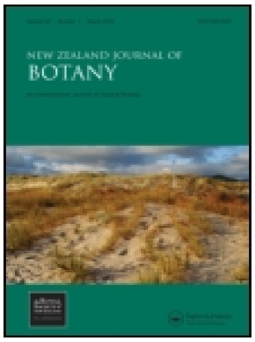

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Derivation of vegetation mapping units for an ecological survey of Tongariro National Park North Island, New Zealand

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Abstract A method of deriving vegetation mapping units from quantitative data is described based on results from an ecological survey of Tongariro National Park. A particular aim was to develop a repeatable procedure. The method of classifying the samples uses a polythetic agglomerative technique in which the sorting strategy has as a priority the combining of similar entities that are closest together in the field. This allows class boundaries to be made more nearly coincidental with map boundaries. A naming system for vegetation mapping units is further refined from an earlier published system. The names convey both structural and compositional information about the vegetation in such a way that diagnostic field criteria for most mapping units are summarised by the unit names. Although emphasising cover estimates, both the classificatory method and naming system are independent of the sampling technique used to estimate cover. The method is suitable for a wide range of terrestrial habitats.

Keywords growth forms; structural classification; Tongariro National Park; vegetation classification; vegetation mapping; vegetation naming; vegetation sampling

INTRODUCTION

An ecological survey of Tongariro National Park was made between 1960 and 1966 in which data were collected on the Park's flora, vegetation, soils, and vertebrates. Based on this survey, a 1:50 000 vegetation map was prepared, together with brief descriptions of the mapping units or types of community that were separated (Atkinson 1981). As this map is likely to be used for other kinds of ecological surveys in the Park, it is important to describe the method used in separating and naming the mapping units. A brief introduction to the method was given by Atkinson (1962) and the present paper modifies and extends the earlier suggestions.

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AIMS OF VEGETATION MAPPING IN TONGARIRO NATIONAL PARK

In mapping the Park's vegetation, three main aims were kept in mind:

1. Inventory and evaluation: To find out "what is there" in terms of the size, numbers, and growth form of plant species in different parts of the area. These data allow the vegetation continuum to be subdivided into areas whose botanical, wildlife, hydrological and soil conservation significance can be assessed.
2. Understanding factors of vegetation development: Whether the changes in vegetation composition across a mapped boundary are abrupt or gradual, the question arises: "What is the explanation for the difference?" The nature of the boundary can give information on the nature of the controlling factors. An answer is sometimes clear, as for example, where fire or other disturbance has left a sharp line of difference between two areas of vegetation of contrasting composition. In other cases there is no obvious answer. Thus boundaries on a vegetation map can be used to generate hypotheses which, with testing, can promote understanding of the factors or processes involved in vegetation development.
3. Providing a baseline for measuring future vegetation change: A vegetation map records the composition of the plant cover at a particular time. The greater the accuracy and degree of repeatability that can be achieved in the mapping, the more value will the map have in the future as a baseline for measuring the amount of change that has occurred.

REQUIREMENTS FOR THE DERIVATION OF VEGETATION MAPPING UNITS

A vegetation map based solely on qualitative data is sometimes adequate for both inventory work and elucidating factors of vegetation development. Such maps also have value for following long-term changes. If, however, a quantitative dimension can be incorporated in the mapping, the power of the mapping technique to detect changes, when the area is re-mapped in the future, is increased. Though quantitative parameters for vegetation are relatively few, the possible ways of treating the data to separate mapping units are many. Furthermore, when criteria are established as to what mapping units should be separated, there still remains the question of where to place boundaries between them. A degree of subjectivity in answering such questions is inevitable and no method will be without faults. Unless the mapper states clearly the procedure used, a future mapper has little chance of making valid comparisons; changes in the vegetation will be confounded with differences resulting from failure to use a similar derivation procedure.

An important requirement for an objective derivation procedure is that it should be able to accommodate any kind of vegetation revealed by the sampling. If a mapper begins with his qualitative observations and creates categories into which all samples are subsequently allocated, there is the likelihood that important differences in sample composition will be included in categories that obscure these differences. An alternative approach is to begin with the quantitative data from each sample and by grouping or separating the samples according to some measure of similarity, synthesise the mapping units through a sequence of comparison, grouping, further comparison and grouping. The resulting mapping units can be tested qualitatively or quantitatively with additional field observations at any stage. For reasons of scale, not all ecologically distinct kinds of vegetation can be shown on the map.

More information can be conveyed by naming rather than merely numbering the mapping units. A logical system of naming can be symbolised to become a shorthand method of showing the structure and composition of the vegetation mapped.

The above requirements can be summarised in relation to the manner in which they were applied to the Tongariro survey:

(i) Mapping units were based primarily on quantitative data recorded in the samples rather than on preconceptions derived from the general appearance of the vegetation.

(ii) A procedure for comparing the results of each sample and then grouping samples to form mapping units was standardised so that valid comparisons with mapping by subsequent workers would be possible.

(iii) A procedure for deciding boundary positions between mapping units was also standardised although there remained a significant element of subjectivity.

(iv) A naming system was adopted which conveyed both structural and compositional information about each mapping unit. In the majority of cases, the names of mapping units summarised the diagnostic field criteria for distinguishing each unit.

FIELD PROCEDURE

Sampling pattern

Some details of the field mapping procedure were given by Atkinson (1962) when the survey was still in progress. Three appearance types in the vegetation were distinguishable from the black and white vertical airphotos: forest, tussock-shrubland, and open communities. The sample lines or traverses were positioned to ensure an adequate sampling of each appearance type; some traverses crossed boundaries between them. Originally it was intended to cover the Park with an open grid of traverses in which distances between grid lines were about 3 km. The realities of topography, access, and weather prevented this from being achieved. Where the vegetation was more variable, distances between traverses were reduced to less than 1 km but in a few places, where reconnaissance showed the canopy to be relatively homogeneous, distances between adjacent traverses or other quantitative samples were increased to 4 km (see reliability map, Atkinson 1981).

The majority of traverses followed compass lines or contour lines at right angles to the radial drainage pattern of the mountains. This allowed the effects of topography and water table, which appeared to be major factors influencing vegetation composition at any one altitude, to be examined. Comparison with traverses higher up or lower down the slope allowed the effects of altitude to be estimated. A few traverses followed the line of greatest slope and thus gave a more complete picture of altitudinal variation.

Both starting points and directions for traverses were predetermined from the airphotos before going into the field. The chief consideration was to ensure that no substantial part of any appearance type was omitted from the quantitative sampling. When it became apparent during sampling that the vegetation was more variable than usual, as for example on some of the slopes of Mt Hauhungatahi, extra traverses were positioned between those originally planned.

To minimise personal bias, samples were spaced regularly by pacing (200, 300, or 400 paces) between samples along the line of the traverse, usually 10 samples per traverse. All effort was made to maintain inter-sample distances as nearly alike as possible for each traverse but unavoidable variation in pace length resulted in a sample spacing that became a stratified-random rather than a systematic pattern of sampling.

Parameters measured

A variety of physical and biological parameters were recorded at each sampling site so that vegetation composition and the presence of vertebrate animals could be related to site factors where appropriate. For the specific purpose of vegetation mapping, two types of measurement were made:

(i) in non-forest vegetation: point intercepts to estimate the percentage crown cover of each species in the canopy layers. In tussockland, shrubland, and open communities, these were obtained using a step-point method in which the uppermost plant crown at the centre-point of the toe of the boot was recorded at every pace along two parallel lines each 25 paces long and spaced 10 paces apart (Atkinson 1962). In dense scrub, the uppermost plant crown above a short pointed stick, held at arm's length and at right angles to the direction of travel, was recorded at every pace along a single 25-pace line.

(ii) in forest: trunk diameter (dbh) measurements to estimate the percentage basal area of each species in the canopy layers. These were obtained from trunk diameter measurements of the five canopy trees nearest to the stopping point for the sample (Atkinson 1962). In forest, percentage basal area was used rather than percentage crown cover because it is easier to measure quickly. No assumptions are made here about the relationship between the two parameters, a relationship that varies from place to place.

The term "canopy" was defined as the layer or layers formed by the uppermost plant crowns or their parts and it was applied to all kinds of vegetation encountered (cf. Atkinson et al. 1968). In forest, a "canopy tree" was defined as one having half or more of its crown exposed to direct radiation from the sky (Atkinson 1962). Although useful in this survey for deciding what trees to measure for basal area, this latter definition is not satisfactory for delimiting the canopy because many plants with less than half their crowns exposed to the sky contribute to the canopy.

When moving between samples, a continuous watch was kept for spatial changes in structure or composition of the vegetation and any changes noted for future reference when drawing boundaries.

Sampling intensity

Quantitative information was obtained from 1 472 samples distributed along 154 traverses. A further 147 quantitative samples were placed in areas of vegetation that were distinct on the airphotos but too small to allow traverse sampling. In these cases the sample positions were determined before going into the field so that each sample was likely to be representative of the vegetation judged from the airphoto. The total area mapped was 85 215 ha and 75 mapping units were distinguished. The average sample density was 1.9 samples/100 ha and the number of samples per mapping unit varied from 1 to 150. As mentioned below, some mapping units were based on both qualitative and quantitative observations.

COMPARISON AND GROUPING OF SAMPLE RESULTS

The following steps were used in deriving the mapping units:

1. *Samples checked for continuity between each other*
Samples from one traverse were treated initially as a single group. If, however, some samples were recognised in the field as clearly distinct in structure and composition from that generally found in the vegetation along the traverse, then these samples were separated at the beginning of the analysis, i.e., samples that were very clearly distinct in height, growth form and canopy composition, such as patches of forest within tussockland or patches of open vegetation within shrubland or scrub. Whether or not these patches appeared on the map depended on their size. When only a small proportion of the samples (< 20%) from a traverse represented a distinct kind of vegetation, these were either eliminated from the mapping-unit analysis (but not necessarily from the vegetation description) or, if possible, grouped with samples of similar kind from neighbouring traverses to form a mosaic mapping unit.

2. *Three leading species identified in each group of samples*
(a) Point-intercept samples In each group of samples, the number of times each species reached 20% or more of the canopy cover was counted and then the three species with the highest counts were listed. When two species among the leading four had equal cover values, preference was given to the taller. When fewer than three species reached 20% cover, all species between 10 and 19% cover were counted in order to determine the three leading species. In open communities it was sometimes necessary to count all species exceeding 5% or 1% cover to determine the leading species.
(b) Basal area samples The frequency of each species was determined among all samples of a group. The three species with the highest frequencies were then listed, giving preference to species with the larger basal area when two among four species had equal frequencies.

3. *Primary grouping of samples*
The aim was to examine the samples within each traverse for compositional similarity. All samples containing one or more of the *three* leading species

identified in step 2 (above) were grouped together and their cover or basal area values averaged. The cover or basal area values of any sample excluded from the initial averaging were then compared with the group average by using an index of dissimilarity that was based on *four* canopy species (*see below*). Inclusion or exclusion of these samples from the traverse group was decided according to the degree of dissimilarity found and the cover or basal area value for the new combined group were averaged when appropriate.

A primary sample group most frequently consisted of a group of samples from a single traverse (= traverse group). Where, however, mixtures of distinct kinds of vegetation occurred together, primary sample groups included samples from more than one traverse.

4. *Secondary grouping of samples*
Qualitative assessment in the field was used to estimate the most frequent kind of stand in the area in question. The traverse group containing the highest proportion of this frequently-occurring stand became the starting point for the secondary grouping. Depending upon the value of the dissimilarity index, other primary sample groups were either grouped with or separated from this first sample group, *beginning with sample groups from the nearest traverses and progressing to those more distant.* The nearest traverse was determined from distance alone, regardless of whether two adjacent traverses were parallel, at right angles, or end to end.

5. *Mapping units*
Grouping of samples was continued only to the point where the index of dissimilarity (DI values, see below) reached 50. Where a certain kind of vegetation occurred only in one place, derivation of the mapping unit sometimes required no more than a primary grouping of samples. Where a kind of vegetation occurred in several geographically separated areas, further group comparisons were sometimes needed to decide whether two or more locally-based mapping units should be combined as a single unit.

Index of dissimilarity

The index of dissimilarity (DI) used was based on a comparison of the four species which showed the highest values of cover or basal area in each sample or group of samples. Although a more comprehensive index of dissimilarity could be obtained by comparing all species in the samples, it was found that the additional information did not justify the extra work. Use of four species gave an index with sufficient power to separate samples or sample groups without unnecessary computation.

To compare two sample groups (or samples), A and B, the values of each of these four species were subtracted and then the absolute differences obtained were added together:

$$DI = \sum_{i=1}^{4} | A_i - B_i |$$

where A1–4 are the cover or basal area values of the four species having highest values for cover or basal area in sample group A and B1–4 are the values for the same four species in sample group B. Where sample groups A and B have a different set of high-value species, two comparisons are possible. However, the sequence of comparisons (discussed under 4 above) determined that the four species of highest cover or basal area in group A samples were used as the basis for comparison rather than those of group B.

When the summed differences (DI value) reached an arbitrary level of 50 or greater, the samples (or sample groups) were separated. Samples with DI values less than 50 were grouped together, their cover or basal area values averaged, and the new values obtained were then used in further comparisons with other sample groups.

DI values can vary between 0 and a theoretical maximum of 200, this maximum value being associated with a comparison between two samples or sample groups each 100% dominated by a single but different species. The arbitrary value of 50, chosen as a threshold value for separating sample groups, was arrived at by a trial and error search to find what could be shown clearly at a scale of 1:50 000, i.e., it is a scale-related value. Lower threshold values of the index may be more useful for separating samples when mapping vegetation at scales larger than 1:50 000.

Use of presence/absence of leading species in steps 2 and 3 to derive primary sample groups from each traverse allows grouping and averaging of a relatively wide range of sample variation. This is necessary as a result of the rather small size of each site sample. The sample group obtained from each traverse is a synthetic sample that in composition will reflect that of the most frequently occurring stands in the field.

The dissimilarity index is much more discriminating than the leading species in the range of sample variation that it will allow to be synthesised. However, the index is not brought into use until a primary sample group is obtained that can be compared with other sample groups that appear distinct.

Where excluded samples contributed less than 20% of the traverse samples they did not contribute further to the analysis; it was common for one or two samples to be excluded from a sample group, particularly in some heterogeneous tussock-shrublands and in open vegetation. Thus in total some-

Table 1 Grouping of samples in traverse HH 4.

Sample No.	% cover of the more common species* Cr	L	E	Dl	G	Ls	Pt	Sp	Primary grouping
4/1	66	26	2	4	-	-	-	-	Included
4/2	12	46	36	-	-	-	-	-	Included
4/3	50	8	8	20	-	-	-	-	Included
4/4	10	40	16	-	16	12	2	-	Included
4/5	20	38	18	2	2	12	4	-	Included
4/6	8	14	42	-	6	6	2	6	Included
4/7	18	14	16	10	18	6	6	4	Included
4/8	24	20	10	6	-	12	14	6	Included
4/9	20	36	24	6	-	8	-	-	Included
4/10	8	28	20	-	-	2	12	28	Included
Average cover values for all samples	24	27	19	5	4	6	4	4	traverse group (n = 10)

*The three leading species (those most frequently ⩾ 20% cover) are Cr (*Chionochloa rubra*), L (*Lepidosperma australe*) and E (*Empodisma minus*). Other species in table are: Dl (*Dracophyllum longifolium*), G (*Gleichenia dicarpa*), Ls (*Leptospermum scoparium*), Pt (*Phormium tenax*) and Sp (*Schoenus pauciflorus*).

thing between 10 and 20% of the samples did not contribute to the mapping units derived for these kinds of vegetation. Although too small to map, some of these samples were of special interest in demonstrating particular ecological relationships and it would be necessary to include them in any more comprehensive analysis of the Park's vegetation. In forest and scrub the level of sample exclusion was lower, usually not exceeding 5–10% of the samples.

If the excluded samples contributed 20% or more of the traverse samples, the same grouping procedure was applied to them. Usually this showed that aggregation of a majority of the excluded samples was possible and a mosaic mapping unit of two dissimilar kinds of vegetation would result. In exceptional cases (see Example 2 below), although a mosaic mapping unit was used, it was still only possible to show a fraction of the vegetation variation on the map.

EXAMPLES OF THE DERIVATION OF MAPPING UNITS

The procedure is illustrated below with four examples from three different kinds of vegetation taken from the results of the Tongariro survey.

Example 1 Tussock, sedge and rush vegetation north of Mt Hauhungatahi bounded by State Highways 4 and 47.
Grid ref. 180 220 (Atkinson 1981). The area was sampled with four traverses (40 samples): HH 4, 9, 10, and 20.
Step 1: Continuity check. Observations showed that variation between samples in the field was generally continuous.
Step 2: Leading species. The three leading species were identified in each traverse; these were not identical for all traverses (Tables 1, 2).
Step 3: Primary grouping of samples. The grouping for two traverses is shown in Tables 1 and 2 and the resultant averages for all four traverses are summarised at the beginning of Table 3.
Steps 4 and 5: Secondary grouping of samples and derivation of mapping units. Sedge communities dominated by lepidosperma (*Lepidosperma australe*) and red tussock (*Chionochloa rubra*) appeared in the field to be by far the most frequent kind of stand in this area. Therefore, the sample group from traverse HH 9, which contained the highest proportion of these stands, was used as a starting point for the sequential comparison of Table 3. Thus the appropriate four species in traverse HH 9 were used for calculating the dissimilarity index and deciding whether to group or separate the samples of HH 10. The dissimilarity index for this particular comparison was 31 (Table 3) indicating that the sample results from these two traverses could be grouped and averaged to give a new synthetic sample group. With each subsequent comparison it was always the four species with highest cover values in the most recently synthesised sample group in the sequence that were used for calculating the dissimilarity index.

As there were no other areas of similar vegetation in the Park, the average cover values for the combined sample group from HH 4, 9, 10, and 20 were used for the quantitative description of the mapping unit.

Table 2 Grouping of samples in traverse HH 20.

Sample No.	% cover of the more common species*								Primary grouping	
	Cr	L	E	DI	G	Ls	Pt	Cv	(i)	(ii)
20/1	62	-	-	6	-	2	-	30	Included	Included
20/2	38	8	-	-	-	14	2	38	Included	Included
20/3	38	26	14	-	6	6	6	-	Included	Included
20/4	38	-	-	4	-	2	-	54	Included	Included
20/5	36	10	8	2	8	-	8	14	Included	Included
20/6	-	-	16	2	28	-	16	-	Excluded	Excluded
20/7	4	24	4	6	-	4	24	10	Included	Included
20/8	32	20	-	-	-	4	-	42	Included	Included
20/9	28	26	6	4	-	-	8	24	Included	Included
20/10	66	4	-	10	-	2	12	4	Included	Included
Average cover values for all samples excluding 20/6	38	13	3.5	3.5	1.5	4	6.5	24	traverse group (n = 9)	
Differences in cover values between sample group (i) and 20/6†	38	13					9.5	24	DI = 84.5; sample 20/6 must be excluded from primary group	

*The three leading species (those most frequently ≥ 20% cover) are Cr (*Chionochloa rubra*), Cv (*Calluna vulgaris*) and L (*Lepidosperma australe*). Other symbols for species as in Table 1.
†Dissimilarity index (DI) calculated using the four species of highest cover in the first sample grouping (i) as a basis for comparison.

Example 2 Vegetation south-east of Mt Ngauruhoe
Grid ref. 430 200 (Atkinson 1981). The area was sampled with four traverses (40 samples): OT 1–4.
Step 1: Continuity check. Observations showed a discontinuous and complex mixture of bare scoria, partly vegetated scoria, tussock, shrub and forest vegetation. Many areas were separated by distinct boundaries and there was scarcely a pair of samples from any one traverse with similar floristic composition. Much of the scoria field, tussock land, and some scrub and forest occurred in areas large enough to map separately (17 samples). The remaining 23 samples required further analysis and were first subdivided according to major differences in structure (Table 4). From this it was apparent that the two most abundant kinds of vegetation were partly-vegetated gravelfield (12 samples) and shrubland (5 samples). Since only two kinds could be shown on the map (see Boundaries and the Demarcation of Mapping Units p. 369), derivation of mapping units was restricted to these samples.

Steps 2 and 3: Leading species and primary grouping of samples. The three leading species were identified in each group of samples and the samples grouped accordingly (Tables 5, 6).

Steps 4 and 5: Secondary grouping of samples and derivation of mapping units. In this example no secondary grouping of samples was possible and the two groups became the basis of a mosaic mapping unit (see Boundaries and the Demarcation of Mapping Units).

Example 3 Podocarp forest on Mt Hauhungatahi
Lower western slopes of Mt Hauhungatahi. Grid ref. 175 165 (Atkinson 1981). These slopes were sampled with five traverses : HH 1, 2, MK 3, 4, and 7 (50 samples).
Step 1: Continuity check. Observations did not reveal any structurally distinctive stands that warranted separation from the remaining forest.
Step 2: Leading species. The three leading species for each traverse were determined from the frequencies of all species in the samples. These included only rimu (*Dacrydium cupressinum*), miro (*Prumnopitys ferruginea*), matai (*P. taxifolia*) and kamahi (*Weinmannia racemosa*) for the five traverses.
Step 3: Primary grouping of samples. In each traverse, one or more of the three leading species were represented in each sample. Thus the sample results were averaged for each traverse to give five primary sample groups (Table 7).

Table 3 Grouping of samples from traverses HH 4, 9, 10, 20.

Sample Groups with number of samples (n)	av. % cover of the more common species*								Dissimilarity Index (DI)	Secondary Grouping
	Cr	L	E	Dl	G	Ls	Pt	Cv		
HH4 (n = 10)	24	27	19	5	4	6	4	-		
HH9 (n = 10)	24	38	12	3	1	2	9	5		
HH10 (n = 10)	23	18	3	9	8	11	10	11		
HH20 (n = 9)	38	13	3.5	3.5	1.5	4	6.5	24		
Differences in cover values between HH9 vs HH10†	1	20	9				1		31	Included
Average cover values for HH9 + HH10	23.5	28	7.5	6	4.5	6.5	9.5	8		
Differences in cover between HH9 + 10 vs HH4†	0.5	1					5.5	8	15	Included
Average cover values for HH9 + HH10 + HH4	24	28	11	6	4	6	8	5		
Differences in cover between HH9 + 10 + 4 vs HH20†	14	15	7.5				1.5		38	Included
Average cover values for all sample groups (HH9 + 10 + 4 + 20)	27	24	9	5	3.5	6	7	10		

*Symbols for species as in Tables 1, 2.
†Dissimilarity index calculated using the four species of highest cover in the first-listed sample group of the comparison.

Table 4 Structural classes for 23 samples from traverses OT 1–4.

Structural class (see Table 9)	Samples in class
Partly vegetated gravelfield	OT 1/1, 1/5, 1/8 1/10, 2/5, 3/2, 3/6 3/7, 4/2, 4/3, 4/4, 4/5
Shrubland	OT 1/3, 1/7, 2/3, 2/4, 3/1
Scrub	OT 1/2, 1/6, 2/1
Gravelfield (within larger areas of partly vegetated gravelfield and shrubland)	OT 1/9, 2/2, 4/1

Steps 4 and 5: Secondary grouping of samples and derivation of mapping units. Observations showed that the most frequent kind of stand in this forest contained both a high proportion of rimu and a significant amount (> 10% basal area) of kamahi in the canopy. The samples of traverse HH 2 typified this composition most closely and hence this sample group was used as the starting point for the secondary grouping. In subsequent comparisons (Table 7) the dissimilarity indices never reached 50, so that the cover values of all five sample groups were averaged to give values for a single mapping unit.

Example 4 Cut-over forest east of Rongokaupo trig

Grid ref. 175 005 (Atkinson 1981).

Cut-over forest is characteristically very heterogeneous and this is illustrated by traverse RK 5 from forest logged in the 1930s and 40s. Some samples

Table 5 Grouping of samples from partly vegetated gravelfields in traverses OT 1–4.

Sample No.	% cover of bare ground and common species*						Primary Grouping	
	Gravel	Dr	Dlf	Pn	Gc	R	(i)	(ii)
1/1	52	-	-	-	4	26	Excluded	Included
1/5	28	18	14	8	4	2	Included	Included
1/8	42	12	10	14	2	-	Included	Included
1/10	36	10	-	-	2	-	Included	Included
2/5	42	2	10	8	12	6	Included	Included
3/2	50	-	-	-	2	12	Excluded	Included
3/6	28	8	-	-	2	8	Included	Included
3/7	32	4	8	4	6	-	Included	Included
4/2	40	6	-	12	-	-	Included	Included
4/3	66	12	-	2	-	-	Included	Included
4/4	38	6	-	-	-	-	Included	Included
4/5	44	14	-	-	-	-	Included	Included
Average cover values for all samples excluding OT 1/1 and 3/2	39.5	9	4	5	3	1.5		
Differences in cover values between sample group (i) and 1/1†	12.5	9	4	5			DI = 30; sample 1/1 can be included with primary group	
Differences in cover values between sample group (i) and 3/2†	10.5	9	4	5			DI = 28.5; sample 3/2 can be included with primary group	
Average cover values for all samples	41	8	3.5	4	3	4.5	Sample group (n = 12)	

*The three leading species (those most frequently ≥ 8% cover) are Dr (*Dracophyllum recurvum*), Dlf (*Lepidothamnus laxifolius*) and Pn (*Podocarpus nivalis*). Other species in table are Gc (*Gaultheria colensoi*) and R (*Racomitrium lanuginosum*).

†Dissimilarity index (DI) calculated using the four species of highest cover in the first sample grouping (i) as a basis for comparison.

Table 6 Grouping of samples from shrubland in traverses OT 1–4.

Sample No.	% cover of bare ground and common species*						Primary Grouping
	Gravel	Dr	Dlf	Pn	Pa	Dl	
1/3	16	32	-	-	-	-	Included
1/7	12	26	6	32	-	-	Included
2/3	36	4	2	16	-	22	Included
2/4	22	8	20	10	20	10	Included
3/1	-	20	6	22	-	10	Included
Average cover values for all samples	17	18	7	16	4	8	Sample group (n = 5)

*The three leading species (those most frequently ≥ 10% cover) are Pn (*Podocarpus nivalis*), Dr (*Dracophyllum recurvum*) and Dl (*Dracophyllum longifolium*). Other species in table are Dlf (*Lepidothamnus laxifolius*) and Pa (*Phyllocladus aspleniifolius* var. *alpinus*).

Table 7 Grouping of samples from traverses HH1, 2, MK3, 4 and 7 (50 samples).

Sample groups (Sample number for each traverse = 10)	% basal area of common species* D	Pf	Wr	Ps	Dissimilarity index (DI)	Secondary grouping
Average cover values for HH1	58	9	7	13		
Average cover values for HH2	50	11	20	11		
Average cover values for MK3	33	23	11	16		
Average cover values for MK4	52	1	8	14		
Average cover values for MK7	27	17	31	7		
Differences in cover values between HH2 and HH1†	8	2	13	2	25	Included
Average cover values for HH2 + HH1	54	10	13.5	12		
Differences in cover between HH2 + HH1 vs MK3	21	13	2.5	4	40.5	Included
Average cover values for HH2 + HH1 + MK3	47	14	13	13		
Differences in cover between HH2 + HH1 + MK3 vs MK7	20	3	18	6	47	Included
Average cover values for HH2 + HH1 + MK3 + MK7	42	15	17	12		
Differences in cover between HH2 + HH1 + MK3 + MK7 vs MK4	10	14	9	2	35	Included
Average cover values for all sample groups	44	12	15.5	12		

*Symbols for species are: D (*Dacrydium cupressinum*), Pf (*Prumnopitys ferruginea*), Wr (*Weinmannia racemosa*) and Ps (*Prumnopitys taxifolia*).

†Dissimilarity indices calculated using the four species of highest cover in the first listed sample group of each comparison. In this example the species were the same for each comparison.

of this traverse contain five different species among the canopy count of five individual trees. Such traverses were treated in the same way as those for more homogeneous forest: the three most frequent canopy species were identified and then basal area values of all samples containing these species were averaged together while remaining samples were excluded (Table 8).

BOUNDARIES AND THE DEMARCATION OF MAPPING UNITS

The sequence of steps in deciding what boundaries were to be shown on the map was as follows:

1. Distinct boundaries, that were associated with distinct spatial differences in structure or composition, could be seen easily in the field and on the aerial photographs. These included boundaries between the three appearance types mentioned under field procedure. Such boundaries were transferred directly to the map. The scale of the map determined the lower size limit of area that could be shown. Where two or more different kinds of mapping unit occurred together in a pattern that was too intricate for their separate areas to be shown, the two most abundant units were mapped as a mosaic unit. A minimum of 20% of the samples was set for any one kind of vegetation to qualify as part of a mosaic mapping unit.
2. Where the composition of the vegetation changed gradually from place to place, with no easily distinguishable boundaries, whether or not to subdivide the area was decided by asking three questions:

(a) If the area was subdivided, would the mapping units so formed show clearly on the map? If not, there was no case for subdivision.

(b) Was the difference in canopy composition, judged by the averages for the sample groups composing the potential mapping units, sufficiently great

Table 8 Grouping of samples from traverse RK5.

Sample	Numbers of each species in samples																Primary grouping
	Aristotelia serrata	*Carpodetus serratus*	*Coprosma grandifolia*	*Coprosma tenuifolia*	*Cyathea smithii*	*Dacrydium cupressinum*	*Dicksonia squarrosa*	*Griselinia littoralis*	*Nestegis cunninghamii*	*Olearia rani*	*Prumnopitys ferruginea*	*Prumnopitys taxifolia*	*Pseudopanax arboreus*	*Pseudowintera colorata*	*Rubus cissoides*	*Weinmannia racemosa*	
5/1			1					1								3	Included
5/2						1			1		2					1	Included
5/3				2	2			1									Included
5/4		1	1					2	1								Included
5/5		1		1			1			1						1	Included
5/6								1	1		1			1		1	Included
5/7	3													1	1		Excluded
5/8		1			2				1							1	Included
5/9	1													3		1	Included
5/10												1	1			3	Included
Frequency	2	3	2	2	2	1	1	4	4	1	2	1	1	3	1	7	Primary group of samples from traverse = 9 samples
% basal area	3	4	1	2	6	8	2	13	15	2	13	4	2	5	1	19	

to justify separation? An arbitrary criterion of what constituted a "sufficiently great" difference was used, this being the values obtained from applying the same index of dissimilarity (DI) described earlier. Where two potential areas for separation, represented by sample groups A and B, had differing sets of leading species, two comparisons were possible. The first comparison calculated the DI value using the four species with highest cover or basal area values in sample group A. The second comparison used the appropriate four species of sample group B to calculate the DI. A DI value of 50 had to be reached in at least one of the comparisons if the two areas were to be shown as separate units.

(c) What physical difference could be associated with the vegetation difference? Having decided, on the basis of the difference level derived from the index of dissimilarity, that an area should be subdivided into two units, a boundary was drawn wherever possible to coincide with a topographic discontinuity that could be identified in the future, e.g., a difference in slope, aspect, landform, rock type that had some topographic expression, or stream course. Altitudinal differences were also used for boundary placement but such differences were usually not related to topographic discontinuities. In these cases, the upper or lower altitudinal limit of a particular plant species was used as a practical boundary criterion. For example, the upper limit of rimu was used to separate rimu and rimu/kamahi forests from Hall's totara-kaikawaka (*Podocarpus hallii-Libocedrus bidwillii*) forest on parts of Hauhungatahi.

At first sight, drawing a vegetation boundary to coincide with a topographic discontinuity, as described above, may suggest that the vegetation itself was no longer being mapped in places where spatial change was gradual. However, the decision to draw a boundary was made as a consequence of spatial differences in the vegetation; it was only the exact position of that boundary that was fixed by the topographic feature. The most important consideration was that the feature chosen to demarcate the boundary, however arbitrary, should be identifiable for future observers.

NAMING OF MAPPING UNITS

A satisfactory naming system for vegetation mapping units should convey as much information as possible about what has been mapped without becoming difficult to comprehend. The procedure adopted was that of distinguishing structural classes of vegetation based on growth forms of the canopy plants or, in open communities, on ground-surface textures. These classes were then subdivided according to the floristic composition of the canopy. Thus, each mapping unit was given a two-part name, the first part characterising floristic composition of the canopy and the second indicating structure as determined by the leading growth form, or the kind of ground surface present where the vegetation was open. Names such as bog, swamp, heath, fellfield, etc. which have been used in various ways, were avoided.

Steps in the naming procedure were as follows:
1. Structural names: Using the averaged values for canopy cover or basal area, the structural class of the mapping unit was determined from the proportion of each growth form in the canopy or, in the case of open communities, the proportion of each kind of ground surface (Table 9).

2. Compositional names: The compositional name of the mapping unit was derived from the names of the major canopy species composing the vegetation as follows:
(a) In most cases, all those species ⩾ 20% of cover or basal area.
(b) Where no species reached the 20% level, the two most abundant species ⩾ 15, 10, 5, or 1% cover or basal area, whichever was the appropriate level.
(c) Where the plant cover was less than 1% the mapping unit was named solely from the nature of the open ground surface.
The 20% level of composition is useful for naming because it is seldom that more than three species need to be named and thus unwieldiness is avoided. When the vegetation was very heterogeneous no species reached the 20% level and so the next lower level (⩾ 15%) was checked for species from which the vegetation could be named. The lowest compositional levels (1–10%) were usually needed for naming open vegetation. With species contributing less than 5% of the total cover, precedence was given to species that were longest lived.

3. Range of % composition. The ranges of % cover or basal area found for the species used in naming the mapping unit were indicated by a system of underlining and brackets incorporated into the unit name. This is illustrated in Table 10.

4. Conspicuous species. Both square and curved brackets (indicating % composition) were used for drawing attention to conspicuous plants in closed vegetation. For example kaikawaka, when emergent above a more or less continuous canopy of mountain beech (*Nothofagus solandri* var. *cliffortioides*), frequently contributed less than 20% of the canopy cover and thus did not at first qualify for inclusion in the name of the mapping unit. However, the conical crowns of this species were conspicuous above the beech canopy and a name that did not mention the species would not convey a realistic picture of the vegetation. Thus, stands in which kaikawaka reached only 10–19% of the canopy were named (kaikawaka)/mountain beech and symbolised by (Lb)/Nc. The criterion for inclusion was that a conspicuous plant must appear in half or more of the samples. The question of what constitutes a "conspicuous" plant remains as a subjective decision of the mapper.

5. Multiple canopy layers. Structural information, in addition to that provided by the structural class name, was incorporated by using hyphen (-) and diagonal sign (/) symbols to convey height relationships between the named species (cf. Atkinson *in* Druce 1959):
(a) Hyphens link species, not greatly different in height, that form part of the same canopy layer, e.g. mountain beech-pink pine (*Halocarpus biformis*) scrub.
(b) Diagonal signs link species that differ significantly in height and that form two or more separate canopy layers, the taller species placed to the left of the diagonal sign symbol, e.g., kanuka/manuka (*Leptospermum ericoides*/*L. scoparium*) scrub.

6. Choice of names. Common names were used in preference to scientific names because they are usually shorter and more often used.

Difficulties of wording are likely with any vegetation naming system that attempts to be logical in structure and the present system is no exception. Thus, because red tussock tussockland is an awkward combination, it was replaced with red-tussock land, part of the compositional name being used to indicate the structural class. This principle was applied to other cases, e.g., wire-rush rushland became wire-rush land.

The naming system need not be restricted to areas of vegetation of mappable size. It can be applied to individual samples although in the case of forest sampled with 5 canopy trees/sample, as in this study, there is too little information to name a single sample unless the forest is relatively homogeneous.

Classification of vegetation structural classes

A classification of vegetation structural classes, based on the growth forms of the canopy species, was described by Atkinson (1962). In its original form this classification included two-part names for each class, e.g., tussock-fernland, gravel-lichenfield. This allowed the secondmost important growth form or ground-surface to be added as a prefix to the name for the main structural class. Subsequent testing, both within Tongariro National Park and elsewhere, has shown this two-part naming to be somewhat unwieldy and complicated for general use in naming vegetation mapping units. For the Tongariro mapping, and in Table 9, the original

Table 9 Diagnostic criteria for terrestrial vegetation structural classes (modified and extended from Atkinson 1962).

Structural class	Diagnostic criteria for structural classes and definitions of growth forms
1. FOREST	Woody vegetation in which the cover of trees and shrubs in the canopy is > 80% and in which tree cover exceeds that of shrubs. Trees are woody plants ⩾ 10 cm dbh. Tree ferns ⩾ 10 cm dbh are treated as trees.
2. TREELAND	Vegetation in which the cover of trees in the canopy is 20–80%, with tree cover exceeding that of any other growth form, and in which the trees form a discontinuous upper canopy above either a lower canopy of predominantly non-woody vegetation or bare ground e.g., mahoe/bracken treeland. (Note: Vegetation consisting of trees above shrubs is classified as either forest or scrub depending on the proportion of trees and shrubs in the canopy).
3. VINELAND	Vegetation in which the cover of *unsupported* (or artificially supported) woody vines in the canopy is 20–100% and in which the cover of these vines exceeds that of any other growth form or bare ground. Vegetation containing woody vines that are supported by trees or shrubs is classified as forest, scrub or shrubland. Examples of woody vines occur in the genera *Actinidia, Clematis, Lonicera, Metrosideros, Muehlenbeckia, Ripogonum, Vitis* and others.
4. SCRUB	Woody vegetation in which the cover of shrubs and trees in the canopy is > 80% and in which shrub cover exceeds that of trees (cf. FOREST). Shrubs are woody plants < 10 cm dbh.
5. SHRUBLAND (including tussock-shrubland)	Vegetation in which the cover of shrubs in the canopy is 20–80% and in which the shrub cover exceeds that of any other growth form or bare ground. It is sometimes useful to separate tussock-shrublands as a sub-class for areas where tussocks are > 20% but less than shrubs. (Note: The term scrubland is not used in this classification).
6. TUSSOCKLAND (including flaxland)	Vegetation in which the cover of tussocks in the canopy is 20–100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussocks include all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and > 10 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia,* and *Phormium,* and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia.* It is sometimes useful to separate *flaxland** as a subclass for areas where species of *Phormium* are dominant.
7. FERNLAND	Vegetation in which the cover of ferns in the canopy is 20–100% and in which the fern cover exceeds that of any other growth form or bare ground. Tree ferns ⩾ 10 cm dbh are excluded as trees (cf. FOREST).
8. GRASSLAND	Vegetation in which the cover of grass in the canopy is 20–100% and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form.
9. SEDGELAND	Vegetation in which the cover of sedges in the canopy is 20–100% and in which the sedge cover exceeds that of any other growth form or bare ground. Included in the sedge growth form are many species of *Carex, Uncinia,* and *Scirpus.* Tussock-sedges and reed-forming sedges (cf. REEDLAND) are excluded.
10. RUSHLAND	Vegetation in which the cover of rushes in the canopy is 20–100% and in which the rush cover exceeds that of any other growth form or bare ground. Included in the rush growth form are some species of *Juncus* and all species of *Sporadanthus, Leptocarpus,* and *Empodisma.* Tussock-rushes are excluded.

*The term "flaxland" could not be used outside New Zealand because elsewhere the name flax is widely applied to species of *Linum.*

Table 9 *cont.*

Structural class	Diagnostic criteria for structural classes and definitions of growth forms
11. REEDLAND	Vegetation in which the cover of reeds in the canopy is 20–100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Example include *Typha, Bolboschoenus, Scirpus lacustris, Eleocharis sphacelata*, and *Baumea articulata*.
12. CUSHIONFIELD	Vegetation in which the cover of cushion plants in the canopy is 20–100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions. The growth form occurs in all species of *Donatia, Gaimardia, Hectorella, Oreobolus*, and *Phyllachne* as well as in some species of *Aciphylla, Celmisia, Centrolepis, Chionohebe, Colobanthus, Dracophyllum, Drapetes, Haastia, Leucogenes, Luzula, Myosotis, Poa, Raoulia*, and *Scleranthus*.
13. HERBFIELD	Vegetation in which the cover of herbs in the canopy is 20–100% and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.
14. MOSSFIELD	Vegetation in which the cover of mosses in the canopy is 20–100% and in which the moss cover exceeds that of any other growth form or bare ground.
15. LICHENFIELD	Vegetation in which the cover of lichens in the canopy is 20–100% and in which the lichen cover exceeds that of any other growth form or bare ground.
16. ROCKLAND	Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover $\geqslant$ 1% e.g., [koromiko] rockland.
17. BOULDERFIELD	Land in which the area of unconsolidated bare boulders (> 200 mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover $\geqslant$ 1%.
18. STONEFIELD/ GRAVELFIELD	Land in which the area of unconsolidated bare stones (20–200 mm diam.) and/or gravel (2–20 mm diam.) exceeds the area covered by any one class of plant growth-form. The appropriate name is given depending on whether stones or gravel form the greater area of ground surface. Stonefields and gravelfields are named from the leading plant species when plant cover $\geqslant$ 1%.
19. SANDFIELD	Land in which the area of bare sand (0.02–2 mm diam.) exceeds the area covered by any one class of plant growth-form. Dune vegetation often includes sandfields which are named from the leading plant species when plant cover $\geqslant$ 1%.
20. LOAMFIELD/ PEATFIELD	Land in which the area of loam and/or peat exceeds the area covered by any one class of plant growth-form. The appropriate name is given depending on whether loam or peat forms the greater area of ground surface. Loamfields and peatfields are named from the leading plant species when plant cover $\geqslant$ 1%.

Table 10 Naming of mapping units: symbols for showing ranges in % cover or % basal area of plant components using vegetation containing Dracophyllum recurvum as an example.

Name of mapping unit	% cover of Dracophyllum recurvum	Map symbol
Mountain inaka shrubland (or scrub)	≥ 50 (> 80 in scrub)	Dr
Mountain inaka shrubland	20–49 (shrub cover > gravel cover of open ground)	Dr
Mountain inaka gravelfield	20–49 (gravel cover > shrub cover)	Dr
(Mountain inaka) gravelfield	10–19 (gravel cover > shrub cover)	(Dr)
[Mountain inaka] gravelfield	1–10 (gravel cover > shrub cover)	[Dr]
Gravelfield	< 1 (gravel cover > shrub cover)	GF

system was simplified although slightly extended. Only single names are now used for each major structural class, the names depending on the dominant growth forms. However, because of its widespread importance at Tongariro, "tussock-shrubland" was retained as a subclass of shrubland (Atkinson 1981). It may be found that this subclass, or other subclasses based on the 1962 system, are useful in particular situations elsewhere. The simplified system does not preclude the use of the earlier system provided the two-part names are applied to subclasses of the main divisions (Table 11).

Diagnostic criteria for each of the structural classes of Table 9 are based on the percentage crown cover of plant growth-forms in the canopy or percentage cover of materials forming the ground surface in open ground. As indicated earlier, in the Tongariro survey basal area was used in forest rather than crown cover.

There has been some debate over the desirability of extending the tussock growth-form to include plants, other than grasses, of diverse taxonomic affinity. Such extensions can be expected in any classification that emphasises growth-forms and occurs in this classification with the forest, scrub, shrubland and cushionfield classes as well as tussockland. Webster's 'Third New International Dictionary' (1976) defines tussock grass as "any of various grasses or sedges that typically grow in tussocks" and Jackson's 'A Glossary of Botanic Terms' (1928) says "Tussock, a tuft of grass or grass-like plants". Tussocks are one of the most distinctive non-woody growth forms in New Zealand and the fact that the same form can be seen in genera as taxonomically distinct as *Chionochloa, Cortaderia, Gahnia, Astelia*, and *Phormium* is likely to have adaptational significance. Equally, the difference in habitat and life-span of tussock-grasses and many pasture grasses justifies separation of tussock-grasses from the remainder.

Vineland and cushionfield are new structural classes introduced since the Tongariro survey was completed. If the classification is applied to vegetation in the New Zealand cultural landscape (as for example by N.Z. Soil Bureau *in prep.*), the importance of orchards containing vines necessitates a vineland class. Work carried out during the 1983/84 summer by the Protected Natural Area survey teams has confirmed that cushion plants are sufficiently abundant in some areas to warrant a structural class to accommodate this very distinctive growth form.

Not all categories of the classification are independent of taxonomic classes. Fernland, mossfield, and lichenfield are closely related to their respective taxonomic classes but each is characterised by particular kinds of growth form so that the basis of the classification is not weakened.

Choice of the suffix -land or -field in this classification has been influenced by common usage. There is no logical reason why -land could not be used throughout except that terms such as 'herbland' 'lichenland', 'stoneland' and 'sandland' would seem more strange to some people than the alternatives. For some surveys of large areas where detail is not required, it may prove more convenient to map the open communities of classes 16–20 as 'openlands'.

In using the system it is important to remember that the same species can sometimes develop a different growth-form in different habitats or at different stages in its life-cycle. A species should not be pigeon-holed into a growth-form class without checking to see how it is actually growing.

Examples of the naming of mapping units

The procedure for naming can be illustrated with examples including those used earlier to illustrate the derivation of mapping units.

Example 1

The final average figures for the secondary sample

Table 11 Naming of structural classes in various kinds of vegetation: some examples.

Canopy composition of vegetation (% cover)	%	Structural class
trees shrubs	81 19	forest
trees shrubs	19 81	scrub
trees shrubs	50 50	forest
trees shrubs	49 51	scrub
trees tussocks	81 19	forest
trees tussocks	80 20	treeland (subclass: tussock-treeland)*
trees tussocks	50 50	treeland (subclass: tussock-treeland)*
trees tussocks	49 51	tussockland (subclass: tree-tussockland)*
trees shrubs tussocks	20 40 40	shrubland (subclass: tussock-shrubland)*
trees shrubs tussocks	20 39 41	tussockland (subclass: shrub-tussockland)*
trees unsupported vines	49 51	vineland (subclass: tree-vineland)*
trees shrubs tussocks grasses sedges	30 20 20 20 10	treeland (subclass: tussock-treeland)* Lower canopy is predominantly non-woody
trees shrubs tussocks grasses sedges	30 10 35 20 5	tussockland (subclass: tree-tussockland)*
shrubs herbs residual rock mosses	20 25 40 15	rockland (subclass: herb-rockland)*
boulders stones gravel plants	15 30 35 20	gravelfield (subclass: stone-gravelfield)*

*The use of these subclasses, based on Atkinson (1962), is not strongly advocated. They are included to make clear that these options are available for descriptive or mapping purposes if local needs make their use desirable.

grouping of Table 3 showed tussocks to be greater in % cover than sedges but, as stated earlier, by far the most frequently occurring stand was that represented by the samples of traverse HH 9. For this reason the area was named a sedgeland rather than a tussockland.

Red-tussock formed an upper canopy layer and consistently overtopped the lepidosperma. However, to name this vegetation from the tussock and sedge components alone would have failed to recognise the conspicuous appearance of flax (*Phormium tenax*) which overtopped the red tussock and, although only averaging 7% of the cover, occurred in more than half the samples (29 of 39 samples). Accordingly, the name given to this mapping unit was [flax]/red tussock/lepidosperma sedgeland, symbolised by [Pt]/Cr/L.

Example 2

In the first part of this mosaic mapping unit, whose derivation is shown in Table 5, the cover of gravel exceeded the shrub cover making it a gravelfield in which mountain inaka (*Dracophyllum recurvum*) and snow totara (*Podocarpus nivalis*) were of greatest physiognomic importance. Both species were present in the 1–10% range of cover. In the second part of the mapping unit the shrub cover exceeded the gravel cover making it a shrubland in which mountain inaka and snow totara were again of greatest importance. Both were present in the 10–19% range of cover. In neither part of the mapping unit was there any significant height difference between the main species. Thus the name given was [mountain inaka-snow totara] gravelfield + (mountain inaka-snow totara) shrubland symbolised by [Dr-Pn] + (Dr-Pn).

It may be noted that *Racomitrium lanuginosum* (R) has a slightly higher cover than snow totara in the overall averages of Table 5. It was excluded from the name on the grounds that its cover was likely to fluctuate from year to year in comparison with the long-lived snow totara.

Example 3

Rimu was the only species in the forest group shown in Table 7 which reached or exceeded the 20% level. General observations and the data of Table 7 showed that it most frequently formed 50% or more of the canopy cover. Thus, the name given was rimu forest symbolised by D.

Example 4

In this cut-over forest illustrated in Table 8 no species reached the 20% level of basal area. The two leading species in the 10 to 19% range were black maire (*Nestegis cunninghamii*) at 15% and kamahi at 19%. Accordingly, when considered as a whole this stand could be named (kamahi-black maire) forest. In fact its samples were grouped with those from other traverses to form a kamahi forest mapping unit symbolised by Wr.

Example 5

Sampling of the "tussock" vegetation north and east of the Chateau Tongariro gave the following composition for growth forms (based on fusion of six sample groups): shrubs 28%, tussocks 27%, ferns 8%, herbs 5%, other growth forms, litter and bare ground 32%. The only species to reach 20% or more of the canopy was red tussock at 24%. Since shrubs were greatest in quantity but a tussock species was the only plant sufficiently common to qualify for inclusion in the unit name, the mapping unit was called red tussock tussock-shrubland, abbreviated to red tussock shrubland, and symbolised by Cr.

Further examples to show how structural class names are given to various kinds of vegetation are given in Table 11.

SOURCES OF BIAS IN DERIVING THE MAPPING UNITS

Notwithstanding the attempt made to eliminate personal bias from both the field sampling and the subsequent treatment of the results, some bias still remains. It is important to identify the various sources of bias present.

1. Differences in intensity of sampling. At any given density of sampling, kinds of vegetation that occurred in larger areas were more frequently sampled and therefore better characterised than those of smaller areas. This is a source of bias difficult to avoid, but where the vegetation pattern was intricate, increasing the density of sampling was sometimes essential if sufficient information to draw a meaningful map was to be obtained. Equally, a reduced density of sampling was used in extensive areas of very homogeneous vegetation to avoid needless repetitive sampling.

2. Positioning of samples. The stratified-random distribution of the samples ensured that only a small amount of bias occurred. This bias resulted mainly from changes of direction associated with moving past large trees or avoiding topographic obstacles and tangles of bush lawyer (*Rubus cissoides*).

3. Grouping of sample results. Although this was largely a mechanical and therefore repeatable procedure, disagreement between observers could occur concerning the most frequent kind of vegetation stand in an area, especially if field observations were limited. This would affect the sequence of sample group comparisons and thus sometimes the composition of the mapping unit derived.

4. Demarcation of boundaries. With regard to distinct structural or floristic boundaries, this step is repeatable provided the map scale is not changed.

Where gradational change and indistinct boundaries are being remapped, this step is repeatable only insofar as use is made of identifiable physical boundaries and the nature of these boundaries is recorded in a retrievable manner.

5. Naming of mapping units. With adequate numbers of samples the procedure is mechanical and therefore repeatable. The recognition of what constitutes a "conspicuous" plant remains as a subjective element but this is expressed only in the name of the mapping unit, not the compositional averages for the unit.

DISCUSSION

Any map that shows differences in vegetation implies a classification. In Küchler's (1967:167) discussion of mapping and classification, the present method would be recognised as a physiognomic-floristic system that uses an *a posteriori* rather than an *a priori* mode of classifying. It is also a numerical classification that employs an hierarchial clustering strategy in which the groups or clusters do not necessarily exhibit the same homogeneity (Clifford & Stephenson 1975). Two main kinds of clustering strategy have been used for ecological work: agglomerative pathways in which, beginning with the data for individual samples, the final groupings or clusters are found by a series of fusions, and divisive pathways in which, beginning with all the data, the final groupings result from a series of fissions.

The present method, though developed independently of other studies, combines attributes of both divisive and agglomerative methods. Because many of the major structural classes such as forest, scrub, tussockland, gravelfield, etc. (Table 9) are easily distinguished in the field and thus can immediately be separated on a map, a prestratification of the data using structural properties is possible. This initial step is essentially divisive in character. The subsequent grouping of sample data within each of these structural classes is an agglomerative procedure. More specifically, it is a polythetic agglomerative technique since a number of attributes (% cover or % basal area of several species) are used to calculate the dissimilarity index for each comparison rather than a single attribute as in monothetic techniques (Williams 1971). (More strictly, because only a few rather than all species are used in each comparison, the method is oligothetic rather than completely polythetic).

In discussing polythetic agglomerative clustering methods, Clifford & Stephenson (1975) distinguish a number of different procedures. Although the present method has features of some of these, it differs from them because the sorting strategy had as a priority the combining of similar entities that were closest together in the field. Thus groups of samples that showed dissimilarity index values less than a threshold value of 50 were combined together in order of geographical proximity. This proved to be a practical way of making class boundaries more nearly coincidental with map boundaries.

Mr J. Leathwick (pers. comm.) has pointed out that when transect data are aggregated in order of geographical proximity the probability of two transects, spaced some distance apart along a compositional gradient, being linked together will be dependent on whether other transects are located between them. The net result is that mapping units derived in areas where vegetational changes are abrupt will tend to be more homogeneous in composition than those from areas where the change is gradual. This may not be a disadvantage provided that the user remembers that the level of homogeneity (i.e., range of variation) is not always comparable between mapping units.

Although the total number of samples for the present study is large, the computations associated with any one mapping unit involve only a limited number of samples: each of the various kinds of vegetation mapped occupy a limited part of the whole area surveyed. Nevertheless, although the present analysis was carried out manually, computer sorting and classification of the sample data would be desirable if this approach was repeated or applied elsewhere.

The method of deriving the mapping units is independent of the sampling method. Only two parameters (% cover of plant crowns and % basal area of trees) using rapid field methods were used. More accurate, although more time-consuming, methods could be used for mapping vegetation but would not necessarily provide more useful information. However, in forest the use of 5 canopy trees/sample site at Tongariro was occasionally inadequate as a canopy sample for the site when the canopy was very heterogeneous. When combined with other samples from a large area, sufficient information for mapping purposes was obtained; but a larger sample size, if practicable, would be preferable. Increasing the number of trees/sample does not necessarily solve the problem. There is firstly a large increase in sampling time associated with locating, identifying and measuring, for example, the nearest 10 trees on the sample site. Secondly, in tall forest or broken topography it is sometimes difficult to find 10 trees on a similar site without overlapping onto sites of a different kind. A possible solution may be to replace the basal area sampling with a point-intercept method made along paired line transects, one either side of the sample centre, with intercepts at appropriate spacing.

The method may prove less than satisfactory where large areas of single-dominant forest or scrub cannot be readily subdivided on the basis of canopy composition; additional attributes such as understorey composition or height class would be needed.

With respect to the naming system, vegetation with a particularly heterogeneous but closed canopy containing 20 or more species, none of them contributing more than 5% of the cover, could not be given a satisfactory compositional name. This seldom occurs in New Zealand but it is not uncommon in warmer latitudes.

Although direct comparisons of boundary positions could be made in the future with those mapped in the present study, the most definitive comparisons are clearly those between samples made along the same traverse lines. All traverse lines with points of origin and spacing distances between samples have been recorded and their positions plotted on aerial photographs.

The method can be applied to reconnaissance surveys where time for quantitative sampling is limited. In such cases, quantitative sampling is best concentrated in kinds of vegetation of particular interest, so that in these areas at least, a reasonable sampling density is reached, e.g., Atkinson *in* Healy (1980). In any case, naming of vegetation units is not dependent on quantitative sampling. Using the criteria of Table 9, estimates of the percentage cover of growth forms and species can be made in rapid inventory surveys to derive "first approximation" vegetation names. These can be modified in the light of subsequent quantitative sampling should the need arise.

Although percentage cover of growth forms in the canopy is the major parameter emphasised in this system, the technique of estimating percentage cover does not affect the use of either the classification or naming procedures. The method can be applied to a wide range of terrestrial habitats whether or not they have a significant plant cover.

Because the present classification was developed specifically for mapping, other kinds of classification, such as indicator species analysis (Hill et al. 1975), ordination methods including detrended correspondence analysis (Hill & Gauch 1980), and the gradient analysis method of Austin et al. (1984), may prove more useful for analysing relationships between environmental gradients and vegetation. This is not to imply that some of these other classifications may not be useful for mapping purposes as well.

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