1	<1	<1	<1	<1	<1	<1	<1		<1	
10 - 15	1	1	1	2	3	2	1	1	2	4	<1	1	<1	1	1	<1	<1	<1	<1	1	
15 - 20	<1	<1	<1	1	1	1	1	1	2	3	<1	1	1	1	2	<1	<1	<1	<1	1	
20 - 30		<1	<1	<1	<1	1	3	3	3	2	1	2	4	3	1	<1	<1	1	2	<1	
> 30					<1	<1	<1	<1	1	<1	<1	1	2	1	<1	<1	1	2	2	<1	

Hawkes Bay: All Genetic Classes

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Hawkes Bay																			
GENETIC CLASS:		ALL																			
NO. MEASUREMENT POINTS:		3957 (100%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
1 - 10	1	1	1	2	17	1	1	<1	1	4		<1			<1		<1	<1		<1	
10 - 15	1	1	1	3	7	1	1	1	2	9	<1	<1	<1	<1	2		<1		<1	<1	
15 - 20	<1	<1	<1	<1	1	<1	1	2	3	5	<1	1	<1	1	2	<1	<1	<1	<1	1	
20 - 30			<1	<1	<1	<1	1	2	2	2	<1	1	3	4	2	<1	<1	1	1	1	
> 30							<1	<1	<1	<1			<1	1	<1			<1	1	1	

Table 1. Bay of Plenty and Hawkes Bay across all genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

West Coast: All Genetic Classes

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		West Coast																		
GENETIC CLASS:		ALL																		
NO. MEASUREMENT POINTS:		1465 (100%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	6	3	2	4	9	1	<1	<1	<1	4		<1	<1	<1						
10 - 15	5	1	1	1	<1	1	1	<1	<1		<1	<1	<1	1					<1	1
15 - 20	3	<1				17	2	<1	<1		<1	<1				<1	<1	<1	<1	
20 - 30	<1					13	2	<1			5	3	<1	<1		<1	1	<1	<1	
> 30	<1					<1	<1				1	2	<1			<1	2	<1		

Otago: All Genetic Classes

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Otago																		
GENETIC CLASS:		ALL																		
NO. MEASUREMENT POINTS:		2043 (100%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	7	8	4	4	2	1	2	1	2	1	<1	<1		<1	<1					<1
10 - 15	5	4	3	1	<1	3	4	4	2	1	<1	<1	1	<1	<1	<1	<1		<1	<1
15 - 20	1	1	<1			4	5	2	1		1	1	1	<1		<1	<1	<1	<1	<1
20 - 30		<1	<1			1	3	1	<1		2	5	1	<1		<1	2	<1	<1	
> 30									<1			<1	<1				<1			

Table 2. West Coast and Otago across all genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Bay of Plenty: By Genetic Class

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Bay of Plenty																			
GENETIC CLASS:		Unimproved																			
NO. MEASUREMENT POINTS:		585 (6%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10		<1	<1	1	13	<1			<1	3											
10 - 15	<1			1	2			1	2	6					1						
15 - 20	<1	<1			1	<1	1	1	1	3	<1		<1	1	4			1	1		
20 - 30		<1				1	2	2	3	3	<1	2	4	5	4			1	1	<1	
> 30						1	1	1	<1			2	8	3	1		3	5	2		

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Bay of Plenty																		
GENETIC CLASS:		Climbing select																		
NO. MEASUREMENT POINTS:		3015 (29%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	2	1	1	2	4	2	1	<1	1	2	<1	<1	<1	<1	<1	<1	<1	<1		<1
10 - 15	1	1	1	1	1	2	2	1	2	1	1	<1	<1	1	<1	<1	<1	<1	<1	1
15 - 20	<1	1	<1	1	2	2	2	2	2	<1	1	1	1	1	<1	1		<1	<1	<1
20 - 30		<1	<1	<1		2	5	4	2	<1	2	4	6	2	<1	1	1	1	1	<1
> 30						<1	<1	<1	<1		1	3	4	1		<1	1	3	1	

Table 3. Bay of Plenty, Unimproved and Climbing Select genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Bay of Plenty: By Genetic Class, continued

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Bay of Plenty																			
GENETIC CLASS:		Open pollinated																			
NO. MEASUREMENT POINTS:		5827 (56%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10	2	1	1	1	13	1	1	<1	<1	4	<1				<1		<1				
10 - 15	<1	<1	1	3	4	2	1	1	2	4	<1	1	<1	1	2		<1	<1	<1	1	
15 - 20	<1	<1	<1	2	1	<1	1	1	2	3	<1	<1	1	2	2	<1	<1	<1	<1	1	
20 - 30		<1	1	<1	<1	1	3	3	5	2	<1	1	3	3	1		<1	1	2	<1	
> 30					<1	<1	<1	<1	1	<1	<1	<1	1	2	<1		<1	1	2	<1	

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Bay of Plenty																			
GENETIC CLASS:		Control pollinated																			
NO. MEASUREMENT POINTS:		951 (9%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10	<1	1	2	2	34				<1	8					2						
10 - 15	<1	1	<1	1	4	<1	1		2	13		1		<1	2						
15 - 20		<1				<1	<1			3		<1		1	5					<1	
20 - 30										3				1	1			<1	1	1	
> 30														2				2	3		

Table 4. Bay of Plenty, Open and Control Pollinated genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Hawkes Bay: By Genetic Class

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Hawkes Bay																		
GENETIC CLASS:		Unimproved																		
NO. MEASUREMENT POINTS:		327 (8%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10		1	<1	2	22		<1			2										
10 - 15		<1	<1	2	9		1	2	5	10					1					
15 - 20				<1	1		2	2	6	2			1	<1					1	
20 - 30					<1			1	4	<1		3	3	6			1	2	2	
> 30													2	1				1	1	

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Hawkes Bay																		
GENETIC CLASS:		Climbing select																		
NO. MEASUREMENT POINTS:		1341 (34%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	<1	<1	1	2	8	<1	<1	<1	1	1										
10 - 15	1	1	2	3	7	1	1	1	1	4		<1		<1	1					
15 - 20		<1	<1	1	1	1	2	3	4	3		1	<1	1	1		<1		1	<1
20 - 30			<1	<1	<1	1	1	4	4	1	1	2	7	9	1	<1	<1	1	3	<1
> 30							<1	<1	<1				1	2				1	3	<1

Table 5. Hawkes Bay, Unimproved and Climbing Select genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Hawkes Bay: By Genetic Class, continued

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Hawkes Bay																			
GENETIC CLASS:		Open pollinated																			
NO. MEASUREMENT POINTS:		1842 (47%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10	1	1	1	2	18	1	1		1	5		<1			<1		<1	<1		<1	
10 - 15	1	1	1	2	7	1	1	1	2	9	<1	<1	<1	<1	3		<1		<1	1	
15 - 20	<1	<1	<1	<1	1	<1	1	2	2	6	<1	<1	<1	1	3	<1	<1	<1	<1	2	
20 - 30					<1	<1	<1	<1	1	3	<1	<1	1	2	4	<1	<1	<1	1	2	
> 30									<1	<1				<1	<1				1	<1	

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Hawkes Bay																			
GENETIC CLASS:		Control pollinated																			
NO. MEASUREMENT POINTS:		447 (11%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10				1	33					6											
10 - 15			1	1	10				1	21				<1	5						
15 - 20					<1				<1	6				<1	4					2	
20 - 30										1					2					2	
> 30																				3	

Table 6. Hawkes Bay, Open Pollinated and Control Pollinated genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

West Coast: By Genetic Class

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		West Coast																		
GENETIC CLASS:		Unimproved																		
NO. MEASUREMENT POINTS:		133 (9%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10				2																
10 - 15	2	1		1																
15 - 20		2				5														
20 - 30						9					17	7				4	4			
> 30							2				6	11	3			3	22	3		

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		West Coast																		
GENETIC CLASS:		Climbing Select																		
NO. MEASUREMENT POINTS:		734 (50%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	4	4	2	4	1	<1	<1													
10 - 15	7	1	1	<1		1	<1													
15 - 20	4	<1				27	1				<1									
20 - 30	1					22	3	<1			5	5	<1			<1	1	<1		
> 30	<1					1	<1				<1	1								

Table 7. West Coast, Unimproved and Climbing Select genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

West Coast: By Genetic Class, continued

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		West Coast																		
GENETIC CLASS:		Open Pollinated																		
NO. MEASUREMENT POINTS:		598 (41%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	10	3	3	5	21	1	1	<1	1	11		<1	1	<1						
10 - 15	3	2	1	1	<1	2	2	1	1		<1	1	1	3					1	2
15 - 20	1	<1				7	4	1	<1		1	<1				<1	1	<1	1	
20 - 30	<1					2	1	1			2	1	<1	<1				1	<1	
> 30																				

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		West Coast																		
GENETIC CLASS:		Control Pollinated																		
NO. MEASUREMENT POINTS:		None																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10																				
10 - 15																				
15 - 20																				
20 - 30																				
> 30																				

Table 8. West Coast, Open Pollinated and Control Pollinated genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Otago: By Genetic Class

PSP MATRIX : Percentage of ALL Measurement Points																					
REGION:		Otago																			
GENETIC CLASS:		Unimproved																			
NO. MEASUREMENT POINTS:		94 (5%)																			
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																				
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)					
	300 INDEX, preliminary (m3 / ha, volume MAI)																				
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	
< 10			3	1			1	1													
10 - 15	4					2	2	1			1					1					
15 - 20	1					10	9	2			2	2				4					
20 - 30						1	1				9	13	2			4	13	2			
> 30																	3	4			

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Otago																		
GENETIC CLASS:		Climbing Select																		
NO. MEASUREMENT POINTS:		1036 (51%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	11	7	3	2	<1	1	1	<1	<1		<1	<1			<1					<1
10 - 15	8	4	1	<1	<1	5	2	1	1			<1	<1	<1			<1			
15 - 20	3	2	<1			6	5	<1	<1		1	2	<1					<1		
20 - 30		<1	<1			1	6	2	<1		4	8	2	<1		<1	4	1		
> 30									<1			<1	<1				<1	<1		

Table 9. Otago, Unimproved and Climbing Select genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Otago: By Genetic Class, continued

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Otago																		
GENETIC CLASS:		Open Pollinated																		
NO. MEASUREMENT POINTS:		805 (39%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10	3	10	5	5	5	1	3	2	4	2		<1		<1	<1					
10 - 15	1	5	5	2	<1	1	8	8	3	1		<1	2	1	<1				<1	<1
15 - 20	<1	<1	<1			1	5	5	2		<1	1	2	1			<1		<1	<1
20 - 30						<1	<1	<1	<1		<1	1	<1	<1			<1	<1	<1	
> 30																				

PSP MATRIX : Percentage of ALL Measurement Points																				
REGION:		Otago																		
GENETIC CLASS:		Control Pollinated																		
NO. MEASUREMENT POINTS:		108 (5%)																		
MCH (m)	STAND DENSITY INDEX (sph, as if dbh _q was 25.4 cm)																			
	SDI LOW (< 250)					SDI MED1 (250 - 500)					SDI MED2 (500 - 750)					SDI HIGH (> 750)				
	300 INDEX, preliminary (m3 / ha, volume MAI)																			
	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50	Low < 20	Med 1 20-28	Med 2 28-35	High 35-50	Extm >50
< 10		14	10	15	4		6	6	16	2										
10 - 15			3	3			1	5	6	3		1	5	4						
15 - 20																				
20 - 30																				
> 30																				

Table 10. Otago, Open Pollinated and Control Pollinated genetic classes: results of filling the matrix by site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH).

Genetic Classes

Region	ALL	Unimproved GF1 - 6	Climbing Select GF7 - 12	Open Pollinated GF13 - 18	Control Pollinated GF >19
Bay of Plenty	100	6	29	56	9
Hawkes Bay	100	8	34	47	11
West Coast	100	9	50	41	
Otago	100	5	51	39	5

SDI Classes (sph, as if dbh_q was 25.4 cm)

Region	ALL	Low < 250	Medium1 250 - 500	Medium2 500 - 750	High > 750
Bay of Plenty	100	28	38	23	11
Hawkes Bay	100	35	37	19	9
West Coast	100	37	43	14	6
Otago	100	41	39	15	5

300 INDEX Classes (m³ / ha, volume MAI)

Region	ALL	Low < 20	Medium1 20 - 28	Medium2 28 - 35	High 35 - 50	Extreme > 50
Bay of Plenty	100	10	15	18	23	34
Hawkes Bay	100	4	8	12	22	54
West Coast	100	53	19	6	8	14
Otago	100	26	38	20	12	4

MCH Classes (m)

Region	ALL	< 10	10 - 15	15 - 20	20 - 30	> 30
Bay of Plenty	100	25	20	17	27	11
Hawkes Bay	100	27	29	19	21	4
West Coast	100	32	13	23	26	6
Otago	100	34	29	19	17	1

AGE Classes (years)

Region	ALL	< 6	6 - 10	10 - 15	15 - 20	> 20
Bay of Plenty	100	11	29	30	20	10
Hawkes Bay	100	10	40	31	14	5
West Coast	100	18	18	13	29	22
Otago	100	2	35	34	17	12

SPH Classes (sph)

Region	ALL	< 200	200 - 400	400 - 600	600 - 800	> 800
Bay of Plenty	100	21	38	20	13	8
Hawkes Bay	100	20	52	16	6	6
West Coast	100	19	51	4	4	22
Otago	100	34	38	18	6	4

Table 11. PSP Matrix: Percentage of ALL Measurement Points By Genetic, SDI, 300 Index (preliminary), MCH, Age, and SPH Classes.

DISCUSSION

General

Figure 2 contrasted against Figure 3 reveals the value of including SDI, instead of stocking (sph) in the matrix. Stocking presents a rather flat surface (insensitive) relative to that of SDI, which presents a more stepped or staggered surface with respect to the range of silviculture (manipulation of growing space) and the two other matrix variables, site (300 Index, preliminary) and tree-size (MCH).

Tables 1 and 2 (combined genetic classes) reveal a stark contrast between regions in the total number of measurement points. All regions contribute PSPs through the range of SDI (silviculture) and 300 Index, preliminary (site); although two regions (Westland and Otago) particularly lack some matrix coverage in MCH (tree-size) or SDI (silviculture).

Tables 3-10 (specific genetic classes) reveal significant gaps in matrix coverage, especially with the highest genetic improvement class, control pollinated (this is not unexpected, although West Coast stands out by showing absolutely none). The genetic classes, climbing select and open pollinated, are fairly well represented across site (300 Index, preliminary), silviculture (SDI), and tree-size (MCH); although the coverage for West Coast climbing select is less continuous relative to West Coast open pollinated.

Included in Table 11 is detail on stocking (sph), revealing that a large proportion of the data across the four regions (BOP, HBAY, WC, and OT) is at stockings < 600 sph, with a bulk of data at stockings 200-400 sph. The previously described matrix coverage (less continuous) for West Coast climbing select may result from a genetics by stocking interaction, as Table 11 shows stocking > 800 sph is disproportionately over-represented (22%).

Unfilled Matrix Cells

The results of the filled matrices (Tables 1 - 10) identify areas of the matrices that are void of observations. In some cases, a void cell may be acceptable (i.e., for whatever legitimate reasons), otherwise, oversight may be responsible. A legitimate reason may be that some regions may not support all silviculture regimes for all GF classes. On the basis of "all genetic classes", voids represent a complete lack of representative data. On the basis of "specific genetic classes", some voids may actually be "represented" by some other genetic class. In a "modelling sense", complete data representation at each specific genetic class level is ideal, however, the representation of the "surface", covered by at least some genetic classes, is better than no representation. Empty cells that are "surrounded" by filled cells, are not quite so serious, as the surface around them is represented, nonetheless.

Disproportionately Filled Matrix Cells

Matrix cells that are disproportionately filled identify possible over-sampling, or spurious matrix variable calculations. For example, the Bay of Plenty and Hawkes Bay, All Genetic Classes matrices identify a disproportionate percentage of the total number of ALL measurement points in the cells for Low SDI, Extreme 300 Index, and MCH < 10 m. This indicates that the 300 Index (preliminary) calculation provides spurious volume MAI

estimates at this combination of stand attributes (relative density, MCH, and volume). To the contrary, the West Coast and Otago matrices do not show this disproportionate percentage of measurement points for this same portion of the matrix. This dissimilarity suggests that young, highly productive stands (as seen in the BOP and HBAY) operate too far outside the existing limits of the 300 Index (preliminary). The West Coast matrix identifies a disproportionate percentage of measurement points in the cells for Medium1 SDI, Low 300 Index, and MCH 15-30 metres, however, in this "safe" portion of the matrix, the disproportionate percentages simply identify over-sampling relative to the other matrix cells.

Uniformly Filled Matrix Cells

In a "modelling sense", even relatively low percentages of the total number of ALL measurement points, which occur uniformly across the matrix, are acceptable (although, more is usually better). Given that a single matrix has 100 cells (5 MCH classes x 20 SDI/300I classes), 1% is the minimum integer percentage that represents a completely uniform distribution across all cells.

CONCLUSION

The PSP matrix described in this report establishes a surface across region (RCB), site (300 Index, preliminary), silviculture (SDI), genetics (GF), and tree-size (MCH) to characterise the national coverage of PSPs. In a test-case of this matrix approach with four regions (BOP, HBAY, WC, and OT), relative similarities and differences among regions became apparent. These similarities and differences in matrices, if obtained on a national basis from combined *Forest Research* and Industry databases, will provide a holistic view towards planning and co-ordinating the establishment and re-measurement of PSPs to help ensure adequate data for growth and yield analyses and modelling.

The next step will be to use the SGMC Email Forum for follow-up discussion on the appropriate manner to continue the work, i.e.:

- discuss any amendments to the approach and development of the matrix,
- include all the other regions,
- include Industry PSPs not currently on the *Forest Research* database, and
- incorporate the improved 300 Index which better predicts productivity at young ages, and with respect to thinning and pruning.

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- SAS Institute Inc. 1999. SAS Proprietary Software Version 8 (TS M0). SAS Institute Inc., Cary, North Carolina, USA.
- SGMC Report No. 22. Hayward, W., Goulding, C., Rawley, B., and West, G. 1991. PSP Future Strategy Committee Report. June. 14p.

APPENDIX 1

Structured Query Language (SQL) Procedure to Extract Data from the *Forest Research PSP System*

```
SELECT P.PLOT_ID, FOREST, REGION, ALTITUDE'ALT', GF_RATING'GF',  
SEEDLOT'SEED', PLANT_DATE'YEAR', HT_ADJ_AGE'AGE', MTH,  
MEAN_HT'MCH', HT_INDEX'SITE', SPH_LIVE, I300,  
SDI=ROUND(1.0147*POWER(10,((LOG10(SPH_LIVE)+1.605*LOG10(QMEAN_DBH  
) - 2.25))),0), PURPOSE_CODES,SLOPE,ASPECT  
FROM PLOT_SUMMARY P, MEAS_DESC M  
WHERE P.PLOT_KEY=M.PLOT_KEY  
AND P.MEAS_KEY=M.MEAS_KEY  
AND FULL_MEAS='Y' AND MEAN_HT>0  
AND PLOT_STATUS='C' AND SPECIES='P.RAD'  
AND CROP_COUNT=1 AND PLANT_DATE>'31 DEC 1969'  
AND STRUCTURE!='NELD' AND SAMPLE_TYPE!='T'  
AND CONTROLLER !='FRIC'  
AND QMEAN_RC=NULL  
AND HT_COUNT>3  
AND HT_ADJ_AGE>3
```