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VEGETATION TYPES OF HIGH MOUNTAIN GRASSLANDS

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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

Danthonia raoulii var. *flavescens* or snow-grass grassland and *D. raoulii* var. *rubra* or red tussock grassland. These specific names are invalid and the correct nomenclature is indicated by Connor (1960). The subsequent taxonomic subdivision of the aggregate species "*D. raoulii* var. *flavescens*" (in part provisional), together with realisation that species distinguishable within it have different ecological amplitudes, necessitates the description of various other vegetation types. Some of this description was carried out by Connor (1960, 1961) and some by Wraight (1960).

The forb element (a forb is a non-graminoid herb with broad leaves) is seldom physiognomically dominant for extensive areas in the high mountain vegetation although many non-graminoid species may be subdominant or occur in the form of mosaics in gaps in the cover of physiognomically dominant *Danthonia* spp. Cockayne's *Tall tussock herbfield* . . . "Where *Danthonia raoulii* var. *flavescens* dominates but the var. *rubra* may be important and probably *D. ovata;* and . . . *D. crassiuscula* herbfield, where that grass is dominant" (Cockayne 1928) are thus better accommodated within *Tall tussock grassland*. Transitions from bog to grassland and mosaics of bog species with grasses are also common. When combinations of stands of shrubs, forbs and grasses are found together there is difficulty in applying any single term. Various combinations with the term mosaic are useful, e.g. scrub-grassland mosaic. Shrubs occur dotted at intervals through some grasslands. Druce (1960) uses the term shrub-tussockland for these. This is etymologically suspect and scrub-grassland or shrub savannah might be better.

Fellfield. Cockayne uses this in a much wider sense than is meant by the Norwegian fjaeldmark (Polunin 1960, Costin and Beadle 1952). The term fellfield should be confined to stable, more or less open communities of dwarfed plants found on exposed mountain tops, crests or ridges, cols and at the upper limits of vegetation on flat or gently sloping ground. It is of limited extent in Canterbury but appears to be widespread on Otago mountains. It is floristically distinct from other vegetation. Vegetation of actively eroding soils and unstable steep ground of the dry Canterbury, Marlborough and Otago mountains is best regarded as degraded remnants of closed grassland and subalpine scrub which formerly covered the slopes and to which it is floristically related.

Billings and Mark (1961) call the vegetation on the Old Man Range *Alpine tundra*. The latter has been used as a blanket term for North American high mountain vegetation above treeline (Daubenmire 1943). There are floristic similarities between this North American mountain vegetation and the Arctic tundra. In New Zealand, however, we cannot equate our vegetation with an Antarctic tundra and the term does not seem to be particularly applicable here. The Old Man Range vegetation contains many endemics to Otago, but otherwise floristically is related to high mountain grassland, herbfield and fellfield in Canterbury.

Mat Grassland. Cockayne uses this term for three ecologically distinct grassland types which are not similar in form to one another. Only one of them, the carpet grass (*D. australis*) grassland is found in the high mountains. The others are *Triodia exigua* grassland on young river-flat soils and *Poa acicularifolia* grassland on limestone outcrops. It is proposed that the term mat grassland be discontinued for high mountain grasslands since it is not descriptive of other short grasslands which should be included with *D. australis* under one heading. It is here replaced by the term *Short grassland* to include vegetation dominated by the sod-forming grasses *D. australis, D. oreophila, D. setifolia* and *Poa colensoi*. (The two latter are also tuft formers.)

CRITERIA OF CLASSIFICATION

Classification systems employed by various writers use several criteria (a) Floristics (b) Ecological relations or habitats (c) Successional status (d) Geographic characteristics (e) Physiognomy (f) Structure and plant form; or combinations of some or all of these. The system used here employs physiognomy, floristics, structure and form. Following recent work in America and Britain (Curtis 1959, Whittaker 1951, Poore 1955, Poore and McVean 1957) on the concept of the plant community, and of preliminary studies by the writer in Canter-

TABLE 1. *Grassland vegetation types in the high mountains of the South Island*

Major Physiognomic Unit (Form)	*Structural Unit (Subform)*	*Physiognomic-Floristic Vegetation Type*	*Facies*	*Structure*	*Habitats*	*Distribution*[1]
L A N D	Tall Tussock Grassland	*Danthonia rigida* (narrow - leaved snowgrass)	*D. rigida* and species such as *Poa colensoi, Celmisia lyallii, C. viscosa, C. spectabilis, Festuca matthewsii.*	Varies from dense growth of *D. rigida* tussocks 2–3 ft. high with few other species, to mosaics of *D. rigida* tussocks with Celmisias, *Poa colensoi* and other species 3–12 in. high or in degraded areas, isolated tussocks of *D. rigida* on bare subsoil or scree.	4000–6000 ft. Moderately shallow to deep well-drained soils. "Continental"[2] climate. Less than 50 in. ann. av. precipitation. Snow lie moderately long to short. Occurs below 3000 ft. where forest has been destroyed.	Extensive Southland to Marlborough, mainly E. of 50 in. ann. av. precipitation line. Often burned and overgrazed by sheep. This is the main grass above treeline in the drier mountains.
		D. sp. (midribbed snowgrass)	*D.* (midrib) and species such as *D. crassiuscula, C. discolor, Poa colensoi.*	Varies from dense growth of *D.* (midrib) tussocks 2–3 ft. high with few other species to mosaics of this species with *D. crassiuscula,* Celmisias and other species 3–16 in. high.	4000–6000 ft. Moderately shallow to deep soils, well to moderately poorly drained. "Oceanic"[3] climate, more than 50 in. ann. av. precipitation. Snow lie moderately long. High rainfall in non-snow season.	Extensive Fiordland to Nelson, W. of 50 in. ann. av. precipitation line. This is the main grass above treeline in the wet mountains except in Fiordland and in *D. australis* areas.
		D. flavescens (broad-leaved snowgrass)	*D. flavescens* and species such as *C. spectabilis, C. coriacea, Dracophyllum* spp.	Varies from *D. flavescens* with scattered shrubs to dense growth of *D. flavescens* tussocks 2–5 ft high with few other species, to mosaics of *D. flavescens* with Celmisias and other species 3–12 in. high or, in degraded areas isolated tussocks of *D. flavescens* on bare subsoil or scree.	3000–4500 ft. (mainly). Scrub zone at treeline, often on rockfalls, cliffs. Extends to 5500 ft. on steep cliffs and below 3000 ft. on slopes where forest has been destroyed.	Throughout the S. Is. mountains. Extensive in easternmost mountains Otago - Marlborough, and parts of inland Canterbury.
		D. sp. (red tussock)	Not known.	Dense growth of *D.* (red tussock) 2–4 ft. high with few other spp. or mosaics of *D.* (red tussock) with bog species.	Up to 4000 ft. Poorly drained slopes, level ground or bog. Occurs below 3000 ft. in bogs and in cold soils where forest has been destroyed. 3500–5000 ft (at least).	Widespread but not very extensive in high mountains above treeline. Very extensive in areas below treeline Southland, S. Otago, parts of Canterbury.
		D. teretifolia (hairy snowgrass)	*D. teretifolia* and species such as *D. crassiuscula, C. petriei, Dracophyllum uniflorum.*	Varies from dense growth of *D. teretifolia* tussocks 1–2 ft. high, to mosaics with *D. crassiuscula,* Celmisias and other species 3–12 in. high.	Deep peaty soils, poorly drained, on exposed slopes. High rainfall — 40–100 in. ann. av. Snow lie short to moderately long.	Extensive in E. Fiordland.

GRASS	Short Grassland	*D. crassiuscula* (curly grass)	*D. crassiuscula* and species such as *C. haastii, C. sessiliflora, Poa colensoi, Aciphylla, Crenulata, Caltha novae-zelandiae.*	Dense growth of *D. crassiuscula* clumps 6–15 in. high and mosaics of herbs 1–12 in. high.	5000–6000 ft. "Oceanic climate, more than 50 in. ann. av. precipitation. Edges of snow patches. Fairly shallow, moderately poorly drained soil. Snow lie long. Grades into bog, marsh.	Fiordland to Waimakariri, W. of 50 in. ann. av. precipitation line. Scattered distribution to Spenser Mts. and St. Arnaud Ra. Not extensive as a pure community.
		D. oreophila (snow-patch grass)	species such as *Poa D. oreophila* and *colensoi, Rostkovia gracilis, Anisotome imbricata, C. sessiliflora.*	Dense uniform sward of *D. oreophila* intermingled with other species, 2–4 in. high.	5000–6000 ft. Snow hollows. Shallow well drained soil. Snow lie very long.	On all mountains Fiordland to Spenser Mts. and St. Arnaud Ra. where snow lies in cirque basins until early or mid-summer. Not very extensive in area.
		D. australis (carpet grass)	*D australis* and species such as *C. discolor, C. viscosa, Dracophyllum* spp.	Very dense uniform, close growing turf of pure *D. australis,* or with other species growing in the sward 3–4 in. high. Mosaics with *D.* sp. (midrib) and *D. rigida* (at its western extent) are common.	4000–6000 ft. Chiefly in "Oceanic" climate, more than 40 in. ann. av. precipitation. Well drained to moderately poorly drained soils, shallow to moderately deep. Snow lie short to moderately long.	Nelson, Westland and Marlborough, S. to Taramakau and Waimakariri Rivers, mainly W. of 50 in. ann. av. precipitation line. Widespread and extensive.
		D. setifolia	Not known.	Single tufts in open ground or close growing dense turf 2–4in. high. Other species grow within the sward.	Up to 6000 ft. Above treeline at eroding edge of closed vegetation, and on rock outcrops. Below treeline on slopes where forest has been removed by fire.	Found throughout the S.I's mountains but not extensive in high mountain grasslands.
		Poa colensoi (blue tussock)	Not known.		Up to 6000 ft. Above treeline colonizes stable scree, stonefield, snow patch or predominates after burning. Below treeline on snow avalanche paths or where forest has been burned, river flats, aluvial fans.	Found throughout the S.I's mountains. Moderately extensive but small area as a pure community in high mountain grasslands.

NOTES:

1. Distributions are the known ones for the species and the vegetation types containing them. Detailed knowledge of distributions for these species and for other important physiognomic species is still required for many areas.
2. "Continental" climate. In the most inland areas with relatively low summer rainfall, high summer temperatures, relatively light winter snowfall and heavy winter frosts.
3. "Oceanic" climate. In areas on or near the main divide with relatively high summer rainfall and heavy winter snowfall which tend to ameliorate the summer drought and winter frost.

bury, Marlborough and Westland it is considered that discrete plant communities in New Zealand high mountain grasslands *per se* do not exist. Nor can they be classified except quite arbitrarily. This is because the vegetation is in the form of multidimensional continua in space (and probably in time). Species composition is found to vary continuously with the varying ranges of tolerance of the plants along environmental gradients between extremes in such factors as soil depth, drainage, lateness of snow release, slope, exposure to wind. These are not often independent of one another so that the resulting vegetation structure is highly complex. Topographic irregularity enhances this. It is useful, however, to be able to recognise species groupings which recur, within rather wide limits of species composition, in response to repeated similar combinations of environmental factors. They are never quantitatively uniform because the environment is never uniform and because of factors associated with competition and reproduction.

THE CLASSIFICATION

It is considered that a scheme incorporating the good points of those employed by Wraight (1960) and Costin and Beadle (1952) will best meet the conditions existing in the high mountain grasslands here and serve the greatest practical purpose. The system proposed is set out in Table 1. The categories are:

Form — the major physiognomic unit, in this case grassland. Other forms are forest, scrub, herbfield, fellfield.

Subform — the structural unit. In the grassland the subforms can conveniently be delimited according to stature of the major grasses.

Type — a physiognomic-floristic vegetation unit. This is recognised according to the most characteristic dominant grass. The dominants cover most ground space, condition the environment in various ways, and thus influence other species present. They make most demands of the environment, are long-lived and unless too much disturbed by fire or sheep grazing, make up stable vegetation which is permanent and continues to regenerate for indefinite periods.

Facies — variants of the type, which contain the characteristic grass and one or several other species of grasses and other plants. In the table some of the species which form facies are listed. Further work will establish species structure of facies of the vegetation types, distinguished by species presence and cover and it is desirable that an ordination of the kind developed by Curtis (1959) is achieved.

This classification is incomplete but the system as proposed will accommodate vegetation types in areas not covered by the writer. The fieldwork upon which the classification was based was carried out in Canterbury, West Southland, Nelson, Marlborough and Westland. The classification applies to vegetation above treeline (ca. 3500 ft in Southland, 3500–4500 ft in Canterbury, 4000–4500 ft in Nelson-Marlborough). Some of the types extend well below these levels, e.g. *D. flavescens* in South and Mid-Canterbury, *D. rigida* in North Otago, red tussock in Southland. This is usually on land where forest was destroyed by fire some centuries ago. Other grasslands below treeline, some of different structural subform, could be fitted into the classification. The *Low tussock grasslands* including *Festuca* and *Poa* grasslands (Cockayne 1928) and the *Poa cockayniana* grasslands of wet mountain valleys (Wraight 1960) are among these. The tussock grasslands of the Subantarctic islands (Cockayne 1928) could also be fitted into the classification.

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A FROST-TOLERANT POROUS-POT EVAPORIMETER

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A severe limitation to the usefulness of porous-pot evaporimeters in the field has been their restriction to frost-free periods, since ice formation causes air locks and often breaks the pot.

In lowland areas with relatively long frost-free periods, measurements may be obtained for most of a year. In mountainous country, however, at least above about 4000 ft., severe frosts usually occur during all months. Thus, using improved, conventional-type evaporimeters (Baylis 1957), only occasional measurements of evaporation from December until March have been possible in the high altitude snow-tussock and alpine zones of the Old Man Range, Central Otago, during the past three years. One short period of sub-freezing temperature is usually sufficient to upset or to destroy the instrument.

Because of this need for frost-tolerant evaporimeters, various modifications to the original design have been attempted. Instruments were subjected to pilot testing in a cold chamber at about 1° F. The one design tested successfully continued to function during April 1961 at 4000 ft. on the Old Man Range when air temperatures fell to 25° F.

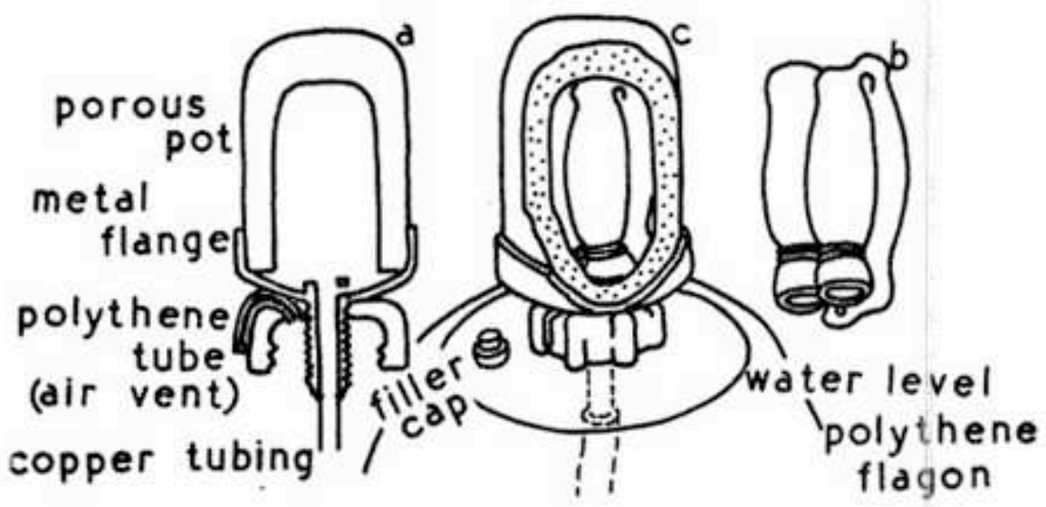

FIGURE 1. *A frost-tolerant porous-pot evaporimeter. "A" shows a conventional evaporimeter in cross section. The polythene air vent tube is shown inserted in the screw cap of the polythene flagon. A hole drilled in the stem of the metal flange to prevent an air lock in the interior of the pot is also shown. "B" shows the rubber surgical tubing ready for insertion into the porous pot. "C" shows the completed instrument, cut away to show the surgical tubing in place.*

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