SEMI-QUANTITATIVE MEASUREMENTS OF CANOPY COMPOSITION AS A BASIS FOR MAPPING VEGETATION

I. A. E. ATKINSON

Botany Division, Department of Scientific and Industrial Research, Lower Hutt

Aims and Definitions

This paper describes a semi-quantitative method of mapping vegetation at scales of the order of one mile to the inch using aerial photographs. It has been developed during a survey of Tongariro National Park in which more information than would normally be derived from a reconnaissance survey is required but where, due to the size of the area, time for sampling is limited. The aim has been to make all steps in the sampling and mapping procedure as repeatable as possible so that precise comparisons can be made between large areas of vegetation, and large-scale changes in the vegetation pattern can be followed over a long period of time.

The composition of the canopy layers has been chosen as a basis for mapping. Reasons for this emphasis are:

(i) It is not practical to show the distribution of all species present in the vegetation on a single map. Selecting the plants of the canopy layers recognises the fact that these plants to some extent control the light, moisture and plant nutrients available to all other plants besides contributing most to the structure of the vegetation.

(ii) The composition of the canopy at a given time appears to be the most satisfactory starting point for following future large-scale changes. This applies both to the quantitative description of a particular mapping unit and to changes in the positions of boundaries.

It is not intended to imply by this emphasis on canopy layers that the lower layers are not important; no description of a mapping unit would be complete without details of the lower layers.

A single method of measuring canopy composition which can be used with equal facility in forest or tussockland is not at present available and for this reason two measurements have been used:

(a) forest: trunk diameter measurements to give basal area of canopy plants.

(b) scrub, tussockland and open communities: point intercept measurements to give cover of canopy plants and other surfaces.

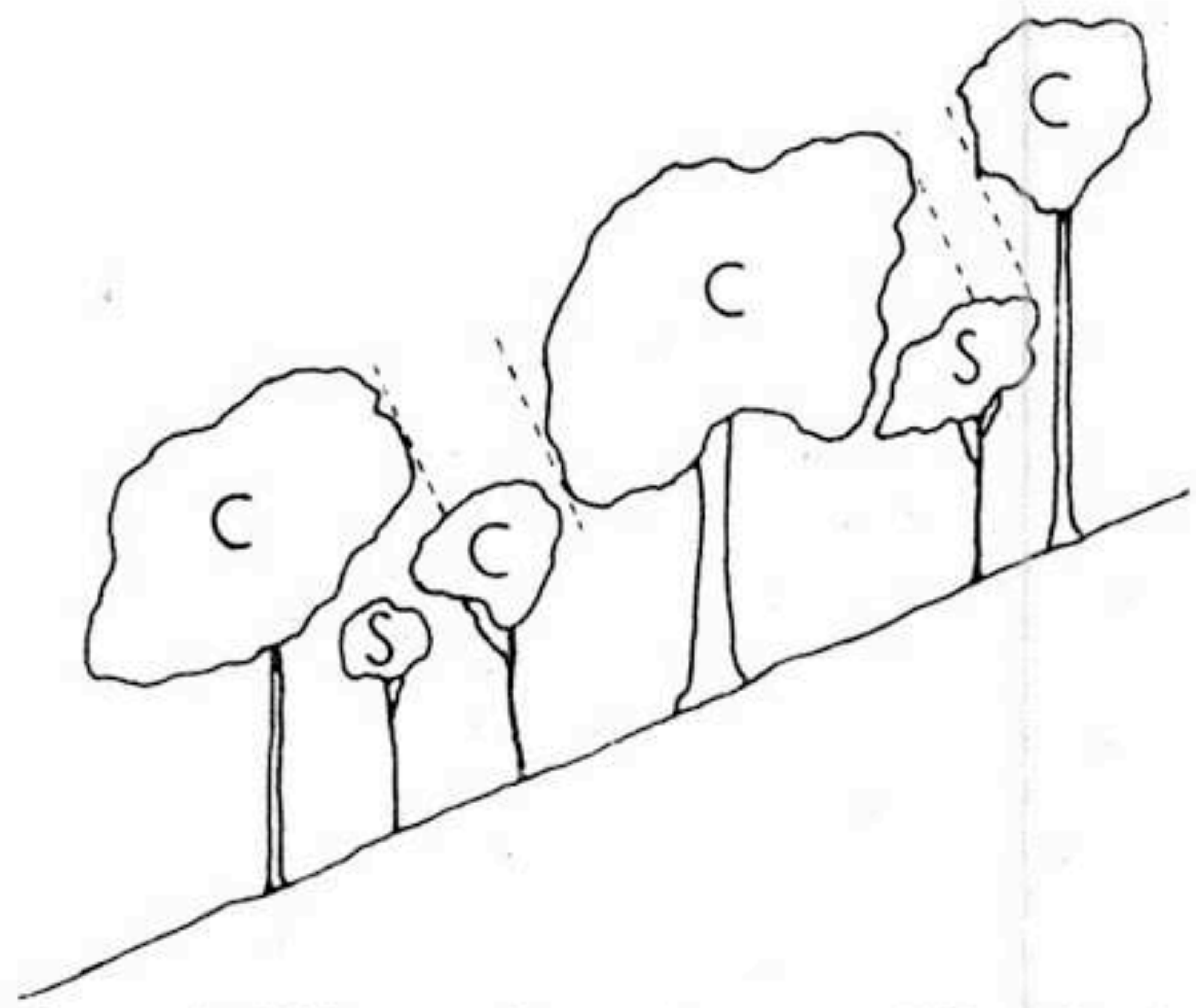

FIGURE 1. *Difference between canopy (C) and sub-canopy plants (S) as determined by proportion of crown exposed to the sky.*

A *canopy plant* is defined as one having half or more of its crown exposed to direct radiation from the sky (Fig. 1), and may be of any growth form.* In communities such as podocarp/dicotylous forest or shrub-tussocklands there may be two or more separate canopy layers. Surfaces such as rock, sand, soil, etc., which are unshaded by plants, are considered to replace the canopy and are sampled in an identical manner.

Sampling Procedure

1. Traverses

Sampling lines or traverses approximately one mile in length are arranged in an open gridded pattern. They follow compass lines, contours or the axes of major land forms depending on whichever type of

* This definition is a practical compromise and the human error which must inevitably accompany judgement of borderline cases prevents the method from becoming completely quantitative. The number of borderline cases is usually few so that any bias which may arise is unlikely to affect the composition figures to a significant degree.

traverse is physically most efficient. In all cases one axis of the grid is orientated at right angles to the local drainage pattern. This ensures that variation due to topography is sampled while leaving the remaining axis for recording variation due to factors such as altitude and soil parent material. The grid can rarely be perfectly regular because of changes in the direction of drainage.

The data from the traverses are used both to describe mapping units and to fix boundaries between them. When completion of a traverse reveals areas of distinct vegetation which have been sampled only at a few places, as may happen with altitudinally zoned vegetation, further traverses are interpolated into the grid with equidistant spacing between adjacent traverses. A limit to the number of intermediate traverses is imposed by the scale at which the mapping units can be illustrated.

In laying out the traverse grid the aim is always to sample the full range of variation present in the vegetation while at the same time ensuring as even a coverage as possible. The routes of all traverses are marked on the aerial photographs.

2. SPACING BETWEEN SAMPLES

A single traverse is a walked line along which 10 stopping places for sampling are made, each 200 paces apart. In steep topography 300 or even 400 paces are necessary between sites to cover distances on the aerial photographs comparable to those of 200 pace spacings in easy topography. Counting of paces becomes automatic with practice and any disadvantages are offset by the reduction in personal bias achieved. At the termination of each 200-pace interval the vegetation is sampled regardless of whether it fits into any preconceived ideas of community classification. Care is taken to ensure, however, that each count is made on one particular type of site. If the last pace of an interval between sampling areas falls on a sharply defined boundary between two distinct sites, e.g., alluvial flat and hillslope, the site furthest from the beginning of the traverse is selected. When the stopping point is near a well defined site boundary then the position of the sample area is moved forward or backwards to clear this boundary and ensure sufficient area for counting. Thus although the initial selection of sample areas is unbiassed, this subsequent restriction of sampling to specific sites results in an under-representation of the vegetation of boundary zones. This is done for practical reasons: one cannot indicate the composition of boundaries on a map, only the composition of the vegetation units shown between them. Because of their ecological significance boundaries would in any case be examined in some detail.

3. SAMPLE AREAS

The ten stopping places or sample areas are described in terms of the sites on which they fall. A site is defined as a portion of the soil mantle which can be described by means of single statements for its gradient, aspect, shape of slope, position relative to the landform in which it occurs, soil parent material, drainage and age of vegetation, e.g., steep, north aspect, concave, midslope site on weathered greywacke; well drained; mature stand. Usually no exact age for the vegetation can be given but it is necessary to distinguish between stands of mature vegetation and those of more recent origin such as pole stands in forest.

Sample areas do not exceed half a square chain in area since otherwise it would sometimes be impossible to relate a sample to a single site because of local variations. Within this limit the sample area may be of any size or shape depending on topography and the amount of space required to do the counting.

4. SAMPLING

One of the two procedures outlined below is carried out on each of the ten sampling areas along the traverse. General notes are made on the vegetation between sample areas particular attention being given to the presence of clearly defined boundaries.

(a) *Open communities, tussockland, shrubland, scrub, etc.*

Two parallel lines, each 25 paces in length, are spaced 10 paces apart across each sample area. At each pace the uppermost plant present at the centre-point of the toe of one's boot is recorded. Among low growing plants which spread vegetatively, it is often not possible to decide whether an individual is a canopy plant by the definition given earlier. In such a case, provided the plant is unshaded vertically above the toe of one's boot, it is recorded.

Plants recorded may be below the toe of the boot as in the case of a moss, or may overarch it as in the case of a tussock. To avoid bias it is necessary to sight on a distant object as one moves forwards for the next pace. The species at one's toe is then recorded and sight shifted back to the distant object before pacing forward again. When vegetation is trodden down it is restored to its natural position before recording. Surfaces such as litter, sand or boulders, encountered during the stepping, are recorded under their particular texture categories (Table 1). In scrub a single straight line of 25 paces is made across each sampling area.

A plant is recorded whenever the centre-point of the toe of one's boot falls within the perimeter of its crown even though this point may coincide with a gap in the leaf mosaic. The resulting figures for canopy cover are therefore estimates of the proportion of the canopy layer or layers contributed by the crowns of each species rather than estimates of leaf cover. The *percentage canopy cover* of each species and surface material is determined for each sampling area by multiplying the number of points recorded by two, or four in the case of scrub. The height ranges of major component plants are also recorded.

Stepping methods have been used by several workers in New Zealand, the first of whom appear to have been Dr. L. Cockayne and Dr. W. D. Reid. They used a point on the toe-cap of one boot as a sampling point and it was from this that the point method of pasture analysis was developed (Levy and Madden 1933).

(b) *Forest*

On each sampling area the diameters of the five canopy trees nearest to the stopping point are measured to the nearest inch and their heights estimated by eye. Trunks of trees which fork from the base are treated as separate trees.

A special case frequently encountered is that of the *canopy gap*. This is a place where there is evidence of the former presence of canopy plants, e.g., fallen trees. Young plants which have established in the gap are by definition canopy plants. Nevertheless, since gaps are usually of short duration relative to the life-span of the surrounding trees, plants in gaps are not measured for basal area unless they reach an arbitrary height of 10 ft. By this stage they are usually forming a new canopy at a lower level than that surrounding. Where the gap is of comparatively recent origin and no plants taller than 10 ft. are present, the five trees nearest the centre of the sample area but beyond the gap, are measured.

The squared diameters are totalled for each species and expressed as a percentage of the total for all species to give a *percentage basal area* of canopy plants.

Note: Diameter at breast height was chosen for the analysis of forest canopies because of the difficulty of measuring cover directly. Measurements of crown areas in three species (*Beilschmiedia tawa, Dacrydium cupressinum* and *Nothofagus truncata*) showed that only in the case of *B. tawa* did the squared trunk diameters give a satisfactory indication of crown area. In all cases, however, squared diameters showed a closer relationship with crown area than the diameter measurements alone.

TREATMENT OF TRAVERSE RESULTS

The canopy composition percentages (cover or basal area) are summarised as a mean for each species in each traverse. For comparisons some measure of the sampling error is necessary. Up to the present, diameter measurements made during forest traverses have been recorded in 8 or 10 in. diameter classes rather than to the nearest inch as suggested above. Examination of these data has shown that recording of diameters in inch classes will be necessary before a satisfactory estimate of sampling error is possible.

In open communities, tussockland, shrubland and scrub, a systematic sampling procedure has been adopted for simplicity and speed of working. Unless great care is taken in choosing a random sample, e.g., by use of a table of random numbers, it is more likely to contain personal bias than a systematic sample. In common with most systematic sampling, a direct estimate of the standard error is not possible. Nevertheless data from timber volume assessments and cover type surveys (Hasel 1938; Osborne 1942; Finney 1948) indicate that the standard error of the mean of a systematic sample is not greater than that for a random sample except in the unlikely case of periodic variation where the period is comparable to the distance between sample points. Thus the formula:

$$S = \sqrt{p(1-p)/n}$$

which is the standard error of the estimate of the proportion (p) of a species based on a sample of n points, gives an upper limit to the standard error obtained from a systematic sample such as is used here. If the distribution of the plants is nearly random this will give a close approximation to the true standard error. On the other hand if the presence of a plant at one point increases the probability of finding plants at neighbouring points, then the standard error of the systematic sample will be appreciably less than the true standard error.

By evaluating p_1, p_2, etc., separately for each sample area in the traverse, a picture of the variation can be given. In many cases there may be no clear trends but some idea of the variation from sample to sample is desirable at least for *major* species, i.e., those with traverse means $\geqq$20%. This variation is most satisfactorily described by taking the root mean square of the deviations.

Since there are 10 sample areas per traverse n will usually equal 10. This procedure has the advantage that it makes it possible to see whether there is any change in the uniformity of distribution of a particular species either at different times along the same traverse or between two traverses.

For comparisons of mean values at different times it is desirable to compare values of p at corresponding sample areas. The samples will not be at identical positions but this comparison will prevent large variation along the traverse obscuring changes in time.

MAPPING PROCEDURE

The differences in canopy composition within and between traverses are used both to demarcate boundaries and to describe the mapping units or *vegetation types* that are separated. A vegetation type can be based either on a single traverse or a group of similar traverses. The procedure is as follows:—

1. Clearly defined boundaries between distinct types of vegetation are marked on the map, e.g. a boundary between forest and tussockland.
2. The demarcation of further boundaries is dependent on the nature of the variation revealed by the traverses. When individual sample counts are compared and related to general observations made along each traverse, three types of variation may be found.

   (a) Continuous and fluctuating variation between samples. No boundaries are recognised and the vegetation is shown as a single type although for many species the variation in canopy composition may be large.

   (b) Discontinuous variation between samples. Observations reveal sharp boundaries between distinct types of stand. A sharp boundary is defined as a clearly recognisable directional change in the composition of the canopy which occurs within a distance of one chain.

   In traverses of this type similar samples are grouped together. When this results in a patchwork of stands too small to be illustrated clearly, the vegetation is mapped as a single mosaic type without internal boundaries, e.g. silver beech: mountain beech forest.

   When a distinct type of stand occurs sporadically in a different type of vegetation, the area covered by such stands may be too small for them to be included in a named type, forming part of a mosaic. An arbitrary rule adopted is to include only those stands which cover 20%

or more of the area as determined by their proportion among samples or from the aerial photographs if the stands are discernable. Distinct stands covering less than 20% of the area are mentioned in the description though sometimes it is necessary to mark the positions of particular stands on the map because of their ecological significance, e.g. an island of forest in tussockland.

(c) Continuous and gradational variation between samples. A boundary is drawn through stands which are mid-way in composition between the extremes of the continuum. If the continuum is extensive two or more divisions can be made again using composition values of the major species to define the boundaries. Mid-points in composition will not always coincide with spatial mid-points so that the width of the demarcated areas will determine whether the continuum is mapped as several units or as a single unit.

3. In describing the vegetation type, the composition values for each species are given as a range of means derived from the traverses included in the type.

4. Large areas of vegetation with comparatively homogeneous canopies can be subdivided into sub-types based on the composition of the sub-canopy layers.

NAMING PROCEDURE

A descriptive name for either a vegetation type or a single traverse becomes a necessity as soon as results are discussed and compared. The principle followed is to name from the proportions of canopy plants and non-living surfaces no matter whether these are trees, tussocks, lichens, mosses, boulders, bare soil, etc. Interpretive names such as bog, swamp, steppe, heath, moor, fell-field, etc., are not used. There are two parts to the name:—

(i) a floristic name which indicates the identity of the major plant components of the canopy layers, e.g. red beech-silver beech forest.

(ii) a structural name based on the proportions of plant growth forms, rocks, bare soil, etc., e.g. scrub, shrub-tussockland, tussock-shrubland, moss-boulderfield.

Floristic Names

Species with mean composition percentages which equal or exceed 20% are included in the floristic name. A maximum of five species could therefore appear in the floristic name but in practice rarely more than 3 plants appear. These species are arranged primarily in order of height and secondarily according to order of cover or basal area. The symbol '/' distinguishes distinct canopy layers, '-' links species in the same layer. Thus if a traverse gave basal area values of 25% for rimu, 70-90 feet in height, and 35% for kamahi, 40-60 feet in height, it would be called rimu/kamahi forest. A forest of similar composition but with little difference in mean heights between the rimu and kamahi would be kamahi-rimu forest.

TABLE 1. *Minimum height differences necessary for recognition of separate canopy layers.*

Mean height	*Difference*
<2 ft.	5 in.
2–20 ft.	2 ft.
>20 ft.	10 ft.

In deciding whether or not a difference between the mean heights of two species is large enough to warrant separation as distinct canopy layers, the arbitrarily chosen values set out in Table 1 are used. Examples of this system applied to forest communities have been given by Druce and Atkinson (1959).

Wherever possible common names are used in preference to scientific names. When the floristic name of the vegetation becomes unwieldy, generic names are used for plants lacking common names. Pairs of species in the same genus are not lumped together in order to reach the 20% level and so name the vegetation. When no species exceeds the 20% level, the name of the species with the highest composition value above a minimum of 5% is shown in brackets, e.g. (*Dracophyllum recurvum*) gravel-shrubland. When no plant reaches the 5% level no floristic name is given.

Structural Names

Structural names are based on the classification of growth forms and other surfaces given in Table 2.

The composition percentages are summed for the species of each growth form and for each type of surface found in a traverse and then averaged for the whole vegetation type. The structural name is derived by adding either -land or -field to the growth form or surface with the highest composition value exceeding 20%, e.g. shrubland, sedgeland, herbfield, boulderfield, siltfield. The term scrub is used for a shrubland with a canopy consisting of 81% or more cover of shrubs, and forest is used for a treeland consisting of 81% or more basal area of trees inclusive of tree ferns.

When a second less extensive growth form or type of surface exceeds 20% cover, this is indicated before the basic part of the name, e.g. shrub-tussockland, sedge-rushland, gravel-lichenfield, herb-loamfield. Should two growth forms have identical composition percentages then the basic part of the name is taken from the tallest growth form, e.g. a vegetation with a canopy composition of 40% ferns (mean height: 50 in.) and 40% shrubs (mean height: 35 in.) would be called a shrub-fernland. If three or four types of growth form or surface exceed the 20% level then the structural name is based on the pair which have the highest composition values.

TABLE 2. *Classification of growth forms and non-living surfaces for the naming of vegetation types.*

	Growth form or surface	*Suffix*	*Description*
1. a.	Tree	-land	plants with erect stems greater than 4 in. diameter breast height; <81% trees in the canopy.
b.	,,	forest	≥ 81% trees in the canopy.
2.	Tree-fern	-land	
3. a.	Shrub	,,	plants with stems less than 4 in. diameter breast height and plants with many semi-prostrate stems greater than 4 in. diameter breast height; <81% shrubs in the canopy.
b.	,,	scrub	≥81% shrubs in the canopy.
4.	Tussock	-land	herbaceous plants, including grasses, sedges and rushes, with leaves densely bunched at the base.
5.	Grass/sedge/rush	,,	herbaceous monocotyledons with narrow linear leaves not densely bunched at the base.
6.	Reed	,,	tall herbaceous monocotyledons with linear leaves containing spongy mesophyll tissue.
7.	Fern	,,	
8.	Herb	-field	herbaceous plants not included in any of the above categories.
9.	Moss	,,	
10.	Lichen	,,	
11.	Rock	,,	outcrops of basement rock.
12.	Boulder	,,	>8 in. major diameter.
13.	Stone	,,	¾–8 in. major diameter.
14.	Gravel	,,	⅛–¾ in. major diameter.
15.	Sand	,,	< ⅛ in. including loamy sands.
16.	Loam	,,	including sandy loams, silt loams, clay loams and peaty loams.
17.	Silt	,,	
18.	Clay	,,	including silty clays and sandy clays.
19.	Peat	,,	including loamy peats.

Prominent species with low composition values

Sometimes a species which forms only a low proportion of the canopy, is nevertheless conspicuous. For example, in the mountain beech forest at Ruapehu, kaikawaka (*Libocedrus bidwillii*), which rarely reaches the 20% level, is emergent above the beech canopy and is so prominent that a descriptive name which made no mention of it would be inadequate.

In this case the words "with kaikawaka" are added after "mountain beech forest" whenever the plant is prominent on half or more of the samples. Whether a species is to be considered prominent or not is a subjective judgment not necessarily repeatable by different observers.

An example of the use of the naming procedure is shown in Table 3.

DISCUSSION

With very large or rugged areas of vegetation, complete coverage with the traverse grid may not be possible. Sectors mapped from traverses and those where only the aerial photographs have been used, should be distinguished on the map.

The sampling often reveals the importance of less conspicuous species. Nevertheless the sample counts must not be divorced from observations made between samples. However systematic the method of sampling, it should not be allowed to become a purely mechanical process.

Starting points and directions of individual traverses must be accurately located if the latter are to be of maximum value in following changes in the vegetation pattern. Ideally the traverse sampling should be followed by the establishment of representative permanent quadrats or transects in which vegetation changes over limited areas can be followed in detail.

Vegetation types, as recognised here, are not comparable in the amount of variation they contain: some include a whole range of distinct communities too small to show on a map, others are comparatively homogeneous consisting of only a single type of community. The mapping and naming of a vegetation type is simply the recognition and statement that a particular group of species compose the upper photosynthetic surface over a particular area at a particular time. Some groups of species are recurring combinations, others are unique. They are not fixed combinations which can move as entities from place to place.

SUMMARY

A semi-quantitive method of mapping vegetation at a scale of one mile to the inch is described which uses estimates of the basal area and cover of plants in the uppermost (canopy) layers. These estimates permit more precise comparisons than possible with qualitative observations. The method of grouping samples to form mapping units (vegetation types) and a procedure for naming these units are given.

TABLE 3. *Application of naming procedure to the stages of a tussockland-forest succession.*

		Canopy composition	
Stage	Vegetation Name	*Festuca novae-zelandiae*	*Pinus contorta*
1.	*Festuca* tussockland ...	$\geq$20%	<20%, not prominent
2.	*Festuca* tussockland with *Pinus*	$\geq$20%	<20%, prominent
3.	*Pinus*/*Festuca* tree-tussockland	$\geq$20% > *P. contorta*	$\geq$20% < *F. novae-zelandiae*
4.	*Pinus*/*Festuca* tussock-treeland	$\geq$20% < *P. contorta*	20–80% > *F. novae-zelandiae*
5.	*Pinus* forest with *Festuca*	<20% prominent	$\geq$81%
6.	*Pinus* forest	<20% not prominent	$\geq$81%

ACKNOWLEDGEMENTS

I am grateful to Dr. R. M. Williams, Applied Mathematics Laboratory, D.S.I.R., for his interest and assistance in dealing with the statistical aspects of this work as well as his advice on several other points of procedure. Mr. A. P. Druce, Botany Division, D.S.I.R., contributed in large measure to the growth form classification of Table 2 and made numerous constructive criticisms of other aspects of the method. Modifications to the original draft were made as a result of helpful criticisms received from Mr. D. R. McQueen, New Zealand Forest Products, Ltd. Mr. W. D. Burke, Victoria University of Wellington, assisted me in the field during the early stages of testing the method and I am indebted to Miss M. T. K. Chung, Applied Mathematics Lab., for examining the data on trunk diameter-crown area relations.

REFERENCES

DRUCE, A. P. and ATKINSON, I. A. E., 1959. Forest variation in the Hutt catchment. *Proc. N.Z. Ecol. Soc.* 6: 41–45.

FINNEY, D. J., 1949. Random and systematic sampling in timber surveys. *Forestry* 22: 64–99.

GREIG-SMITH, P., 1957. *Quantitative plant ecology*. Butterworths Scientific Publications, London.

HASEL, A. A., 1938. Sampling error in timber surveys. *J. Agric. Res.* 57: 713–736.

LEVY, E. B. and MADDEN, E. A., 1933. The point method of pasture analysis. *N.Z. J. Agric.* 46: 267–279.

OSBORNE, J. G., 1942. Sampling errors of systematic and random surveys of cover type areas. *J. Amer. Stat.* 37: 256–264.

VEGETATION TYPES OF HIGH MOUNTAIN GRASSLANDS

C. J. BURROWS

University of Canterbury

In any study when a considerable body of information has been collected together it becomes essential to define carefully terms which are to be used. That stage has been reached in the ecological nomenclature of high mountain grasslands in New Zealand. Cockayne's (1921, 1928) terms, coined when the study was in its infancy, have often been used uncritically (e.g. by Allan 1926, Barker 1953, Poole 1951, Relph 1957). Some workers (Barker 1953, Druce 1960, Connor 1960, 1961, and Wraight 1960) have made new contributions for the areas in which they worked but it is considered that an overall, unified approach is necessary. The resolution of published taxonomic knowledge on *Danthonia* spp. (Connor 1960) has done a lot to clarify the situation. In the following discussion the terms used by Cockayne are reassessed.

As a basic criterion for classification of all the mountain vegetation it is proposed here that the vegetation be termed grassland where grasses, by their size, predominance in cover, and general physiognomic importance are the apparent vegetation. There is often no clear boundary, however, between grassland, scrub, herbfield or bog. In these other forms of vegetation, plants other than grasses are physiognomically important. Some of the usages of Cockayne (certain herbfields, transitions to bog, some fellfield and even some vegetation where grassland merges into scrub) fall into the above definition of grassland. Confusion has arisen in New Zealand plant geography and ecology from acceptance of the Cockayne terms which were based on no clear definitions.

Tall tussock grassland. The term applies to many grassland types, dominated by several important species of the genus *Danthonia* with different ecological amplitudes. The usage is equivalent, for example, to the terms beech forest or coastal scrub and is at the level of the *structural sub-form* (Costin and Beadle, 1952). Some subdivision is required. The only subdivision attempted on a floristic basis by Cockayne was into