TFL 23 GROUND SAMPLING AND WORK PLAN FOR OLD GROWTH PRODUCTIVITY ESTIMATES

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INTRODUCTION

In the 1999 field season, a vegetation resources inventory (VRI) using timber emphasis plots was carried out in second growth stands (10-80 years old), in Tree Farm Licence (TFL) 23. In all, 164 plot clusters were established. At each integrated plot centre (IPC) the site series was determined. This project was designed and managed by Sterling Wood Group Inc. Eleven plots were not completed in 1999. Three of these were danger plots or were inaccessible, and will not be replaced. The remaining eight will be completed in the 2000 field season. These are listed in appendix I.

This document describes a ground sampling and work plan for the 2000 field season. This field work supports the strategic goals that will add value to the VRI data by using a statistical technique called discriminant analysis to extrapolate site series to forest polygons outside the VRI sample. This process will then allow for an inexpensive and efficient means of ecosystem mapping for second growth polygons in the biogeoclimatic variant samples by the VRI.

Included in this proposal is a field sampling project for the 2000 field season in stands 80 years or older, followed by the use of discriminant analysis to extrapolate site series and produce ecosystem maps for the old growth biogeoclimatic variants sampled.

GROUND SAMPLING PLAN

Accurate site productivity information will help Pope & Talbot to develop forest crop plans, which will ensure a sustainable supply and variety of high valued wood products. The end result will be the maintenance and creation of high paying jobs necessary to provide long term stability and growth within the local community of Nakusp and other communities in the Arrow Lakes area.

A growth and yield strategy was put in place last year. The objectives are:

1. to accurately determine species specific site productivity, stand structure and volume per hectare in second growth stands.

2. to predict the site index of young stands that will replace current old growth stands after logging.

In BC, several different methods have been used to map site productivity and to predict old growth site index conversion. This includes TEM and PEM mapping. TEM mapping has proved to be too expensive for practical use. PEM mapping is cheaper, but relies on subjective interpretations of aerial photography.

In a previous document an objective, statistically valid method to develop maps of forest ecosystem productivity and to convert old growth site index to site index for young replacement stands was described. This is attached as appendix II.

LAND BASE

TFL 23 is located in the West Kootenay region between Revelstoke and Castlegar. It lies on both sides of the Upper and Lower Arrow Lakes and is a significant portion of the Arrow Lakes catchment. The map in figure 1 shows the boundaries of the TFL.

The mountainous terrain of the TFL is bounded by the Monashee Mountains on the west side and the Selkirk Mountains to the east. The relatively gentle terrain on the main valley floors quickly gives rise to steep slopes. These slopes often have gullies through benches and rocky outcrops. Climatically the area is referred to as the interior wet belt. It has a moister and milder climate than the rest of the southern interior. Typically it has hot, moist summers and cool, snowy winters. In normal winters the soils tend not to freeze to any depth or for prolonged periods.

This continental climate encourages the growth of mixed conifer stands. Eleven conifer species and four deciduous species grow in mixed stands. The conifer species are: Douglas-fir, larch, western red cedar, western hemlock, Engelmann spruce, subalpine fir, lodgepole pine, western white pine and grand fir. Ponderosa pine grows in some southern areas and there is a rare occurrence of mountain hemlock. Deciduous species are: aspen, cottonwood, alder and birch. Commonly, hemlock/red cedar types are found at the lower elevations with Douglas-fir/larch on the drier and south facing slopes. At the mid and higher elevations the forest changes to mixed stands of Engelmann spruce and subalpine fir. The total area of TFL 23 is 556,389 hectares. The productive forest area is 371,834 hectares.

Figure 1: Key Map

OLD GROWTH PRODUCTIVITY SAMPLING PLAN

The VRI in second growth stands sampled the age range 10-80 years. The year 2000 samples will be in stands 80 years or older.

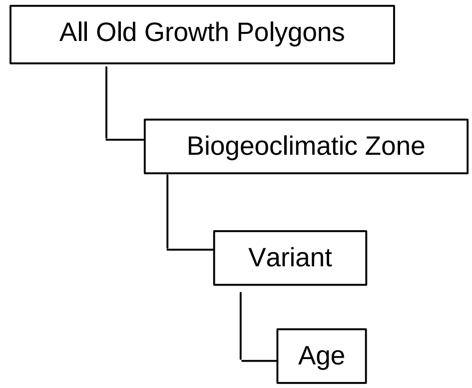
Table 1: Target Populations of 80+ Years Polygons

BEC Zone	Variant	# of Polygons
AT		6
AT	p	234
ESSF	vc	108
ESSF	vcp	36
ESSF	wc1	4,523
ESSF	wc4	6,027
ESSF	wcp4	1,321
ICH	dw	987
ICH	mw2	5,628
ICH	mw3	411
ICH	vk1	1,060
ICH	wk1	2,882
IDF	unn	49
Total		23,272

Table 1 shows that 23,272 forest cover polygons make up the 254,543 hectares of productive forests in stands 80 years or older on TFL 23. Average polygon size is 10.9 hectares. These polygons are distributed over 13 strata-defined by biogeoclimatic zone and variant.

The list of 23,272 polygons was sorted by variant and within variant sorted by ascending age. Figure 2 shows the sort criteria.

Figure 2: Sort Criteria for Old Growth



SAMPLE SIZE

The number of samples depends on theoretical considerations, available funds and length of field season. Too large a sample implies a waste of resources and too small a sample diminishes the utility of the results. Calculations of a theoretical sample size requires:

- an estimate of variation in the key attributes of interest (often expressed as coefficient of variation),

- a statement of the precision desired in the attributes.

In this project, the key attributes are height and age because they are the determinants of site index. For both attributes we calculated the coefficient of variation (CV) from the entire population of 23,272 polygons.

The coefficient of variation is the ratio of the standard deviation to the mean. A standard deviation of two for a mean of ten indicates the same relative variability as a standard deviation of 16 for a mean of 80. The coefficient of variation is 20 percent in each case.

In this project, the sample size as a fraction of population size (the sampling fraction) is likely to be less than 0.05. For this reason we have ignored the finite population correction factor in the estimation of sample size. The formula for sample size can be expressed as:

$$n = \left[\frac{t * cv}{E} \right]^2 \qquad (1)$$

Where n = required number of samples.
t = students t value for a selected probability level.
cv = estimated standard deviation expressed as a proportion of the mean.

$$cv = \frac{s}{\bar{x}}$$

Where s = estimated standard deviation.
$\bar{x}$ = estimated population mean.
E = desired precision expressed as a proportion of the mean.

The sample size calculated in this way will be a guide, not an exact requirement. The sample size used in practice will be a trade off between the calculated sample size and the expected cost and timing of the inventory.

The goal of this project is to assess site productivity as determined by stand height and age. Therefore, we have calculated sample sizes for both attributes. In both cases our precision target is ±10%. In keeping with current MoF practices, sample sizes are calculated with the assumption of zero measurement errors.

We have also calculated sample size for height and age using precision targets ranging from three percent for age and from four percent for height to 30 percent. These data are presented as graphs to show the relationship between sample size and required precision. In calculating the mean and standard deviation we excluded stands less than ten years old to reduce the chance of selecting stands whose height is less than 1.3 metres in these calculations.

In the sample size formula we used a *t* value of 1.96 because the sample size of the polygon attributes used to calculate the standard deviation was 20,557. When sample size is greater than 1,000 the *t* value is equal to 1.96 (95% probability). The sample size formula used was:

$$n = \left[\frac{1.96 * cv}{0.1}\right]^2 \qquad (2)$$

This produced the results shown in table 2.

Table 2: Sample size results when precision target is 10%

Attribute	Mean	Standard Deviation	Calculated Sample Size
Stand height	27.8m	6.1	19
Stand age	184.7years	66.8	50

The relationships between precision target and sample size for height and age are shown in figure 3.

Figure 3: TFL 23 stands 80+ years old
Sampling error and sample size

Figure 3 shows how, at first, increasing sample size causes a big increase in precision. After a time, increases in sample size are rewarded with diminishing increases in precision. Eventually, minimal benefits to precision are gained from increasing sample size.

Table 2 and figure 3 suggest that only a small sample is required to achieve a precision target of 10 percent, as a result of low variability in old growth heights and ages. These inventory values are class values assigned from aerial photography, which underestimates the true variability. For this reason and to achieve a representative sample of ecosystem types we will establish 120 plots in stands 100 years or older. These plots will also tell us how much variation in old growth stands is not being picked up by the inventory. Figure 3 suggests that 120 samples will give a nominal precision of 5 percent.

SAMPLE SELECTION

The list of 23,272 polygons of table 1 was sorted by biogeoclimatic zone, variant and age as shown in figure 3. These polygons total 254,543 hectares. A sample size of 120 polygons gives a sampling interval of 2,121 hectares. A random starting point within this interval was chosen by picking from a random number between zero and 2,121. This number turned out to be 86.45.

Additional polygons were selected systematically by repeating the sampling interval until 120 polygons were selected. Appendix I contains this full list, showing mapsheet and polygon number.

Table 3 summarizes the selected polygons. No polygon was assigned more than one cluster.

Table 3: Selected Polygons

BEC Zone	Variant	# of Polygons	Area(ha)
AT		0	0
AT	p	1	10
ESSF	vc	1	10
ESSF	vcp	0	0
ESSF	wc1	12	176
ESSF	wc4	36	1,399
ESSF	wcp4	3	76
ICH	dw	8	294
ICH	mw2	40	1,430
ICH	mw3	3	57
ICH	vk1	4	45
ICH	wk1	12	264
IDF	unn	0	0
Total		120	3,761

Figure 4 is a bar chart comparing the distribution of polygons in the zone/variant population with the distribution of polygons in the zone/variant sample.

Figure 4: Bar Chart

Table 4 shows the number of polygons sampled by leading species.

Table 4: Number of Polygons sampled by leading species

BEC	Variant	Leading Species											
		B	CW	EP	FD	H	HW	L	PL	PW	PY	S	TOTAL
AT	p											1	1
ESSF	vc											1	1
ESSF	wc1	4			1	1	3		1			2	12
ESSF	wc4	20			1		1		2			12	36
ESSF	wcp4											3	3
ICH	dw		1		6				1				8
ICH	mw2	3	3	1	15		9	6	3				40
ICH	mw3				1		1					1	3
ICH	vk1		4										4
ICH	wk1	2	1				7					2	12
Total		29	9	1	24		21	6	7	0	0	22	120

The range of ages, heights and site index in both target and sample populations is shown in table 5.

Table 5: Age and Site Index Ranges

	Population	Min.	Max.	Mean
Target				
	Age	80	711	184.7
	Site Index	1.6	58.8	14.1
	Height	2.2	72	27.8
Sample				
	Age	81	324	178.9
	Site Index	4.4	24.5	14
	Height	16.9	43.7	27.4

COMPLETING THE ELEVEN PLOTS FROM 1999

Of the plots not completed last year, 2 were danger plots and 1 was inaccessible. These plots will not be replaced from last years sample list. The remaining 8 plots will be visited this year. These 8 second growth plots are listed in appendix I - polygon list.

SAMPLING METHODOLOGY AND STANDARDS

Ground sampling methodologies and standards will be those described in the documents *Vegetation Resource Inventory Ground Sampling Procedures*, Version 4.0 March 1999. Web site: http://www.for.gov.bc.ca/RIC/Pubs/teVeg/gsp/index.htp; *Quality Assurance Procedures*, March 2000; *Quality Assurance Standards*, March 2000.

One, five-plot cluster will be established in each polygon. The plots will be timber emphasis plots (TEP). Variable length call grading will be applied to the integrated plots, but not to the auxiliary plots.

Height and age measurements will be made for each species in the stand that forms part of the canopy. It is expected that different species will occur in the five plots. Therefore, in order to get the required measurements for every species, height and age measurements may be distributed over all five plots.

Guiding chapters of the VRI sampling manual will be:

Chapter 3: Plot Establishment
Chapter 4: Inventory Cruising
Chapter 6: Call Grading
Chapter 7: Plants, soils and old growth.

IMPLEMENTATION OF SAMPLING PLAN

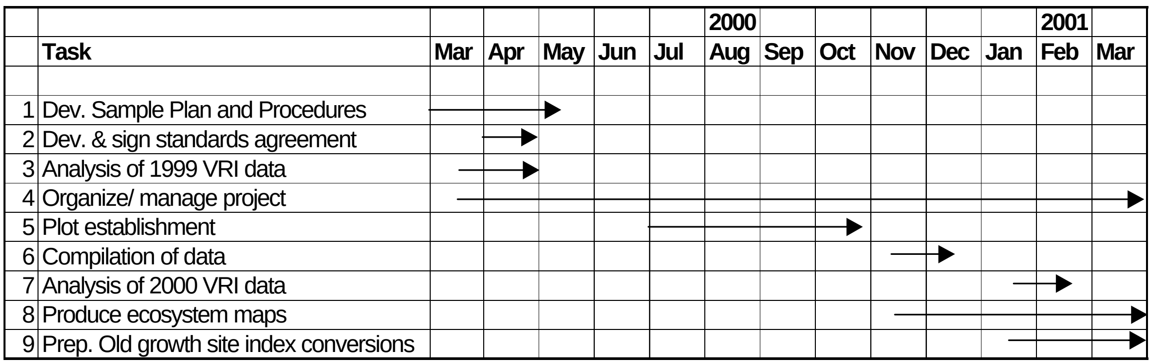
The sampling plan will be implemented over a single field season in 2000. Sterling Wood Group will manage the project as a 'turn key' operation. The Sterling Wood Group consulting practice has a wide experience of managing large, complex projects. The individuals involved in the project have managed large, complex projects throughout the province and in Yukon Territory. In each of the past five years, we have completed several projects of more than $500,000, plus two or three each year that were more than $200,000. These projects have all had a significant field component and have been conducted in both summer and winter.

The implementation of this project includes the following tasks:

1. Development of a sample plan and field procedures for the 2000 field season.
2. Develop & sign a standards agreement.
3. Discriminant analysis of 1999 VRI data and cross referencing to site series.
4. Organization and management of project including field sampling, data preparation, data analysis.
5. Field plot establishment.
6. Compilation of old growth sample data.
7. Discriminant analysis of year 2000 old growth samples and cross referencing to site series.
8. Production of ecosystem maps for the variants sub-sampled.
9. Preparation of old growth site index conversions based on species and site series.

The Gantt chart that follows (figure 5) shows the planned schedule for these tasks.

Figure 5: TFL 23 Second Growth Productivity Gantt Chart



PROJECT PERSONNEL

The project will be led by Dr. Stephen Smith. Dr. Smith is a senior forester with consulting experience that ranges from field operations to the corporate boardroom and cabinet members' offices. He has worked for clients in every part of BC, and has managed projects up to four million dollars in size. Dr. Smith will also carry out the discriminant analysis.

The field inventory expert on this project will be Linda Fear. Linda is qualified and experienced in all aspects of vegetation inventory, net factoring and log scaling. Linda will organize and direct the establishment of old growth field plots.

An important part of preparing data for field crews is the photo-interpretation required to locate plot centres on aerial photographs. Don Wilson did this successfully for the 1999 VRI and will repeat the process for the old growth samples.

Diana Brown produced all the maps for the 1999 VRI and will be responsible for map production in this project.

In this project, Huili Liu will be responsible for inventory database manipulation and will work with Diana to link databases and GIS coverages.

APPENDICES

APPENDIX I

POLYGON LIST

APPENDIX II

DISCRIMINANT ANALYSIS PROPOSAL

POLYGON LIST

Mapsheet	Polygon	Species	Proj Age	Proj. Ht.	BEC		Area(ha)
082E049	105	H	167	30.2	ESSF	wc 1	35.9
082E049	287	HW	131	29.4	ESSF	wc 1	6.7
082E050	211	FD	186	22.5	ICH	dw	18.5
082E050	422	FD	81	28.7	ICH	dw	4.6
082E060	131	PL	91	17.3	ICH	mw 2	11.4
082E060	196	FD	141	34.2	ICH	dw	9.9
082E060	263	PL	101	19.1	ICH	dw	105.2
082E069	22	HW	211	33.7	ICH	mw 2	30.6
082E070	456	FD	91	21.8	ICH	dw	30.2
082E080	27	FD	111	23.4	ICH	dw	20.4
082E080	159	FD	131	27.2	ICH	mw 2	25.5
082E080	218	PL	111	25	ICH	mw 2	49.2
082E080	305	B	171	25	ICH	mw 2	10.8
082E090	14	CW	211	33.6	ICH	dw	26.8
082E100	171	FD	101	26.8	ICH	mw 2	41.9
082E100	432	FD	106	29.8	ICH	mw 2	42.2
082F031	22	FD	89	26.8	ICH	dw	78.3
082F031	36	FD	89	19.4	ICH	mw 2	25.5
082F041	12	S	211	27.8	ESSF	wc 4	27.9
082F041	303	EP	81	18.4	ICH	mw 2	12.7
082F081	56	B	224	25.5	ESSF	wc 4	9.9
082F081	430	PL	81	22.6	ESSF	wc 4	13.9
082F082	169	B	204	21.6	ESSF	wc 4	8.8
082F091	250	PL	91	24.4	ICH	mw 2	19.3
082F091	265	FD	141	34.2	ICH	mw 2	17.2
082F091	343	L	116	30.5	ICH	mw 2	78.2
082F092	19	PL	91	19.3	ESSF	wc 1	0.6
082F092	248	B	141	18	ESSF	wc 4	46.2
082F092	268	B	211	24.7	ESSF	wc 4	24.2
082K001	76	B	211	24.7	ICH	mw 2	3.9
082K001	80	FD	111	28.6	ICH	mw 2	15.7
082K001	138	B	211	24.7	ESSF	wc 1	11.7
082K001	177	HW	119	27.2	ICH	mw 2	30.3
082K001	198	FD	121	27.3	ICH	mw 2	18.7
082K011	200	B	224	18.2	ESSF	wc 4	7.0
082K011	426	HW	224	34.5	ICH	mw 2	83.3
082K021	49	FD	101	18.3	ICH	mw 2	67.5
082K021	224	HW	126	25.1	ICH	mw 2	27.0
082K031	49	FD	106	27.7	ICH	mw 2	21.0
082K031	237	L	99	25.5	ICH	mw 2	16.7
082K031	323	FD	96	29.1	ICH	mw 2	17.6
082K032	159	B	91	17.8	ESSF	wc 4	44.1
082K032	187	B	224	28.7	ESSF	wc 4	14.2
082K041	150	HW	109	29.5	ICH	mw 2	77.8
082K041	298	L	154	25.9	ICH	mw 2	5.5

Mapsheet	Polygon	Species	Proj Age	Proj. Ht.	BEC		Area(ha)
082K041	308	HW	224	25.2	ICH	wk 1	8.8
082K041	373	PL	324	24.3	ESSF	wc 4	14.2
082K041	387	L	111	29.6	ICH	mw 2	146.3
082K041	487	HW	324	30.7	ICH	mw 2	13.0
082K042	37	B	324	24.9	ESSF	wc 1	11.1
082K042	217	B	224	25.5	ESSF	wc 4	66.3
082K042	247	B	224	32.8	ESSF	wc 1	17.2
082K042	416	HW	211	24.6	ESSF	wc 4	3.5
082K042	562	B	224	25.5	ESSF	wc 4	44.8
082K051	224	FD	84	19.4	ICH	mw 2	73.3
082K051	312	HW	211	33.7	ICH	mw 2	61.7
082K051	425	B	224	32.8	ESSF	wc 4	18.7
082K051	534	L	224	26.7	ICH	mw 2	64.0
082K052	370	S	224	34.2	ICH	wk 1	26.1
082K052	373	S	324	28.2	ICH	wk 1	26.7
082K053	116	S	224	32.4	ESSF	wc 1	2.8
082K053	231	S	224	16.9	ESSF	wc 4	29.9
082K061	119	HW	224	34.5	ICH	mw 3	35.3
082K062	405	HW	121	31.6	ICH	wk 1	25.6
082K062	638	HW	154	35.9	ICH	wk 1	9.2
082K062	723	CW	134	37.5	ICH	vk 1	27.8
082K062	756	S	154	17.8	ESSF	wc 4	12.0
082K062	762	S	224	19	ESSF	wcp 4	50.5
082K063	34	S	224	28.6	ESSF	wc 4	5.1
082K063	264	CW	224	34.4	ICH	wk 1	2.8
082K064	233	HW	224	25.2	ICH	wk 1	20.9
082K064	283	B	224	25.5	ESSF	wc 1	2.9
082K064	294	B	224	18.2	ESSF	wc 4	4.7
082K072	245	HW	324	24.6	ICH	wk 1	59.7
082K072	411	HW	224	34.5	ICH	mw 2	9.8
082K073	110	S	224	32.4	ESSF	wc 4	177.3
082K073	333	B	224	25.5	ESSF	wc 4	6.5
082K073	444	S	224	28.6	ESSF	wcp 4	16.7
082K073	455	HW	224	31	ICH	wk 1	26.1
082K082	245	CW	224	25	ICH	vk 1	7.2
082K083	94	S	224	25.8	ESSF	wc 4	7.3
082K083	135	HW	224	43.7	ESSF	wc 1	12.8
082K093	1	CW	324	24.6	ICH	vk 1	0.9
082K093	469	B	224	25.5	ESSF	wc 4	11.7
082L009	57	B	129	28.3	ESSF	wc 4	84.3
082L010	5	S	211	24.9	ESSF	wcp 4	9.0
082L010	14	B	211	27.8	ESSF	wc 4	9.4
082L010	126	B	101	20.8	ICH	mw 2	27.7
082L010	127	CW	91	25	ICH	mw 2	20.5
082L010	259	B	111	19.5	ESSF	wc 4	42.7
082L010	389	CW	144	31.9	ICH	mw 2	109.7
082L010	546	FD	101	25.7	ESSF	wc 4	4.2
082L010	566	FD	106	23.5	ESSF	wc 1	5.7

Mapsheet	Polygon	Species	Proj Age	Proj. Ht.	BEC		Area(ha)
082L020	420	B	224	18.2	ESSF	wc 4	42.5
082L020	464	FD	134	30	ICH	mw 2	39.8
082L020	699	FD	101	31	ICH	mw 2	53.2
082L029	44	B	211	22.7	ESSF	wc 4	27.3
082L030	249	B	224	28.7	ESSF	wc 4	41.4
082L030	275	HW	211	33.7	ESSF	wc 1	42.8
082L030	322	FD	121	29.4	ICH	mw 2	2.2
082L039	41	B	96	19.8	ICH	wk 1	0.2
082L039	209	S	224	32.4	ESSF	wc 1	25.5
082L039	252	S	224	25.8	ESSF	wc 4	396.1
082L040	654	FD	111	28.6	ICH	mw 2	6.1
082L040	754	L	94	26.6	ICH	mw 2	33.7
082L040	765	CW	211	33.6	ICH	mw 2	6.4
082L050	83	S	224	32.4	ESSF	wc 4	18.6
082L050	131	B	224	32.8	ICH	wk 1	9.7
082L050	388	HW	224	25.2	ICH	mw 2	12.6
082L060	9	S	224	32.4	AT	p	9.8
082L060	262	S	224	28.6	ESSF	wc 4	51.9
082L070	374	S	224	28.6	ESSF	wc 4	16.6
082L080	454	S	224	42.9	ESSF	wc 4	32.3
082L089	82	S	224	34.2	ICH	mw 3	10.6
082L089	174	S	324	42.4	ESSF	wc 4	19.1
082L090	169	B	224	34.8	ESSF	wc 4	13.9
082L090	219	HW	224	25.2	ICH	wk 1	48.3
082L090	333	FD	100	21.4	ICH	mw 3	11.4
082N003	32	CW	224	34.4	ICH	vk 1	9.5
082N003	293	S	224	28.6	ESSF	vc	9.9

1999 SECOND GROWTH PLOTS FOR COMPLETION IN 2000

Sample #	Mapsheet	Polygon	Species	Proj Age	Proj. Ht.	BEC	Area(ha)
54	082E090	166	PL	51	17.1	ESSF wc 4	0.75
71	082F081	178	FD	66	23.1	ICH mw 2	32.8
74	082F081	555	B	26	2.6	ESSF wc 4	16.97
76	082F092	105	PL	76	23.9	ICH mw 2	5.23
85	082K011	288	L	39	15.8	ICH mw 2	58.9
87	082K011	396	PL	71	23.1	ICH mw 2	52.47
95	082K021	369	HW	21	3.8	ICH mw 2	85.49
182	082L050	283	HW	21	7.0	ESSF wc 4	48.94

DISCRIMINANT ANALYSIS

The discriminant function is a multivariate technique for studying the extent to which different populations overlap one another or diverge from one another. One of its uses has been in classification and diagnosis.

Historically, it is interesting that the discriminant function was developed independently by Fisher in 1936, whose primary interest was in classification; by Mahalanobis in 1930 in connection with a large study of the relations between Indian castes and tribes; and by Hotelling in 1931 who produced the multivariate t-test.

Discriminant analysis can be used to explore:

- which variables are most useful for discriminating among groups
- which groups are most alike and most different
- if one subset of variables perform equally as well as another

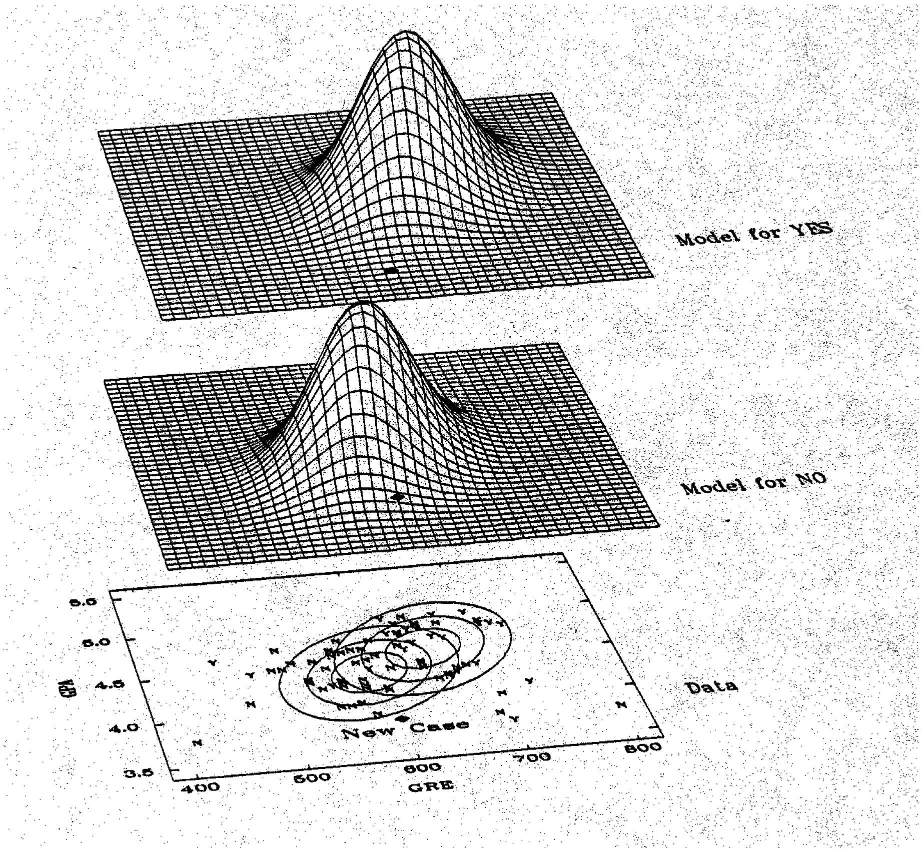
Discriminant analysis provides linear or quadratic functions of variables that best separate cases into two or more groups.

When we have categorical variables in a model, it is often because we are trying to classify cases, that is, what group does someone or something belong to? For example, we might want to know whether someone with a grade point average (GPA) of 3.5 (out of 4) and an Advanced Psychology Test (APT) score of 600 is more like the group of graduate students successfully completing a PhD, or more like a group that fails.

Once we attempt to classify, our attention turns from parameters (coefficients) in a model to the consequences of classification. We now want to know what proportion of subjects will be classified correctly and what proportion incorrectly. Discriminant analysis is one method for assessing these questions.

If we know that our classifying variables are normally distributed within groups we can use a classification procedure called **linear discriminant analysis**. In this procedure **Mahalanobis distances** are calculated between cases we want to classify and the centre of each group in the multidimensional space. The closer a case is to the centre of one group (relative to its distance to other groups), the more likely it is to be classified as belonging to that group. An example from the SYSTAT 8.0 statistics manual (Engelman 1998), figure 2, illustrates this using two grouping variables. The borders of the graph comprise the two predictors, GPA and APT. The two “hills” are centered at the mean values of the two groups (PhD, no PhD). Most of the data in each group are supposed to be under the highest part of each hill. The hills, in other words, mathematically represent the concentration of data values in the scatter plot beneath.

Figure 2: Bivariate distributions for two grouping variables (After Engelman 1998)



How do we classify a new case into one group or the other? In figure 2, the diamond shape on each model represents a new case, relative to each hill. The new case could belong to either group but it is more likely to belong to the closer group. The simple way to find out how far this case is from the centre of each group would be to take a direct walk from the new case to the centre of each group in the data plot. Instead of walking in sample data space below, we must climb the hills of our theoretical model when using the normal classification model. We have to use our theoretical model to calculate distances, using the covariance matrix calculated for the two predictor variables. The covariance matrix makes the distances depend on the direction in which we are heading. The distance to a group is thus proportional to the altitude (not the horizontal distance) we must climb to get to the top of the corresponding hill.

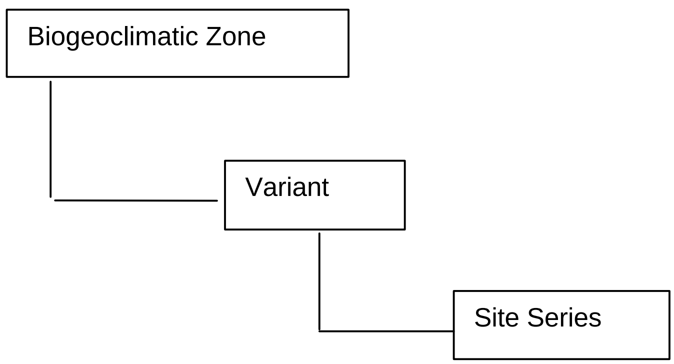
Because these hills can vary in shape and may be long and narrow, it is possible to be quite far from the top of the hill as the crow flies, yet have little altitude to cover in a climb. Conversely, it is possible to be close to the centre of the hill and have a steep climb to get to the top. Discriminant analysis adjusts for the covariance that causes this variety in hill shape.

The discriminant model generalizes to more than two groups. The multiple group yields more than one discriminant axis. For n groups we get an n-1 axes. If we have fewer variables than groups we get only as many sets as there are variables.

APPLICATION TO VRI DATA

First a predetermined number of groups will be determined within each biogeoclimatic variant sampled during the vegetation resources inventory of 1999. The number of groups will be equal to the number of site series sampled. This determination is shown in figure 3.

Figure 3: Defining the number of groups



In the TFL 23, second growth VRI, two biogeoclimatic zones were sampled (ESSF and ICH). Three variants were sampled within the ESSF zone and five variants within the ICH zone. An average of about four site series were sampled within each variant. This gives a total of 32 site series.

Second, a database will be constructed with a separate record for each VRI integrated plot centre (IPC). Each record in the database will have fields shown in table 1.

Table 1: Database Record Structure

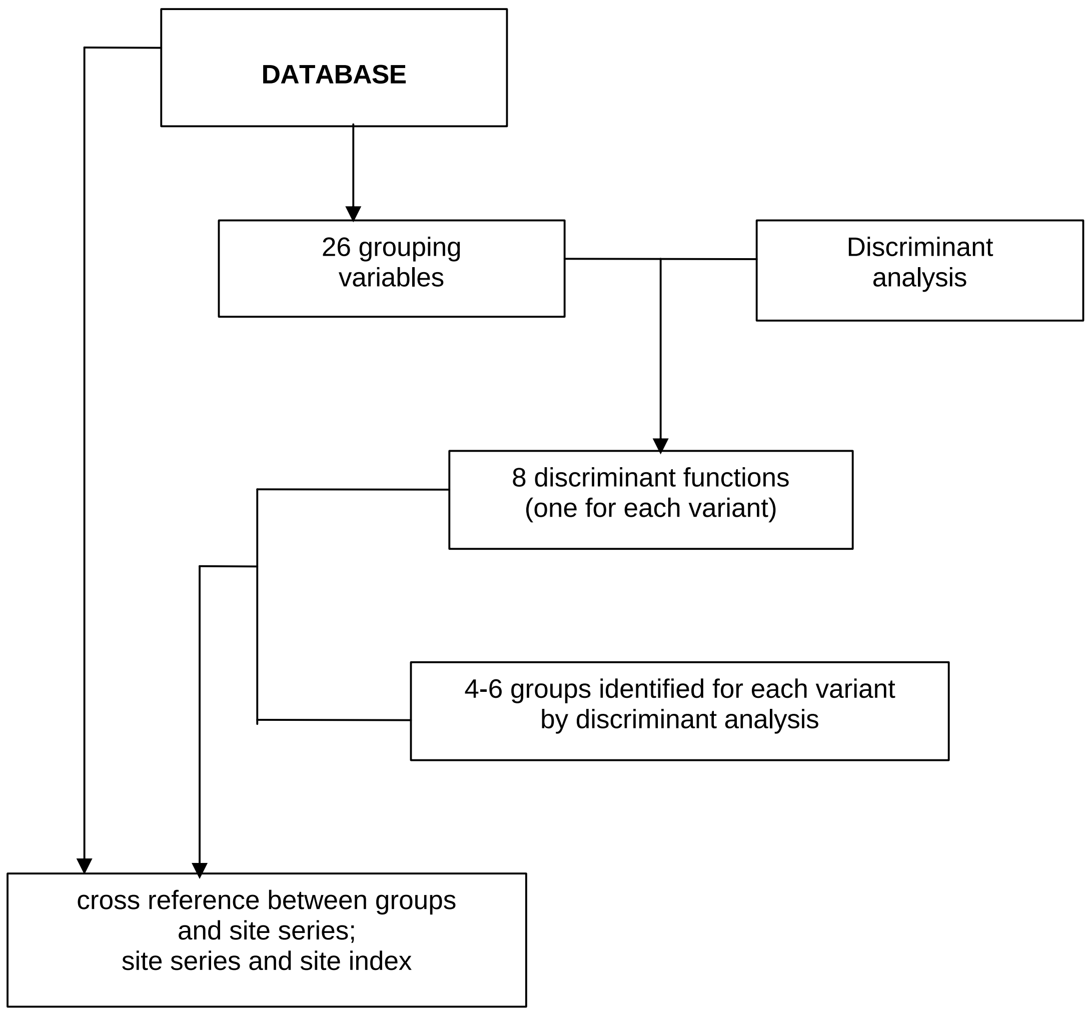
Field #	Variable Name
1	VRI plot #
2	VRI mapsheet
3	VRI polygon
4	Biogeoclimatic zone
5	Biogeoclimatic subzone
6	Biogeoclimatic variant
7	Site series number
8	Plot leading tree species
9-23	Plot % cover of the 15 tree species found on TFL 23
24	Plot age
25	Plot height
26	Plot site index
27	Plot stems/ha
28	Plot quadratic mean diameter
29	Plot basal area/ha
30	Plot aspect
31	Plot elevation
32	Plot slope percent
33	Plot latitude
34	Plot longitude

A subset of the variables in table 1 will be used as **grouping** variables in the discriminant analysis. For each of the eight biogeoclimatic variants, a separate discriminant function will be determined. The number of groups within each variant will be equal to the number of site series sampled during the VRI. The number of grouping variables used will be much greater than the number of site series within each variant. Grouping variables used in the discriminant analysis will be:

- % cover of the 15 tree species found on TFL 23 (15 variables)
- age
- height
- site index
- stems/ha
- quadratic mean diameter
- basal area/ha
- aspect
- elevation
- slope percent
- latitude
- longitude

These 26 grouping variables, or a best subset determined during the discriminant analysis, will be used to define groups within each variant. A discriminant function will be built for each variant. The groups identified by the discriminant analysis will be cross referenced to their respective site series using the database defined in table 1. This process is shown graphically in figure 4.

Figure 4: Discriminant Analysis



Within each variant the number of groups (4-6) is far less than the number of grouping variables (26). Therefore the number of groups identified by each discriminant analysis within each biogeoclimatic variant will not be constrained by the number of grouping variables. The final set of variables used in the discriminant function will be the same in both plots and polygons. Site series at the IPC will be reflected by the tree variables at IPC. The analysis is looking for relationships between site series and the trees on the same site. These are best determined by an exact match between inventory plot and site series. During extrapolation these relationships will be applied to overall polygon attributes. Therefore, the site series assigned should apply to the overall polygon. Following precedents set in TFL's 49 and 8, site series was determined for the IPC. In our second growth inventory, site series was determined for a ten metre radius around the IPC. We want the old growth procedures to be consistent with the second growth.

The cross referencing will enable each group to be identified with a site series. For each group, the average site index will also be calculated.

A practical method was devised for recording supporting information for site series determination at each plot centre. This method allows office and field verification of site series and is repeatable by third parties.

The method is described below as a set of instructions that were issued to each field crew.

1. Use the comments section on the back of cluster layout card #3.
2. Determine the biogeoclimatic zone variant from the map provided to you.
3. Using the "Field Guide for Site Identification and Interpretation for the Nelson Forest Region":
    - record the indicator shrubs, herbs and mosses/lichens present in a 10 metre radius from the Integrated Plot Centre (IPC),
    - only record plant species that are listed in the vegetation table given in the field guide for each zone variant,
    - determine the soil moisture regime (0-7),
    - determine the soil nutrient regime (A-E).
4. From the information recorded in (3) above and any other information visible on the site, assign and record a site series.
5. On card #3, record the site series information as shown on the attached example.
6. It may be necessary to dig a small soil pit to confirm soil moisture and soil nutrient regimes. These pits do not need to be very deep and are required only to confirm moisture and nutrient regimes.
7. An example of a completed card for site series identification is attached.

Quality assurance of the site series assignments for the 1999 field season included:

1. An office check of 100% of the site series assignments.
2. A field check of 5% of the site series assignments.

In the office, first the assignment of variant was checked against the biogeoclimatic maps provided by the MoF. Very rarely a crew changed the variant assignment based on field evidence. If this happened they provided supporting notes. Next, in the office, the recorded indicator species, soil moisture and soil nutrient regimes were checked to see if the recorded site series was consistent with these recorded data.

In the field, 5% of the integrated plot centres were visited. At each plot an independent assessment of site series was made, by repeating the method described above. During field checking, a soil pit was dug at every plot.

Further field checks by a third party could be made. During the 2000 field season we propose that 10% of the 1999 IPCs and of the 2000 IPCs be field checked for site series assignments by someone not associated with the project. It will be important to restrict the site series determination to a ten metre radius around the IPC because we are interested in the relationship between site series and tree growth on the same piece of ground.

The interpretation of site series in the field using the recorded indicator species, and the assessment of soil moisture and soil nutrient regimes were made using the following MoF guidebooks:

- A Field Guide for Site Identification and Interpretation for the Nelson Forest Region,
- A Guide to Site Identification and Interpretation for the Kamloops Forest Region.

Should the third party field checks find that these interpretations are faulty, then we will use biogeoclimatic variant as our unit for comparison of old growth and second growth site index. This will allow average site index for old growth and second growth to be compared for each biogeoclimatic variant.

EXTRAPOLATING THE RESULTS

Discriminant analysis and the discriminant function can be used to classify new polygons into one group or another, using the forest inventory attribute.

SECOND GROWTH POLYGONS

From the VRI, eight discriminant functions will be produced for the second growth stands (10-80 years) sampled (one function for each variant). For all other second growth polygons not sampled in the eight variants, a discriminant function will be used to compute a score and assign the polygon to one of the groups identified in the statistical analysis. For polygons within a given variant, the score will be computed from the coefficients of the discriminant function and the values of the grouping variables found in the polygon.

The score for each polygon will be used to assign it to the group with the closest mean score. The cross references to site series will be used to assign site series. This process will apply to all polygons in the age range 10-80 years in the following biogeoclimatic variants.

ESSF	wc 1
	wc 4
	wcp 4
ICH	dw
	mw 2
	mw 3
	vk 1
	wk 1

All other second growth polygons will have an assigned variant but not a site series. Theme maps of site series can be easily produced by assigning the same colour to all polygons with the same site series. The discriminant analysis will result in some site series being grouped because they have equivalent site index values. As long as the old growth and second growth site series belong to the same group then second growth site index can be assigned. In the case where there is not an equivalent site series group, the second growth site index assigned will be the biogeoclimatic variant average, determined from the second growth inventory.

OLD GROWTH POLYGONS

The same techniques of discriminant analysis will be applied to mature polygons (141 years or older). In the 2000 field season, a random sample of old growth stands will be taken. There are two objectives for the old growth sample:

1. to build discriminant functions for the old growth inventory attributes;
2. to determine the old growth site index conversion for a given tree species on the same site series.

During the 2000 field season a random sample of old growth stands will be established. These will be VRI timber emphasis clusters. In addition to diameter measurements, site height and site age will be determined.

As with the VRI plots, within each variant, discriminant analysis will be used to identify groups which will then be cross referenced to equivalent site series.

EXTRAPOLATING THE RESULTS

Using the discriminant functions to classify old growth polygons that were not sampled, ecosystem maps will be produced for those biogeoclimatic variants that were sampled.

For TFL 23, an ecosystem map is being produced using traditional Predictive Ecosystem Mapping (PEM) methods. This will be available to provide a comparison to the map produced by discriminant analysis.

Standard goodness of fit tests, for example chi-squared tests and Kolmogorov-Smirnov two sample tests; data summary comparisons and visual checks will be used to determine the similarity of the two maps.

If they are found to be different, the traditional PEM map will be assumed to be correct. If they are similar then the discriminant analysis technique will be explored further by Sterling Wood Group, but the PEM map will be used for TFL 23.

The additional cost of producing the discriminant analysis will be only $6,000 - $8,000. This is because, in the field, determining site series during plot establishment does not add to total plot cost. The additional costs will be incurred only for data input, statistical analysis and map production. Maps will be produced using the existing GIS data.

OLD GROWTH SITE INDEX CONVERSION

From the second growth VRI data we will know the average second growth site index for each site series sampled. From the year 2000 old growth field sample we will know the average old growth site index for each site series sampled. Combining the results of the VRI and the old growth sample will give us the information shown below:

The site index conversion is most likely to be done from a look-up table. The table values will be average old growth site index for a given tree species and site series, and the corresponding average second growth site index for the same site series.

To extrapolate to old growth polygons not sampled, the site series assigned from discriminant analysis will be known. The site index conversion will be made using the same look-up table derived from the second growth samples. This table will provide the average site index values for the assigned old growth site series and the equivalent second growth site index for the same site series.

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