Classification of New Zealand forest and shrubland communities based on national plot sampling on an 8-km grid

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Manaaki Whenua

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ABSTRACT

We present a vegetation classification based on 1177 vegetation plots systematically located in New Zealand forest and shrublands. Three separate analyses were undertaken using NZCMS data. First, all NZCMS forest and shrubland plots were classified using only the vascular plant species recorded on each plot. To determine whether the inclusion of non-vascular species has an important influence on classification results, we then included the non-vascular species recorded on each plot in a second analysis. We also produced a classification based on woody species only, to determine how the inclusion of herbaceous species was influencing the classification. Using all plots and vascular species only, 24 forest and shrubland classes were recognised, each comprising 19–105 plots. We recognised seven shrubland classes. These range from weedy, successional classes to montane and subalpine shrublands. We grouped the forest classes into species-group types to allow ready comparison with previous classifications. Four classes were designated as beech forest, five as beech–broadleaved forest, four as beech–broadleaved–podocarp forest, two as broadleaved forest and two as broadleaved–podocarp forest. DCA, CCA, and MANOVA showed the mappable parameters of mean annual temperature, minimum temperature, northing, and easting as likely to be the most useful parameters for mapping, with the others being of secondary importance. The distinction made in our classification between forest and shrublands (or forest and non-forest) is progressively better matched by the Forest Class Maps, Vegetative Cover Map, ECOSAT woody classification and LCDB2 (Table 7). At a species-group category level, our beech forest classes map well onto previous classifications; whereas there are more discrepancies with the other groups. A classification that incorporated non-vascular species had closer correspondence to the vascular-species-based classification than did one based on woody species alone.

Keywords: classification, cluster analysis, OPTIMCLASS, vegetation maps, successional shrubland, subalpine shrubland, beech forest, beech–broadleaved forest, beech–broadleaved–podocarp forest, broadleaved forest, broadleaved–podocarp forest

1. Introduction & Background

This investigation is part of a programme of research and development designed to support development of the Natural Heritage Management System (NHMS) of the Department of Conservation (DOC).

Internationally, vegetation classifications have been used to provide a framework for a wide range of management interests and activities including conservation planning for reserves (e.g. Wilson et al. 2002; Faber-Langendoen et al. 2007), guiding forest silviculture (e.g. Beveridge 1973; von dem Bussche 1974; Pojar et al. 1987), understanding patterns of distribution of coarse woody debris (Schlegel & Donoso 2008), management of fauna (e.g. Dziezciolowski 1970; Zinner et al. 2001), protection of forests against disease (e.g. Havel 1975), catchment management (Rutter et al. 1975), interpretation of long-term monitoring data (e.g. Large et al. 2007), and success of restoration activities (e.g. Pakeman et al. 2005). In New Zealand, the Ecological Districts and Regions Classification (which incorporated both vegetation and abiotic features) was developed to inform the establishment of a representative set of reserves to encompass the ecological diversity described (McEwen 1987).

There are numerous ways to produce vegetation classifications. At large spatial scales, vegetation often correlates with regional climate and many classifications have attempted to group ecosystems influenced by the same climates into a reference framework for management (Pojar et al. 1987). Climate is usually expressed through parameters such as mean annual temperature and precipitation. Additional abiotic factors such as soil moisture (e.g. Thornthwaite 1948) and nutrient regimes (e.g. Bakuzis 1969) can also be used to classify ecosystems. Ecosystems also reflect the impact of disturbance, chance, time, and species, factors which may, or may not, correlate with abiotic factors. One approach to removing the influence of disturbance is to define a ‘potential successional climax’ forest to represent vegetation for any abiotic environmental regime (e.g. Daubenmire 1976; Pojar et al 1987; Sims et al. 1996). However, classification based on climax vegetation has conceptual and methodological problems (Mueller-Dombois & Ellenberg 1974), not the least of which is that vegetation that could develop on a site at one point in time is not necessarily identical to that which would become established at another time under otherwise similar conditions (e.g. McCune & Allen 1985).

Alternatively, the actual composition and/or structure of vegetation have commonly been used to classify vegetation into management units (Havel 1980). This approach is based on the view that variation in vegetation attributes best reflects the full range of factors (e.g. climatic and disturbance) influencing vegetation, a concept that dates back to Humboldt’s work and was first applied to forestry by Cajander (Jahn 1982). One criticism of classifications based on vegetation attributes alone is that these attributes change over time and therefore such a classification may not represent a stable framework for management in the long term (Sims et al. 1996). Another criticism is that communities are not ‘precise entities of fixed and unvarying composition’ (Curtis 1959); rather it is well known that species are typically distributed individualistically along gradients. However, practical considerations of conservation often require plant community classifications and vegetation maps, as attempting to address the needs of all species in the landscape (and their interactions) individually would be an impossible task (Noss 1987).

New Zealand needs a systematic framework for reporting upon the range of natural heritage indicators proposed by Lee et al. (2005). Summaries of data collected from the systematic plot network underpinning the work described here provide much of this information. A robust vegetation classification will complement this by providing a framework for this reporting and permitting extrapolation to areas that were not sampled by the plot network.

Those indicator measures for which a robust vegetation classification is essential include:

1.5.1 Land under indigenous vegetation
5.1.1 Size-class structure of canopy dominants
5.1.3 Representation of plant functional types
7.2.2 Changing natural distributions of indigenous taxa and biomes

Those indicator measures for which a robust vegetation classification will provide an especially informative framework include:

1.1.1 Soil carbon status
1.2.1 Net primary productivity of natural terrestrial vegetation
1.2.2 Mast flowering and fruit production
1.3.1 Catchment water yield
1.3.2 Water chemistry
1.3.3 Stream invertebrate index
2.2.1 Distribution of exotic weeds and pests considered a threat
2.2.2 Indigenous systems released from exotic pests
4.2.1 Number of acutely threatened indigenous taxa
5.2.1 Extent potential range occupied by focal indigenous taxa
5.3.1 Degree of connectivity in transformed landscapes
8.2.2 Volume of harvested material (e.g. sphagnum)

A New Zealand vegetation classification will have numerous other uses in addition to underpinning indicators. These include, but are not restricted to, serving as surrogates for 'biodiversity' in the absence of detailed information to rank and set priorities for conservation management, for planning – e.g. identification and management of priority vegetation communities, for understanding responses to perturbations, for improving existing vegetation cover maps, and for the development of a flammability index for vegetation communities to support the wildfire threat analysis programme.

A classification based on actual composition and structure of New Zealand vegetation will produce the information needed for the reporting described above derived directly from real, on-the-ground data. We use data collected under the auspices of the New Zealand Carbon Monitoring System (NZCMS; Payton et al. 2004) for this purpose. The primary focus of the NZCMS is to monitor carbon sequestrian rates, but plant biodiversity information is also collected. Permanent plots were established on an 8-km^2 grid across the areas mapped as indigenous forest (6.25 million hectares) and shrubland (2.65 million hectares) by the 1996/97 version of the LandcCover Database (LCDB1). Where pre-existing plots occurred within 4 km of a grid point, they were used to maximally build on previous efforts. This is the first systematic, unbiased collection of vegetation composition across all of New Zealand forest and shrublands and provides an ideal dataset on which to base the classification.

To provide the necessary background to the classification of New Zealand forest and shrublands presented here, we first review vegetation-based classifications that have been widely applied in the past. We then review international and New Zealand conventions for naming vegetation classification units based on their composition and structure.

1.1 NATIONAL-SCALE CLASSIFICATIONS OF NEW ZEALAND VEGETATION

1.1.1 Classifications of all vegetation types

- The **Vegetative Cover Map** of New Zealand (Newsome 1987) provided national coverage for all vegetation communities. It was compiled for publication at the coarse scale of 1:1 000 000 and resolved vegetation communities with a reasonable degree of fidelity, but could only delineate map units greater than 500 ha in area. The underpinning data were primarily from the New Zealand Land Resource Information Survey and were supplemented by regional vegetation maps with extensive ground truthing. The NZLRI recorded 6863 different combinations of vegetation cover in 89 875 map units (polygons of different sizes) across New Zealand; these polygons were delineated based on landform and soils (Blaschke et al. 1981). Within these polygons the dominant and minor vegetation types (as assessed from aerial photographs and rapid ground surveys) were listed according to a picklist of five major classes (cropland, grassland, scrubland, forest, miscellaneous), which were in turn subdivided into between 4 and 13 vegetation types (e.g. ‘forest’ was subdivided into coastal forest, kauri forest, podocarp–hardwood forest, beech forest, etc.).

- **Land Cover Database** (LCDB2; Thompson et al. 2004) provided aerial extent estimates of 33 classes of land cover or land use derived from a classification of Landsat satellite imagery acquired in the summer of 2001/02. All indigenous forest was grouped into one class whereas eight shrubland classes (Fernland, Gorse and Broom, Mānuka and/or kānuka, Matagouri, Broadleaved indigenous hardwoods, subalpine shrubland, mixed exotic shrubland and grey scrub) are recognised. The minimum mapping unit is 1 ha. LCDB2 is known to have errors in its boundaries of different vegetation classes. For example, Brockerhoff et al. (2008) examined 5554 ha classed as exotic forest by LCDB2 and found that 43% of the area was classed incorrectly.

1.1.2 Classifications of forests

- **Forest Class Maps** provided national coverage for forest classes in New Zealand. The maps were compiled at a scale of 1: 250 000 (NZ Forest Service Mapping Series 6). A small part of the North Island was mapped following McKelvey & Nicholls (1957) at a scale of 1:63 360 (NZ Forest Service Mapping Series 5). The 1:250 000 and 1:63 360 maps were based upon a mixture of quantitative data collected during the National Forest Survey 1946–55 (Thomson 1946; Masters et al. 1957), the North Island Forest Ecological Survey (McKelvey 1995), and regional publications. The National Forest Survey entailed the preparation of detailed forest class maps, based initially on aerial photo interpretation, with ground-based assessments of the forest within each mapped class. For plots of little timber production value, walk-through reconnaissance was done, with limited plot sampling, to verify forest typing. For forests with production potential, plots were measured at quarter-mile intervals on lines spaced one mile apart. On each plot all trees of merchantable species greater than 12 inches diameter at breast height (dbh) were identified and their diameters and merchantable heights measured. Culturally modified forest was not sampled. The

North Island Forest Ecological Survey focused on forest with little perceived timber production value. The 1:250 000 maps primarily follow the qualitative classification of these data presented in McKelvey & Nicholls (1957) and later in Nicholls (1976, 1977). A cluster analysis was used to produce a quantitatively based classification of South Island forests (McKelvey 1984). This provides more detail about the variation within the broad classes recognised by Nicholls (1977), but was never used for mapping.

- **ECOSAT Woody vegetation layer** used satellite imagery to produce land information at 1:50,000 scale. Woody vegetation was classified using binary split rules developed from visual examination of typical spectral signatures (Dymond & Shepherd 2004) matching mapped pixels to a selection of ground data sites (277 forest plots of 0.04 ha) in the Wellington Region. This classification reflected the proportions of beech, broadleaf species, and conifer species in the forest, as each has a unique spectral signature. Predictions of the proportion of beech and conifer species match the plot data reasonably well, whereas prediction of the proportion of broadleaf species is less accurate. In 2004, this work was used as the basis for deriving a national woody vegetation layer where indigenous forest classes were computed, based on canopy reflectance, and included podocarp–broadleaved forest, beech forest, broadleaved forest, podocarp–broadleaved–beech forest, beech–broadleaved forest, podocarp forest, kauri forest, coastal forest, and subalpine shrubland.

- **Maps of New Zealand potential forest cover** predicted potential forest composition. Leathwick (2001) employed regressions relating the distributions of 37 major canopy tree species to environmental variables reflecting climate, landform and parent material, and spatial variables to reflect contagion and disjunction in species distributions. Data on species distributions were obtained from c. 15 000 vegetation plots of 0.04–0.4 ha distributed unevenly around the country. Predictions of species abundance were made for points on a 1-km grid across New Zealand, and the resulting matrix was quantitatively classified to derive 20 groups of similar composition, which were then mapped. Hall and McGlone (2006) used process-based modelling to predict potential forest composition in New Zealand. The underlying model, LINKNZ, assembled a forest ecosystem at a scale of half-hectare patches by simulating the establishment, growth and mortality of individual stems from among 78 species. It did this by modelling the interactions between these demographic processes, species traits, environment and feedbacks with water and nutrient availability. Based on their traits, species were assigned to plant functional types comprising combinations of broad vegetation classes (kauri, broadleaf, podocarp, beech), structural type (forest v. scrub), temperature class (warm, temperate, cool), and drought-tolerance class (intolerant, medium, tolerant). These were used to define 21 plant functional types (e.g. cool dry beech forest). Each landscape unit was then assigned the predominant plant functional type and these were mapped.

1.1.3 Classifications of other vegetation types

- **Wetlands** – Johnson and Gerbeaux (2004) produced a classification of New Zealand wetlands with the goal of facilitating international and national reporting. This classification includes inland freshwater wetlands, those near coastal estuaries, and those of lake and river margins. Some wetland forest and shrubland classes are recognised. This classification has been mapped nationally under the Waters of National Importance project led by DOC (http://www.landcareresearch.co.nz/services/informatics/ecosat/applications.asp#Wetland).

- **Historically rare ecosystems** – Williams et al. (2007) compiled a list of 72 rare ecosystems from the literature and by canvassing New Zealand ecologists and land managers. Rare ecosystems were defined as those having a total historical extent less than 0.5% (i.e. < 134 000 ha) of New Zealand's total area (268 680 km^2). To define the ecosystems in a robust fashion, a framework was developed based on descriptors of physical environments (selected from soil age, parent material, soil chemistry and particle size, landform, drainage regime, disturbance, and climate) that distinguish rare ecosystems from each other and from more common ecosystems. Most of the systems are non-woody, but one forest class (cloud forest) and several shrubland classes are recognised. The extent of each of these 72 ecosystems is currently being mapped by DOC.

1.2 COMMUNITY NAMING CONVENTIONS

When vegetation is classified, names are required for the classes and typically this naming follows a specified set of rules. Below, we describe the main international standard and the primary system that has been used in New Zealand.

1.2.1 International Vegetation Classification

The International Vegetation Classification (IVC) consists of a seven-level hierarchy (Grossman et al. 1998; Table 1). The finest level, association, corresponds to an 'element of biological diversity', although the next higher level (alliance) may also be considered an element in cases where associations have not yet been defined within the alliance. The IVC builds on over a century of work on vegetation classification that has been reviewed by earlier works (see list provided by Jennings et al. 2003), particularly that of Braun-Blanquet (1928; also referred to as the 'Zurich–Montpelier School'). The Braun-Blanquet system is the most widely applied vegetation classification system in the world.

TABLE 1. A SUMMARY OF THE CLASSIFICATION HIERARCHY OF THE INTERNATIONAL VEGETATION CLASSIFICATION

Level	Primary basis for classification	Level divisions and examples
Class	The type, height, and relative percentage of cover of the dominant, uppermost vegetation	Seven classes: Forest, Woodland, Shrubland, Dwarf-shrubland, Herbaceous, Non-vascular, and Sparse Vegetation
Subclass	For Forest, Woodland, Shrubland, and Dwarf Shrubland classes: leaf character	Three subclasses in each: evergreen, deciduous, and mixed evergreen–deciduous (no mixed evergreen–deciduous, dwarf-shrubland subclasses have yet been defined)
	For Herbaceous Class: persistence and growth-form	Four subclasses: perennial grasslands, perennial forb vegetation, annual grass and forb vegetation, and hydromorphic vegetation
	For Non-vascular Class: relative dominance of non-vascular vegetation type	Three subclasses: lichens, mosses, algae
	For Sparse Vegetation Class: particle sizes of the substrate features	Three subclasses: consolidated rock; boulder, gravel, cobble, or talus; and unconsolidated material (soil, sand, or ash).
Group	Varies by class: leaf characteristics, broad climatic types, presence and character of woody strata, major topographic position types or landforms	About 60 groups Example: Temperate or Subpolar Needle-leaved Evergreen Forest
Subgroup	Relative human impact	Two subgroups: Natural/Semi-natural or Cultural
Formation	Additional structural and environmental factors, including hydrology	Many Example: Saturated Temperate or Subpolar Needle-Leaved Evergreen Forest
Alliance	Dominant/diagnostic species, usually of the uppermost or dominant stratum	Many Example: *Picea mariana* Saturated Forest Alliance
Association	Additional dominant/diagnostic species from any strata	Many Example: *Picea mariana* / *Alnus incana* / *Sphagnum* spp. Forest

Three interrelated criteria – species composition, structure, and habitat – conceptually define an association: it represents plant assemblages that exhibit similar total species composition and vegetation structure and that occur under similar habitat conditions. The association concept encompasses both the dominant species (those that cover the greatest area) and diagnostic species (those found consistently in some vegetation classes but not others) regardless of whether they are large trees or diminutive understorey plants. This means associations can reflect a greater ecological specificity than can a ‘cover type’ or other type based solely on the dominant species of the upper stratum.

Alliance and association definitions are either adopted from compatible local classification systems, or determined through field studies in which new vegetation information is collected and analysed. Most associations are defined through a mixture of quantitative analysis of vegetation data (such as plot data) and review of qualitative, descriptive information about vegetation classes. In every case, it is critical to have structured peer review by ecologists experienced in the regions being described.

Plant species that are dominant (cover the greatest area) and diagnostic (found consistently in some vegetation classes but not others) are the foundation of alliance and association names. At least one species from the dominant and/or uppermost stratum is included in each name. The following guidelines apply to alliance and association names:

- An enrule ('–') indicates species occurring in the same stratum.
- A slash ('/') indicates species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.
- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around species name indicate species less consistently found either in all associations of an alliance, or in all occurrences of an association.

Alliance names include the class (e.g. 'Forest', 'Woodland', 'Herbaceous') in which they are classified, followed by the word 'alliance' to distinguish them from associations. The lowest possible number of species is used for an alliance name, up to a maximum of four.
Examples of alliance names:

- *Pseudotsuga menziesii* Forest Alliance
- *Fagus grandifolia – Magnolia grandiflora* Forest Alliance
- *Pinus palustris / Quercus* spp. Woodland Alliance
- *Andropogon gerardii – (Calamagrostis canadensis, Panicum virgatum)* Herbaceous Alliance

Association names include the class in which they are classified. The lowest possible number of species is used in an association name. Up to six species may be necessary to define classes with very diverse vegetation, relatively even dominance, and variable total composition.

In cases where diagnostic species are unknown or in question, a more general term (such as 'Prairie forbs') is currently allowed as a 'placeholder'. An environmental or geographic term (e.g. 'Northern'), or one that is descriptive of the height of the vegetation ('dwarf'), can also be used as a modifier when such a term is necessary to adequately characterise the association. When confidence in the circumscription of the association is low, the name is followed by the term '[provisional]'.

Examples of association names:

- *Abies lasiocarpa / Vaccinium scoparium* Forest
- *Metopium toxiferum – Eugenia foetida – Krugiodendron ferreum – Swietenia mahagoni/Capparis flexuosa* Forest
- *Rhododendron carolinianum* Shrubland
- *Quercus macrocarpa* – (*Quercus alba – Quercus velutina*) / *Andropogon gerardii* Wooded Herbaceous Vegetation

1.2.2 New Zealand systems for naming vegetation classes

In New Zealand, the Atkinson (1962, 1985) system for naming and delineating vegetation classes is the most widely used formal system and is applicable to all terrestrial ecosystems. It comprises two components – a structural name based on the proportion of plant growth forms and a floristic name that indicates the identity of the major canopy layers.

Structural names are based on a classification of growth forms and other surfaces provided in Atkinson (1962) such as 'forest', 'treeland', 'scrub', 'shrubland'.

Species with mean percentage cover equal to or greater than 20% are included in the floristic name. Species are arranged in order of height, cover, or basal area. The symbol '/' distinguishes distinct canopy layers whereas '–' links species in the same layer. Common names are used in preference to scientific names; generic names are used for species with no common name. When no species exceeds 20% cover, the species with the highest composition value above a minimum of 5% is shown in brackets. If no species has greater than 5% cover, then no floristic name is given.

1.2.3 Comparison between the Atkinson system and the IVC

The structural name provided by the Atkinson (1962, 1985) system is analogous to the 'Class' level in the IVC. For the purposes of the work here a wider range of synonymies are provided in Table 2.

TABLE 2. COMPARISON BETWEEN ATKINSON NAMING SYSTEM AND IVC

Feature	Atkinson	IVC
Hierarchical levels	Structural name	Class
	Floristic name	Alliance or Association
Physiognomic names	Forest	Forest
	Treeland	Woodland
	Scrub	Shrubland
	Shrubland	Shrubland, Dwarf-shrubland
Rule-base for floristic names	Only includes species in the canopy	Alliance: typically includes only species in the dominant stratum Association: can include species from any stratum
	Species included based on % cover (dominance)	Includes species that are dominant or diagnostic
	Common names preferred	Scientific names preferred
Construction of floristic names	'–' links species in the same stratum	'–' links species in the same stratum
	'/' links species in different strata	'/' links species in different strata
	Species with cover >50% underlined. Species with cover of 10–20% and constancy >50%, shown in brackets. Species with cover <10% and constancy >50%, shown in square brackets	Species less consistently found either in all associations of an alliance or in all occurrences of an association shown in brackets

2. Objectives

2.1 CLASSIFICATIONS OF NZCMS FOREST AND SHRUBLAND DATA

Objective 1: The first objective of the current study is to classify New Zealand's forests and shrublands based on current plant assemblages. Vegetation plots are a widely accepted source of data for vegetation classifications. For this component of the present study we use the Carbon Monitoring System (NZCMS) dataset. The NZCMS provides the first near-systematic unbiased inventory of New Zealand forest and shrubland vegetation, capturing at a specific time and scale the vascular (and a subset of non-vascular) plant community composition and structure throughout New Zealand's main islands. An grid of 8 × 8 km comprising 1372 points was placed across the areas mapped as forest and shrubland on New Zealand's main islands according to LCDB1. NZCMS plots were established at 1258 of these points, using existing forest plots (20 × 20 m; Allen 1993; Hurst & Allen 2007) where possible (206 plots) and establishing new plots where none existed (1052 plots). A total of 114 of the grid points were abandoned either because they were too steep or because access was denied. This meant that in the end, 92% of the points on the initial grid were sampled. There was a slight geographic bias in that a larger percentage of North Island plots were abandoned (or access denied). In the North Island 65 of 519 plots were not measured (12.5%) while in the South Island 49 of 772 plots were not measured (6.3%). Within the North Island, the region where the highest percentage of plots was not measured was Northland (11 of 56 plots or 19.6% plots not measured).

Three separate analyses were undertaken using NZCMS data. First, all NZCMS forest and shrubland plots were classified using only the vascular plant species recorded on each plot. To determine whether the inclusion of non-vascular species has an important influence on classification results, we then included the non-vascular species recorded on each plot in a second analysis. We also produced a classification based on woody species only, to determine how the inclusion of herbaceous species was influencing the classification.

2.2 COMPARISON WITH PREVIOUS CLASSIFICATIONS

Objective 2: An important part of developing a classification is to put it into the context of previous classifications. We compare the outcomes of Objective 1 with the classifications described in section 1.1 above.

2.3 EFFECT OF SAMPLING INTENSITY ON CLASSIFICATION RESULTS

Objective 3: Each vegetation dataset represents a specific set of attributes (e.g. size of plot, spatial arrangement of plots) from complex and spatially heterogeneous vegetation. As a result of such variation, a logical expectation is that sampling intensity could affect the outcome of any classification. We use Recce plots (Allen & McLennan 1983) established for the South Westland Management Evaluation Programme (SWMEP) to assess the effect of sampling intensity. These data were collected in 1984/85 with plots located at 500-yard intervals along east–west transects 1000 yards apart, based on the NZMS 1 mapping grid (S78, S70). Additional plots were subjectively located where pronounced vegetation changes were encountered along transects.

2.4 VEGETATION MAPPING PLAN

Objective 4: Taking account of all the above results, the utility of the plot classifications for later stages of the project, including for mapping and measuring change, are discussed. A plan for carrying out this work is presented.

3. Methods

3.1 DATA SOURCES

We use two sources of vegetation data in this project: the NZCMS data and the SWMEP data.

3.1.1 NZCMS data

Landcare Research staff (Susan Wiser, Rob Allen, Nick Spencer, Meredith Mckay) liaised with DOC (Elaine Wright), MfE (Pam Coutts) and Interpine personnel (David Herries), and obtained access to the MfE NZCMS database in August 2007.

Electronic versions of the NZCMS year 1–2 data were drawn from the National Vegetation Survey (NVS) Databank. Electronic versions of the NZCMS year 3–5 data were drawn from the MfE/Interpine database. Errors were identified in NZCMS data. These included, but were not limited to, use of unknown/unrecognised species codes (including errors related to entry of incorrect species codes – either deviating from those recorded on field sheets or use of the incorrect 'duplicate' codes); errors in the entry of tier cover-class scores; data not entered. Landcare Research staff with experience collecting vegetation data undertook a data-checking and correction procedure by comparing the electronic data to the data recorded on the original data sheets (stored in the NVS archive). This was undertaken on all year 3–5 data within the MfE/Interpine database (funded by DOC and Landcare Research). Data errors and corrections were documented, so this process will also benefit other users of NZCMS data. The data-checking and correction exercise resulted in >11 000 corrections or additions to NZCMS Recce data. The vast majority of the issues identified were able to be resolved. Unresolved errors, which we omitted from the data used in the present study, amounted to 55 and 31 030 rows in tiers 6b–7b respectively and 68 and 37 620 rows in tiers 1–6a respectively, amounting to less than 0.2% of the rows in the two combined Recce species data tables in the Interpine/Mfe database. Plans are in place for the year 1–2 data to receive the same rigorous checking and correction procedure undertaken on year 3–5 data.

3.1.2 Plot selection from NZCMS databases

Of the 12 58l NZCMS plots measured, we selected all of those where field teams described the vegetation as either shrubland or indigenous forest. We excluded those plots where the land cover observed by field teams was described as 'Bare ground', 'Coastal sands', 'Coastal wetlands', 'Grassland', 'Inland water', 'Inland wetlands', 'Pasture', 'Planted forest', 'Primarily pastoral', 'Riparian planting', 'Scree', 'Shelterbelts', or 'Urban'. We also excluded plots with expected LCDB1 categories other than forest or shrubland, on the assumption that these resulted from confusion between the 'LCDB1 Expected' and 'LCDB1 Observed' datafields when recorded on fieldsheets (fieldstaff reported that these datafields were problematic to complete correctly). Some plots were only partially measured (i.e. an incomplete species list was made only). The reasons for this included similar reasons to plots not being measured at all, e.g. the terrain was too steep, wasps were present, or access from landowners was denied (many plots were located on freehold land). Once the above plots had been excluded, 21 plots remained within the dataset where an observed land-cover type had not been recorded. Recce vegetation description data from these plots indicated that all 21 were comprised of woody or forest vegetation, so these plots were retained within the dataset. The criteria we imposed resulted in 1177 plots selected (from a total of 1372) from the NZCMS Indigenous Forest and Shrubland survey data. We used our list of qualifying plots (described above) to select 851 plots from the MfE/Interpine vesion of the NZCMS Recce data, with the remaining 326 plots selected from the NVS version of NZCMS year 1–2 data.

3.1.3 NVS data

Data from the SWMEP survey, which is archived in the NVS Databank, was obtained following standard NVS protocols (see http://nvs.landcareresearch.co.nz/). This dataset is listed as 'Level 1' data, meaning it could be accessed without obtaining special permissions.

3.2 PREPARATION OF DATA FOR CLASSIFICATIONS

3.2.1 NZCMS data

Each NZCMS plot is a permanently marked plot, 20 × 20 m, on which the cover of all vascular species is recorded within height tiers as part of a reconnaissance (Recce) description, saplings are counted, and seedling frequency data are recorded on understorey subplots (Payton et al. 2004). The plot location and selected site data (e.g. altitude, slope) are also recorded. In forest vegetation, tree stems are tagged and their diameters measured (Payton et al. 2004). Moss, liverwort and lichen species that provided the majority of non-vascular plant cover on the plot are recorded. This includes both species growing on the ground and occurring as epiphytes.

To enable analysis of NZCMS data from both forest and shrubland plots, we use the NZCMS Recce data, since stem diameter data were not collected on NZCMS shrubland plots. The Recce vegetation description also provides the most complete record of the composition of the plot, as it includes rare or epiphytic species that may not be included in the stem diameter, sapling, or understorey data. In addition, for any future validation and extension of the classification, there is likely to be more historical Recce data available.

In NZCMS Recce data, species abundance is recorded in height tiers using a cover-abundance scale (Payton et al. 2004). Before data analysis, an overall importance value was generated for each species on each plot. The approach taken here follows that used in previous studies (e.g. Wiser et al. 2002). Each cover-class score within each tier was converted to the midpoint of the percent cover range represented by that cover class score. These values were then summed for each species on each plot to generate an overall index of cover across all tiers. Thus, each importance value reflected the difference in relative volume occupied by each species, as opposed to relative aerial cover.

3.2.2 SWMEP data

The SWMEP Recce descriptions were subjectively located along transect lines in South Westland forest, shrubland and wetlands. A total of 5024 Recce descriptions were completed. To obtain a representative sample of Recce descriptions from this survey, we wrote computer algorithms that selected plots closest to systematic grid points that we specified. To derive alternative selections of plots with different sampling intensities, we altered our specified grid spacings to select plots on averages of 1-mile, 2-mile and 4-mile grid spacing.

In SWMEP Recce data species abundance is recorded in height tiers using a cover-abundance scale (Allen 1992) as for NZCMS. An overall importance value was generated for each species on each plot following the same procedure used for the NZCMS Recce data (described above).

3.2.3 Synonyms and taxonomic standards

To account for the changing taxonomic treatment of some species through time, we identified occurrences of out-of-date species names in each dataset, and updated these based upon the NZ Plant Names database http://nzflora.landcareresearch.co.nz/. We also identified names in the data that represented variety and subspecies concepts. To obtain greater consistency between plots and surveys, we translated each of these into the *sensu lato* (broad sense) forms of the species name. For example for hangehange, *Geniostoma rupestre* var. *ligustrifolium* and *Geniostoma rupestre* var. *rupestre* are both denoted as *Geniostoma rupestre* (GENRUP) in the data. Our treatment of synonyms, subspecies and varieties resulted in 1597 vascular species names in the NZCMS dataset and 706 species in the SWMEP dataset

3.3 ANALYTICAL APPROACH FOR CLASSIFICATIONS

The present study comprises a number of separate analyses, as outlined in the objectives. We followed the same general analytical approach in each of the analyses we undertook.

3.3.1 Selection of clustering algorithms

Any quantitatively based vegetation classification requires the use of some sort of clustering algorithm. Many different algorithms exist, but most software packages only implement one or two. To overcome this limitation we used the JUICE analysis program (Tichý 2002; http://www.sci.muni.cz/botany/juice/). Use of the 'OPTIMCLASS' routine in the JUICE program allowed us to simultaneously compare and evaluate clusters defined using different classification algorithms (Tichý et al in press). This ensured that clustering results were optimised for each dataset we analysed. We were interested in optimisation because a huge variety of clustering methods produce 'reasonable' results. Subjective selection of the clustering method is usually based on the empirical experience of the analyst. Using OPTIMCLASS, we compared 28 classification approaches, which employed one of four methods of hierarchical classification: (1) beta-flexible clustering, (2) Ward's minimum variance method, (3) unweighted pair-group method of averaging (UPGMA) and (4) two-way indicator species analysis (TWINSPAN), modified so that it can produce uneven numbers of clusters. For the first three methods, resemblance measures used were Euclidean, Manhattan and Sorenson's (Bray-Curtis) distance, and species importance values were untransformed, log-transformed, and ordinally transformed (to approximate the original Recce cover classes), resulting in nine analyses for each method.

Most optimisation algorithms available identify optimal classification methods mathematically, without consideration of the ecological interpretation of the clusters conceived. The OPTIMCLASS routine takes a different approach, however – by attempting to maximise the ecological interpretability of the classification, as indicated by the number of diagnostic species identified. We used two approaches in OPTIMCLASS to detect the optimal partition and optimal number of classes for our data. The first measures the quality of the partition by the total count of diagnostic species (see section 3.3.2) across all clusters of that partition. With this method, a partition is evaluated as 'good' if most clusters have a high or moderate number of diagnostic species. The second method measures the quality of each partition by the count of clusters that contain at least a specified number (*k*) of diagnostic species. With this method, a partition is evaluated as good if more than *k* clusters have a high or moderate number of diagnostic species.

3.3.2 Determination of diagnostic species for vegetation classes

Diagnostic species are those species having a distinct concentration, occurrence or abundance within a particular vegetation class (other terms such as 'differential species' or 'indicator species' are often used with similar meanings). In vegetation classifications based on compositional data, determination of diagnostic species is of critical importance, as they may better allow an observed area of vegetation to be placed within a defined vegetation class.

Associated with the concept of diagnostic species is the concept of the 'fidelity' of a species. This refers to a statistical measure of a species occurrence or abundance within a particular vegetation class compared with its occurrence in other vegetation classes. Species with a high frequency within a vegetation class, but which also occur elsewhere, are of less use in defining vegetation classes, and have a lower measure of fidelity. Conversely, some species, particularly rare species, may be highly diagnostic because they are absent elsewhere, yet they may not be constant within the vegetation class, and hence have low fidelity. Similarly, a species may be constant, yet have low fidelity and not be diagnostic, if it is common both within and outside a vegetation class.

In the present study, we brought these two concepts together by determining diagnostic species using Fisher's exact test for the right-tailed hypothesis (Sokal & Rohlf 1995; Chytry et al. 2002). For each species and each cluster of each partition, this test compares the observed number of species occurrences within the cluster with the total number of occurrences in the entire dataset. Then it compares the observed pattern with the pattern of random distribution of the species across the dataset and calculates the probability *P* of the observed pattern under the null expectation of random distribution of species across sites. Here *P* is not used for hypothesis testing but rather as a measure of the positive fidelity of the species to the cluster. The lower the *P* value, the higher the species fidelity. Diagnostic species are determined by a subjective choice of the threshold *P* value. We based this choice on the nature of the peaks shown when graphing the results with different partitions following Tichý et al. (in press).

Once the NZCMS plots were classified, we followed the IVC naming conventions outlined in section 1.2 to devise names for each class. Classes with an overall mean canopy height of >8 m were categorised as forest, and classes with overall mean canopy height < 8 m variously categorised as shrubland or scrub, following Atkinson (1962). This results in a generous assignment of classes to shrubland in comparison with other commonly used cutoff heights (e.g. LCDB uses 6 m). Environmental characteristics of the plots in each group were examined (e.g. altitude, slope). When clear and obvious patterns emerged (e.g. classes were confined to a distinctive altitudinal range) this was incorporated into the vegetation class name (e.g. Class 5. *Schoenus–Dracophyllum* subalpine shrubland).

3.3.3 Interpretation of vegetation classes

We used a range of information sources to interpret the vegetation classes. We produced a tree diagram to illustrate the clustering pattern and a synoptic table to summarise species distributions and abundance across the classes. We graphed means and standard errors of a range of environmental parameters both collected with the plot data (altitude, slope, mesotopographic index) and derived from GIS layers (mean annual temperature, minimum temperature, October vapour pressure deficit) and features of the vegetation (mean canopy height). We mapped the geographic distribution of the vegetation classes (ArcMap 9.2). We also calculated basic statistics for each class (e.g. area, average species richness and richness of exotics). We then described each vegetation class.

If the distribution of forest and shrubland classes is tightly controlled by environmental parameters that are already mapped across New Zealand (e.g. climate, geological stratigraphy), then mapping their distribution could most easily be accomplished by mapping their environments. To address this issue we used two approaches. First, we tested the correlation between unconstrained and environmentally constrained (by mappable environmental parameters that underpin LENZ and spatial parameters of northing and easting) ordination scores on the NZCMS plots using DCA and CCA. This tested whether there is variation in composition that was poorly explained by environmental variables. Comparisons of ordination eigenvalues (a surrogate for 'variation explained') were also made. We conducted MANOVA to test the relationships between our classification and the mappable environmental parameters.

3.4 COMPARISON OF CLASSIFICATION RESULTS WITH PREVIOUS CLASSIFICATIONS

We determined the previous classifications of each of the NZCMS plots by overlaying the grid coordinates of the plots on spatial layers of the Vegetative Cover Map, LCDB2 forest class and shrubland classes, Forest Class Maps, ECOSAT woody vegetation layer and New Zealand potential forest cover.

To improve our ability to compare our species-based classification with previous ones for forests and shrublands, we used the cover and constancy (% frequency within the class) of beeches, podocarps and broadleaved tree species within our classes to assign them to broader species-group-based categories. These were shrublands, beech forest, beech–broadleaved forest, beech–broadleaved–podocarp forest, broadleaved forest, and broadleaved–podocarp forest. We found we maximised matches with previous classifications by using the following criteria in our assignment. 'Beech' was included in the name if the sum cover of all beech species averaged >25% and constancy >65%. 'Broadleaved' was included in the name if the sum cover of all broadleaved species averaged >65% and constancy = 100%. A higher threshold was used for 'broadleaved' than beech because there are so many more species included in the calculation of 'broadleaved' cover and constancy. We were generous in our inclusion of 'podocarp' in the name, to correspond to inclusion of scattered, emergent podocarps in names used in previous classifications. 'Podocarp' was included in the name if the sum cover of all podocarp species averaged >5% and constancy >65%.

We did a cross-tabulation between our forest and shrubland classification and against each of the previous classifications at three levels of resolution: forest v. shrubland; broad species-groups, and forest and shrubland classes.

3.5 COMPARISON OF CLASSIFICATION RESULTS WITH CLASSIFICATIONS INCLUDING NON-VASCULAR SPECIES AND WOODY SPECIES ONLY

We applied the clustering algorithm and distance measure (Flexible Beta with Sorenson's Distance) and importance values (Recce cover classes) that produced the optimal partition for the vascular-species-based classification to classifications based on (a) both vascular and non-vascular species and (b) woody species only. We used OPTIMCLUS to determine the optimal number of clusters to recognise.

3.6 EFFECT OF SAMPLING INTENSITY ON CLASSIFICATION RESULTS

The sampling density of the NZCMS (plots on an 8-km grid) means that there is one plot per 6400 ha. Any forest class that occupies less than 6400 ha nationally will, on average, not contain a plot. Also, as only 0.04 ha (a 20 × 20-m plot) is sampled per 6400 ha, this will represent only a small subset of the compositional variation present within the 6400 ha. We used previous data collected at a much finer scale to explore the implications of the NZCMS plots sampling density more directly

We compared classifications resulting from a selection of plots from the SWMEP dataset on 1-mile, 2-mile and 4-mile grids respectively (approximating 2-km, 4-km and 8-km grids respectively). We summarised the classification according to the 4-mile grid (equivalent in density to the NZCMS grid) by naming each vegetation class, identifying diagnostic species, and constructing a tree diagram, as described above. We did a cross-tabulation of the vegetation class according to the 4-mile-grid classification versus the 1-mile and 2-mile classifications separately. We then compared these classifications in terms of similarity of dominant and indicator species, respectively.

4. Results

4.1 CLASSIFICATIONS OF NZCMS FOREST AND SHRUBLAND DATA

4.1.1 NZCMS classification including only vascular species data

The OPTIMCLASS routine identified the beta-flexible clustering method (computed using PC-ORD) using a Manhattan (Sorenson's) distance measure and ordinally transformed cover scores (approximated Recce class values) as importance values, as the clustering method that maximised the number of diagnostic species occurrences in the classification (Fig. 1). A Fisher's exact test *P*-value of 12 gave the most interpretable optimisation graphs (closest to unimodal; Fig. 1a–f). We recognised 24 classes, each comprising 19–105 plots from the total of 1177 NZCMS plots analysed. The rationale for this was that recognising 24 classes provided the more diagnostic species (327) than other numbers of classes and resulted in 18 classes having greater than four diagnostic species (Fig. 1c & d).

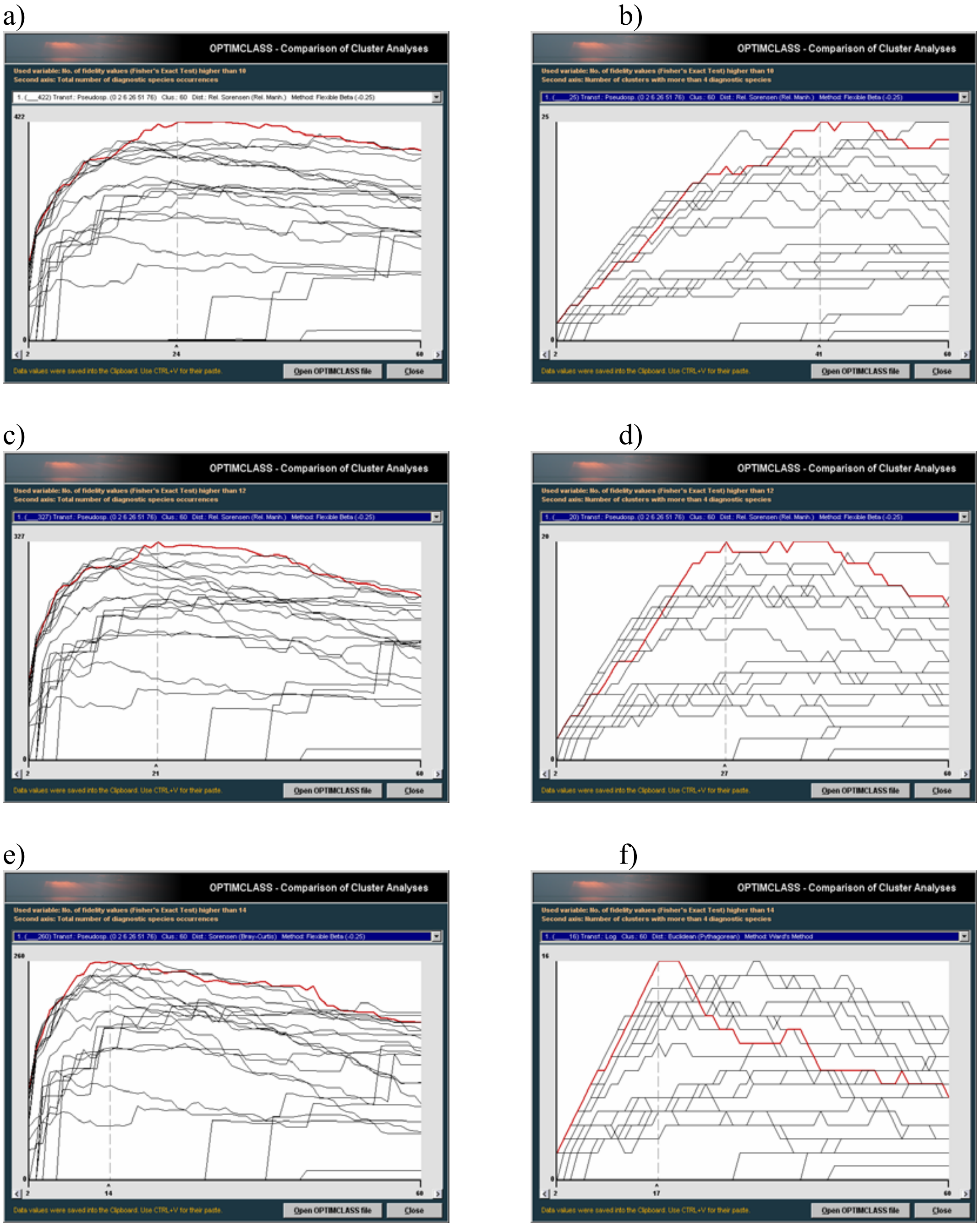


Figure 1. OPTIMCLASS analysis of 28 different partitions of the 1177 CMS plots, based on: diagnostic species having fidelity values as determined by *P*-values of Fisher's exact test (a) & (b) greater than 10, (c) & (d) greater than 12, and (e) and (f) greater than 14. The horizontal axis represents partitions with 2, 3, 4,…60 clusters. The vertical axis for (a), (c) and (e) is the number of diagnostic species occurring over all the clusters in the given partition. The vertical axis for (b), (d) and (f) is the number of clusters with more than four diagnostic species. Each line represents the results for individual partitions; the red line shows the partition that is optimal at the top of the curve.

The relationships among the classes are shown in the cluster diagram in Fig 2. Classes number sequentially, from top to bottom, based on their relative location in the cluster diagram.

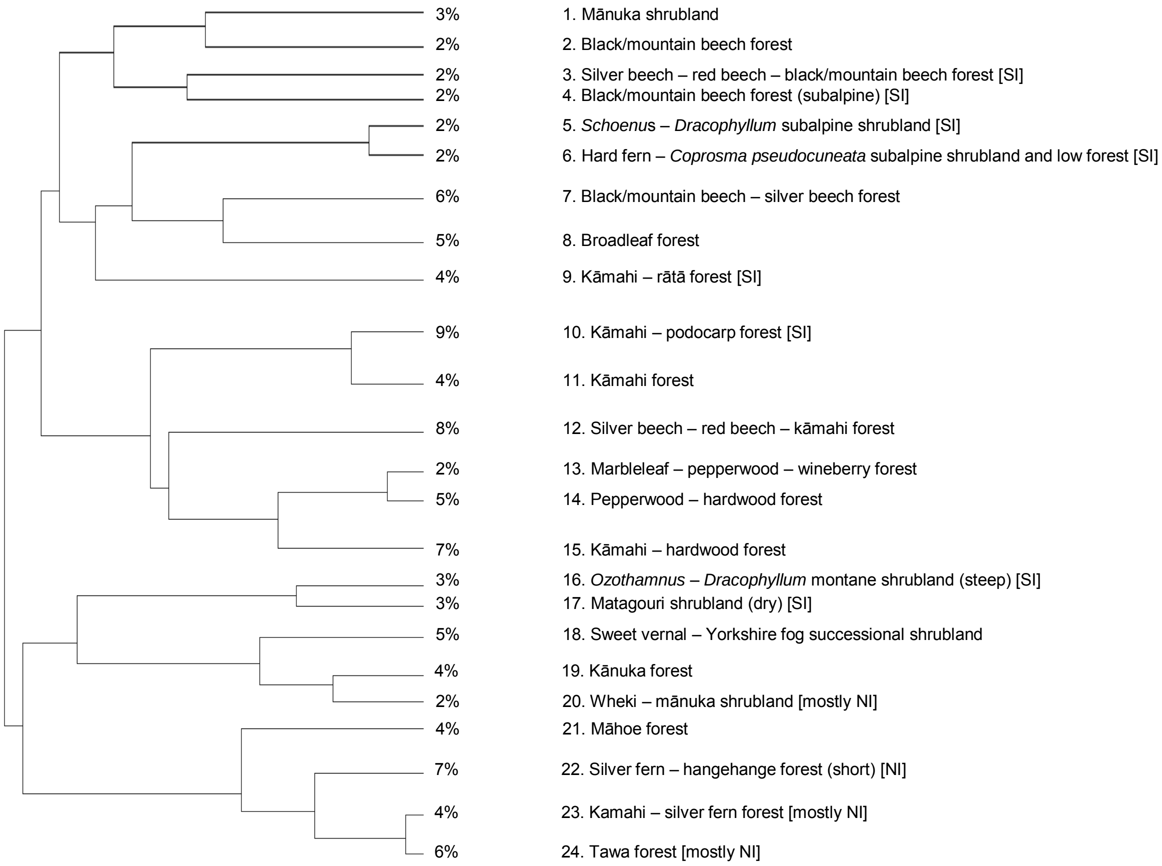


Figure 2. Tree diagram for the classification of 1177 CMS plots into 24 classes, showing the percentage of plots within each vegetation class. Classes are labelled using the International Vegetation Classification system (reflecting dominance in terms of cover and constancy). The classification is based on flexible beta clustering with Sorenson's distance measure and an ordinal transformation of cover values as importance values. NI = North Island, SI = South Island. A more fully annotated diagram with Linnean names and indicator species is given in Appendix 1.

The names of the classes using both Atkinson system and the International Vegetation Classification system are provided in Table 3. We found the IVC names to make more intuitive sense. As the Atkinson system was designed for naming mapped polygons over limited areas (e.g. Tongariro National Park), it relies more heavily on cover than on constancy. The Atkinson system resulted in species being included in the name that frequently were absent from individual plots in that community. Our criteria for selecting important dominant and diagnostic species under the IVC was to rank the species in terms of their relative constancy and relative cover and focus on the top four ranked species. A synoptic table summarises species distributions and abundance across the 24 classes (Appendix 2). All species with significant (Fisher's exact test with $P < 0.01$) fidelity values of >0.5 and constancy (frequency within a vegetation class) of >50% for any one or more classes was included (totalling 131 species). For those classes in which none of the species present met these criteria, we selected those species that ranked highest in terms of their fidelity value and constancy, taking preference for those species that had significant fidelity values in the fewest groups.

Figure 3. Distribution of forest v. shrubland vegetation classes.

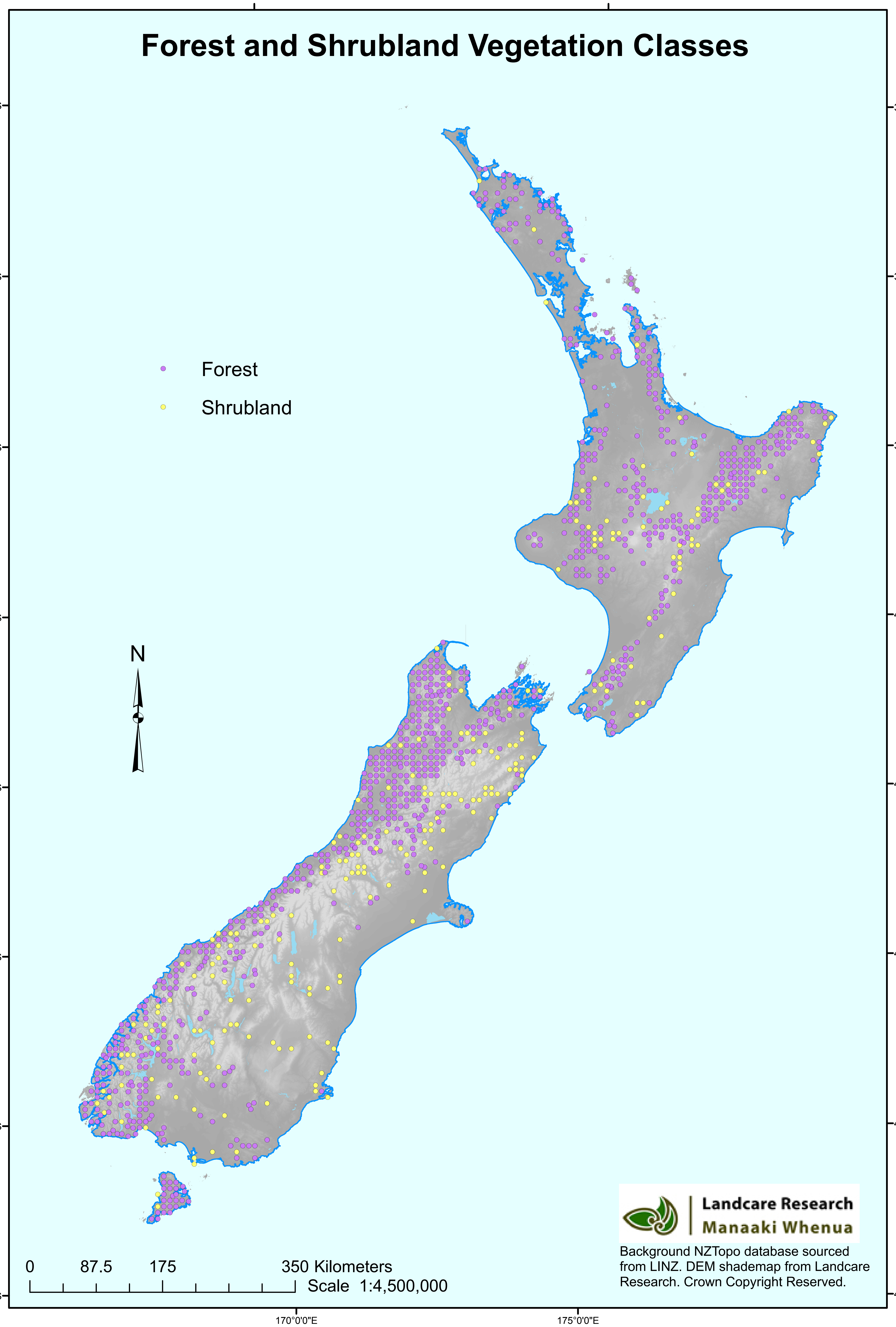


Figure 4. Forest species group categories. Each vegetation class was assigned to a broad species group category, based on frequency and cover of beeches, podocaps and broadleaved species.

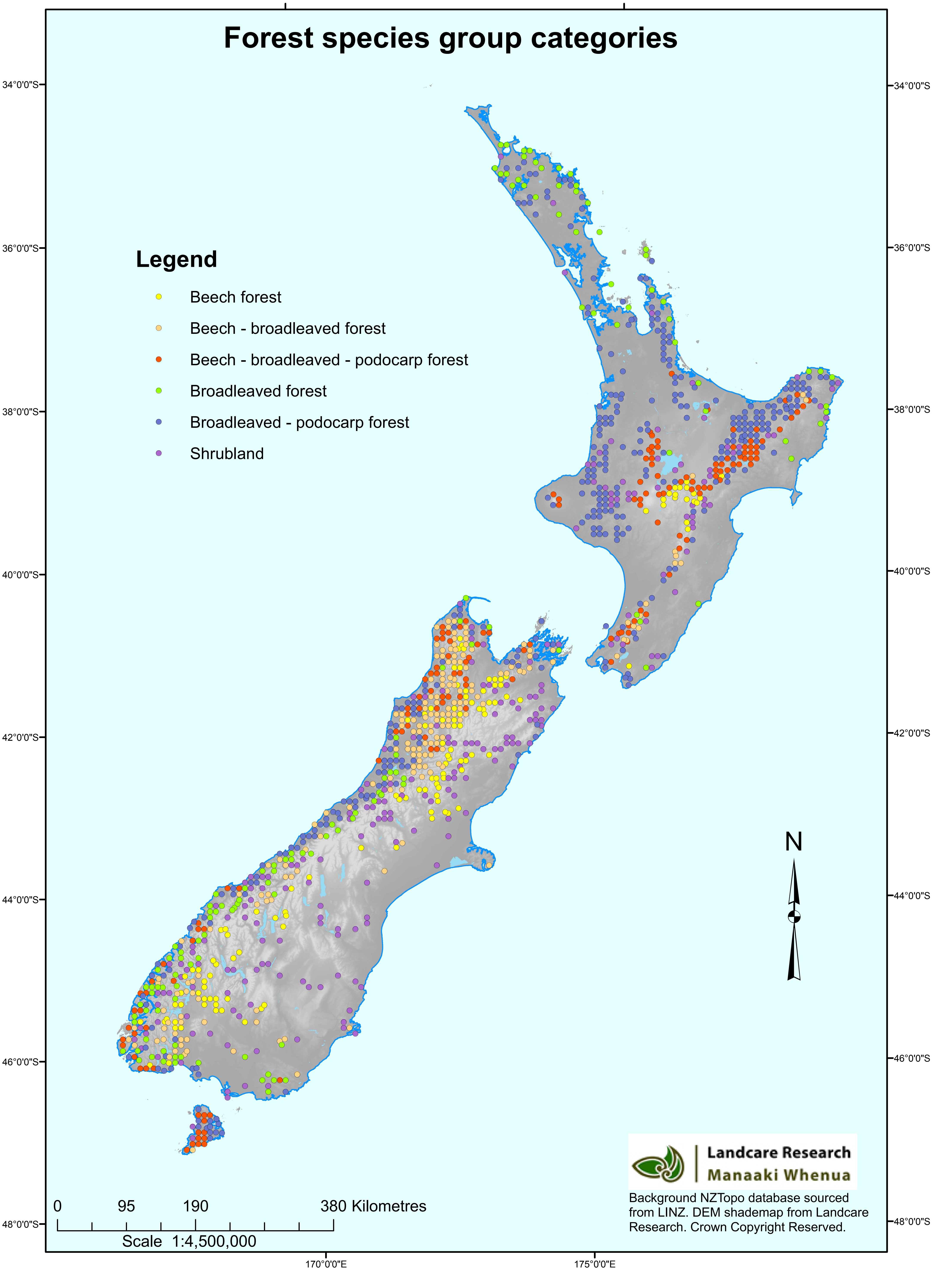


Figure 5. North Island shrubland vegetation classes.

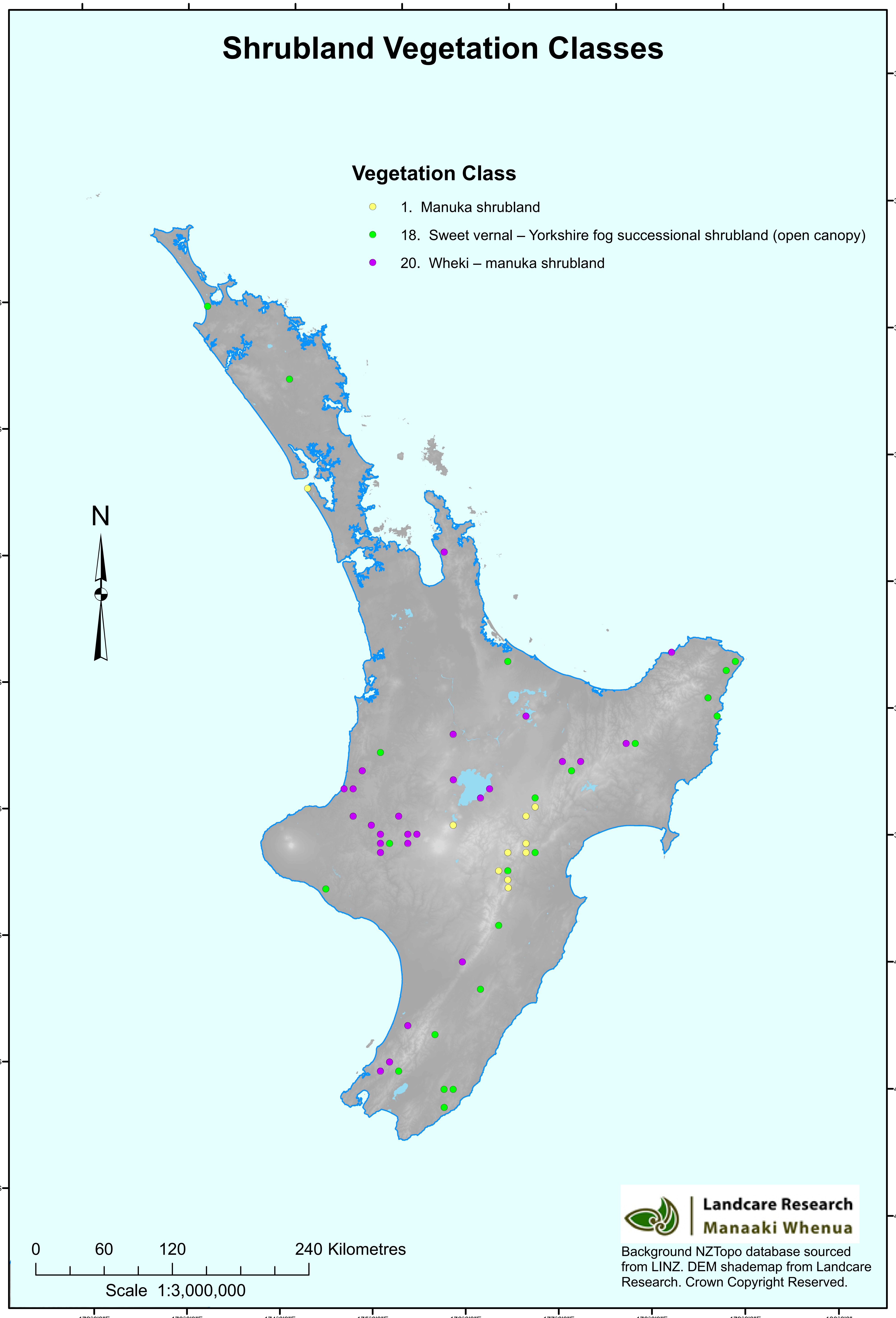


Figure 6. South Island shrubland vegetation classes.

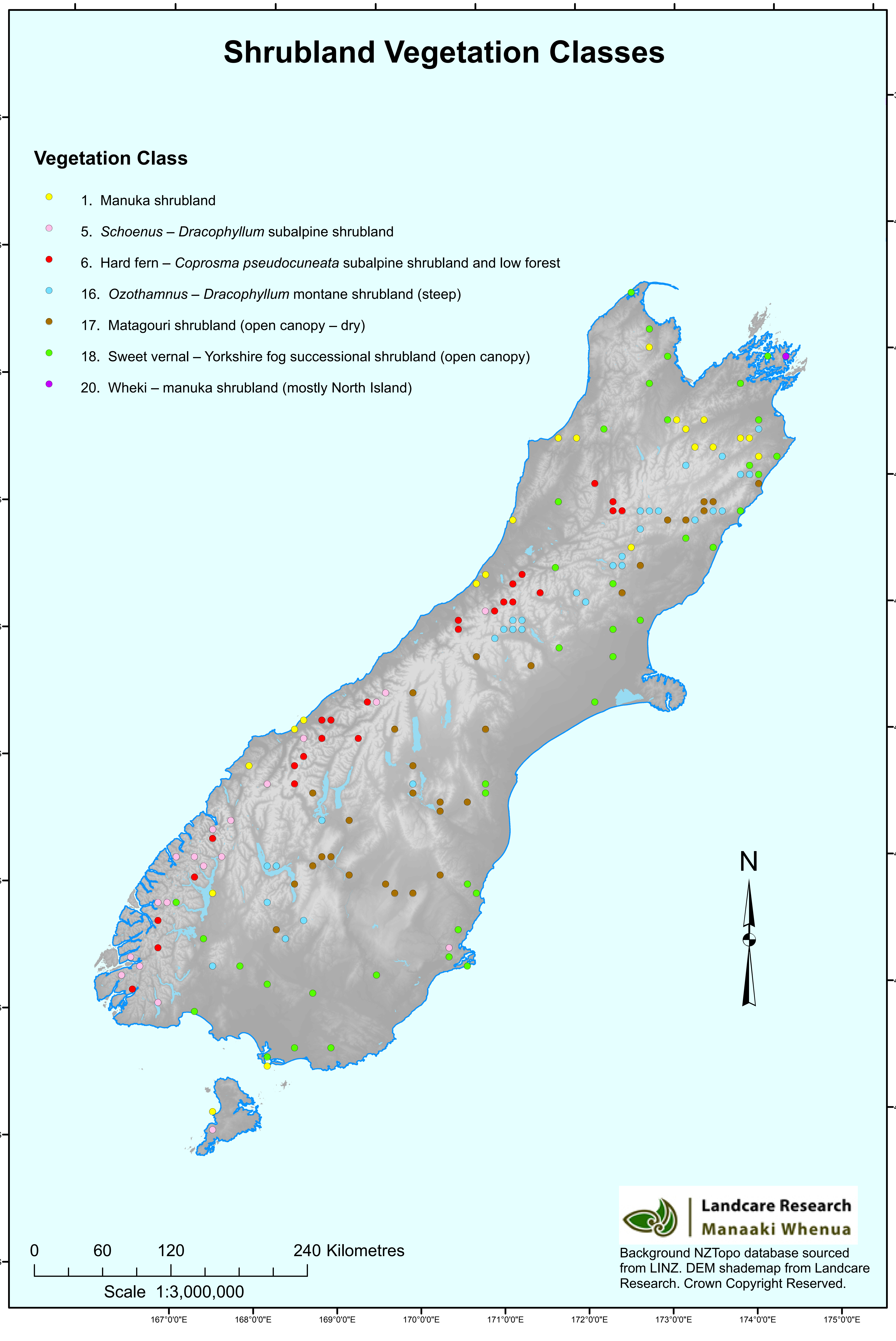


Figure 7. North Island forest vegetation classes.

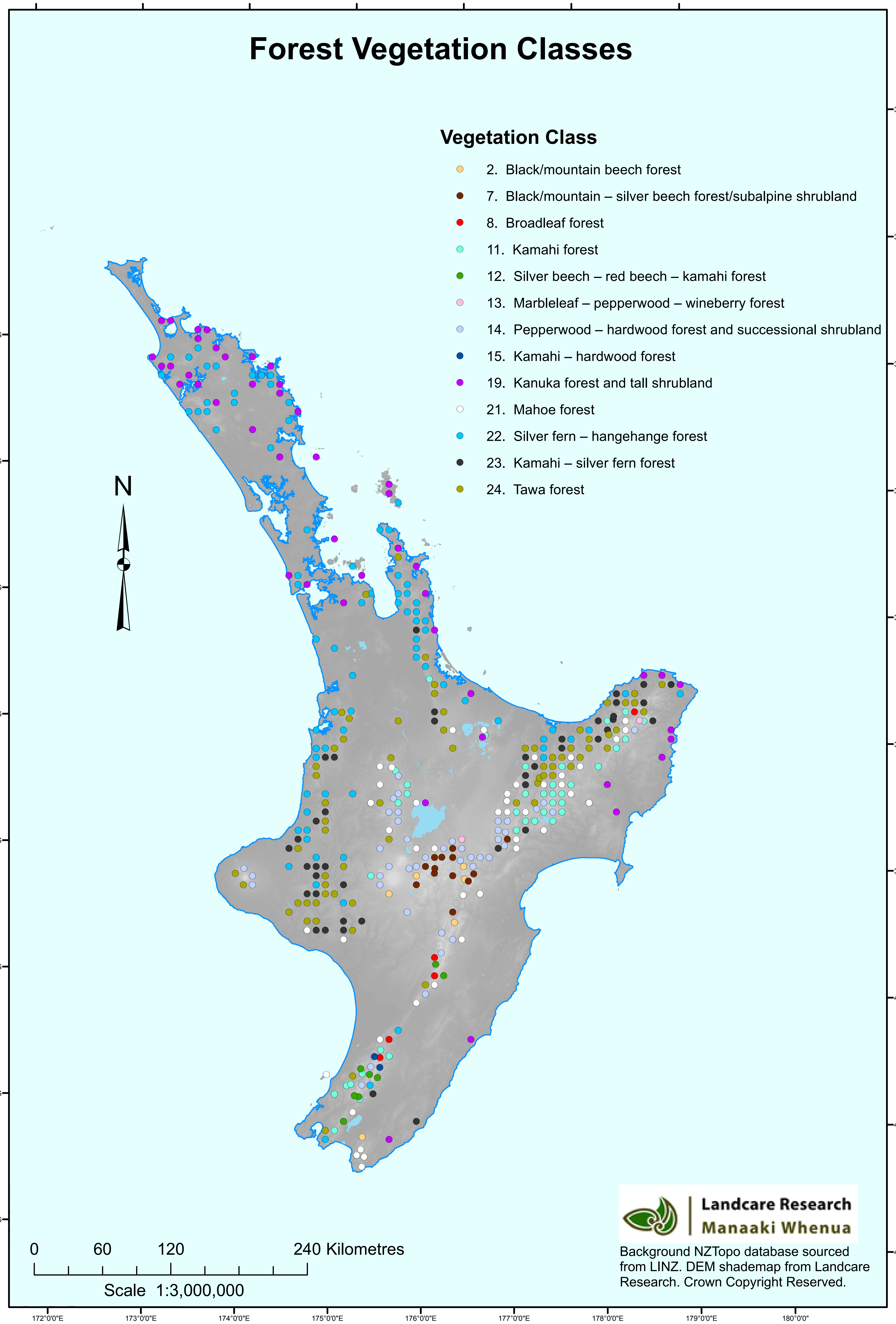


Figure 8. South Island forest vegetation classes

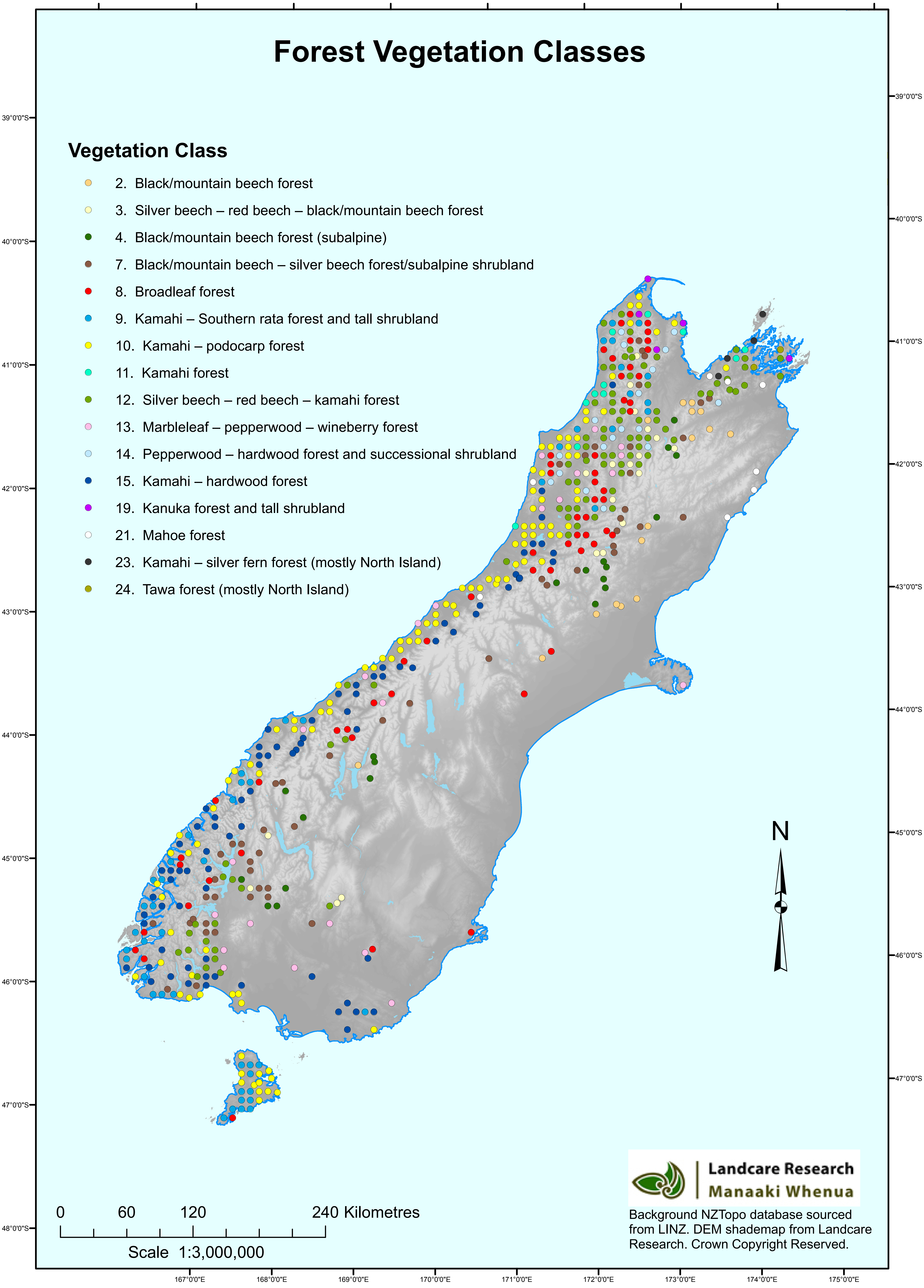


TABLE 3. FOREST AND SHRUBLAND CLASSES. FOR THE INTERNATIONAL NAMING SYSTEM, PARENTHESES ARE USED TO DENOTE IMPORTANT DIAGNOSTIC SPECIES THAT MAY HAVE RELATIVELY LOW *CONSTANCY* WITHIN THE VEGETATION CLASS (USED HERE WHERE CONSTANCY < 60%). IN THE ATKINSON NAMING SYSTEM, PARENTHESES AND SQUARE BRACKETS DENOTE VARIOUS *AVERAGE COVER* VALUES FOR THE SPECIES WITHIN THE VEGETATION CLASS (SEE SECTION 1.2 FOR DETAILS).

Cover type/Species group	Class number + ShortName (based on International name)	International name	Atkinson name
Shrubland	1. Mānuka shrubland	*Leptospermum scoparium* (*Leptecophylla juniperina)*	*Leptospermum scoparium [Leptecophylla juniperina]*
	5. *Schoenus–Dracophyllum* subalpine shrubland [SI]	*Schoenus pauciflorus–Dracophyllum uniflorum* (*D. longifolium*) */ Hymenophyllum multifidum*	*(Schoenus pauciflorus) [Olearia colensoi–Dracophyllum uniflorum]*
	6. Hard fern–*Coprosma pseudocuneata* subalpine shrubland and low forest [SI]	*Polystichum vestitum–Coprosma pseudocuneata–Olearia ilicifolia*	*Polystichum vestitum [Coprosma pseudocuneata–Olearia ilicifolia–Phormium cookianum]*
	16. *Ozothamnus–Dracophyllum* montane shrubland (steep) [SI]	*Ozothamnus leptophylla* (*Dracophyllum uniflorum*)	*Dracophyllum uniflorum (Ozothamnus leptophylla–Gaultheria* spp.*)*
	17. Matagouri shrubland (open canopy–dry) [SI]	*Discaria toumatou–Anthoxanthum odoratum–Coprosma propinqua–Dactylis glomerata*	*Discaria toumatou (Coprosma propinqua) [Rosa rubiginosa]*
	18. Sweet vernal–Yorkshire fog successional shrubland (open canopy)	*Anthoxanthum odoratum–Holcus lanatus* (*Pteridium esculentum–Ulex europaeus*)	*Anthoxanthum odoratum–Holcus lanatus (with successional hardwoods)*
	20. Wheki–mānuka shrubland [mostly NI]	*Blechnum novae-zelandiae–Dicksonia squarrosa–Leptospermum scoparium / Lotus pedunculatus–Holcus lanatus*	*Leptospermum scoparium (Pteridium esculentum–Pseudopanax arboreus–Dicksonia squarrosa) [Weinmannia racemosa]*
Beech forest	2. Black/mountain beech forest	*Nothofagus solandri–Coprosma microcarpa–Cyathea juniperina–Leucopogon fasciculatus*	*Nothofagus solandri–Nothofagus fusca (Leucopogon fasciculatus) [Coprosma microcarpa]*
	3. Silver beech–red beech–black/mountain beech forest [SI]	*Nothofagus menziesii–Nothofagus fusca–Nothofagus solandri*	*Nothofagus menziesii–Nothofagus fusca–Nothofagus solandri*
	4. Black/mountain beech forest (subalpine) [SI]	*Nothofagus solandri* (*Peraxilla tetrapetala–Coprosma pseudocuneata*)	*Nothofagus solandri*

	7. Black/mountain beech–silver beech forest/subalpine shrubland	*Nothofagus solandri– Nothofagus menziesii–Coprosma pseudocuneata / Hymenophyllum multifidum*	*Nothofagus solandri–Nothofagus menziesii [Coprosma pseudocuneata]*
Beech–broad-leaved forest	8. Broadleaf forest	*Griselinia littoralis–Nothofagus menziesii–Coprosma pseudocuneata*	*Nothofagus menziesii (Griselinia littoralis) [Coprosma pseudocuneata]*
	12. Silver beech–red beech–kāmahi forest	*Blechnum discolor–Nothofagus menziesii–Weinmannia racemosa–Nothofagus fusca*	*Nothofagus fusca–Nothofagus menziesii–Weinmannia racemosa (Pseudowintera colorata–Griselinia littoralis)*
	13. Marbleleaf–pepperwood–wineberry forest	*Carpodetus serratus–Pseudowintera colorata–Aristotelia serrata / Blechnum discolor*	*Nothofagus menziesii [Pseudowintera colorata–Aristotelia serrata–Fuchsia excorticata]*
Beech–broadleaved–podocarp forest	9. Kāmahi–Southern rātā forest and tall shrubland	*Weinmannia racemosa–Metrosideros umbellata–Nothofagus solandri / Gahnia procera*	*(Lepidothamnus intermedius–Nothofagus solandri–Weinmannia racemosa–Metrosideros umbellata)*
	11. Kāmahi forest	*Weinmannia racemosa–Cyathea smithii–Prumnopitys ferruginea / Blechnum discolor*	*Weinmannia racemosa (Ixerba brexioides–Cyathea smithii) [Prumnopitys ferruginea]*
	14. Pepperwood–hardwood forest and successional shrubland	*Pseudowintera colorata–Griselinia littoralis–Nothofagus fusca / Microlaena avenacea*	*Pseudowintera colorata–Nothofagus menziesii–Nothofagus fusca [Neomyrtus pedunculata–Griselinia littoralis]*
Broadleaved forest	15. Kāmahi–hardwood forest	*Weinmannia racemosa–Griselinia littoralis–Pseudowintera colorata / Blechnum discolor*	*Nothofagus menziesii–Weinmannia racemosa (Cyathea smithii–Pseudowintera colorata–Griselinia littoralis)*
	19. Kānuka forest and tall shrubland	*Kunzea ericoides–Coprosma rhamnoides–Cyathea dealbata–Leucopogon fasciculatus–Geniostoma rupestre*	*Kunzea ericoides (Leptospermum scoparium) [Cyathea dealbata–Coprosma rhamnoides]*
Broadleaved–podocarp forest	10. Kāmahi–podocarp forest [SI]	*Weinmannia racemosa–Prumnopitys ferruginea–Dacrydium cupressinum / Blechnum discolor*	*Weinmannia racemosa (Dacrydium cupressinum) [Prumnopitys ferruginea]*
	21. Māhoe forest	*Melicytus ramiflorus–Cyathea smithii–Dicksonia squarrosa–Carpodetus serratus*	*Beilschmiedia tawa–Melicytus ramiflorus [Dicksonia squarrosa–Cyathea smithii]*

Broadleaved–podocarp forest cont.	22. Silver fern–hangehange forest [NI]	*Cyathea dealbata–Geniostoma rupestre–Freycinetia baueriana–Ripogonum scandens*	*Cyathea dealbata (Freycinetia baueriana–Beilschmiedia tawa–Melicytus ramiflorus)*
	23. Kāmahi–silver fern forest [mostly NI]	*Weinmannia racemosa–Cyathea dealbata–Leucopogon fasciculatus–Knightia excelsa*	*(Weinmannia racemosa–Beilschmiedia tawa–Cyathea dealbata–Knightia excelsa)*
	24. Tawa forest [mostly NI]	*Beilschmiedia tawa–Ripogonum scandens–Weinmannia racemosa–Hedycarya arborea*	*Beilschmiedia tawa (Weinmannia racemosa–Cyathea* spp.*–Hedycarya arborea–Ripogonum scandens)*

The distribution of the classes designated as ‘forest’ or ‘shrubland’ is mapped in Fig. 3. The distribution of the forest species group categories are mapped in Fig. 4. The distribution of all forest and shrubland classes is mapped in Figs 5–8. Vegetation attributes of the 24 groups are summarised in Fig. 9 and their environmental characteristics in Fig. 10. Descriptions of each class include geographic distribution, areal extent (calculated as the proportion of the 1177 sampled plots in the class that represents the proportion of the 8.9 million hectares defined as forest or shrubland by LCDB1 that was sampled by the NZCMS), environmental characteristics, dominant and diagnostic species, how composition varies with environment, and characteristic non-vascular species.

a) Mean canopy height b) Species richness

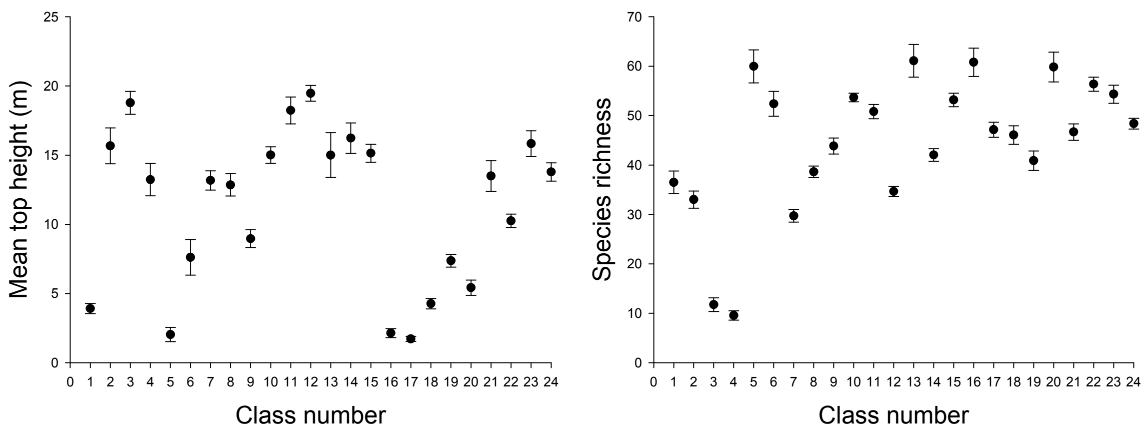
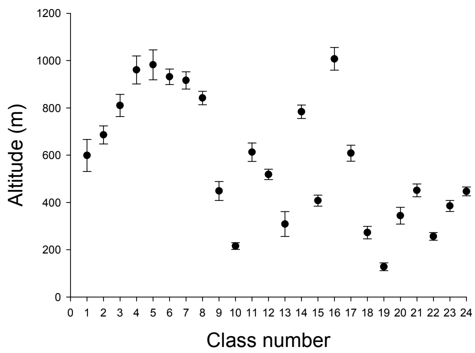
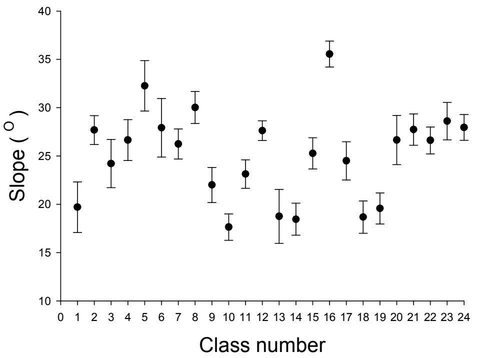


Figure 9. Differences (means and standard errors) in vegetation attributes of the 24 forest and shrubland classes.

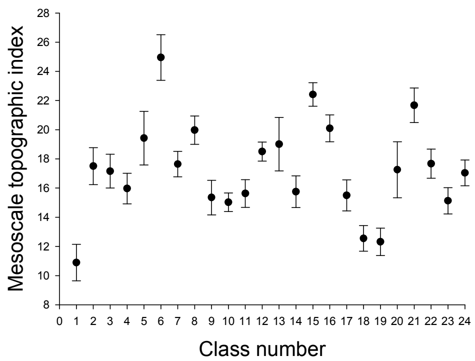
a) Altitude



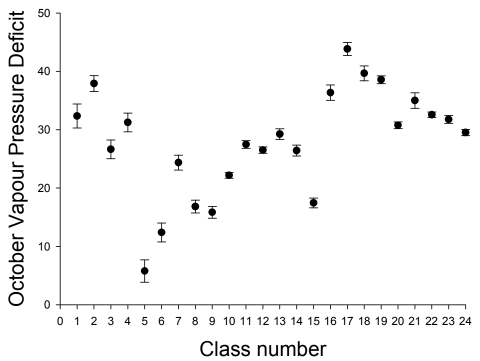
b) Slope



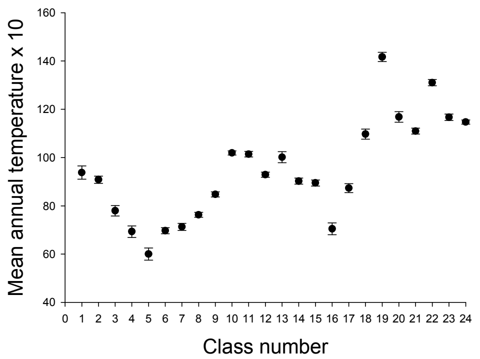
c) Mesoscale topographic index



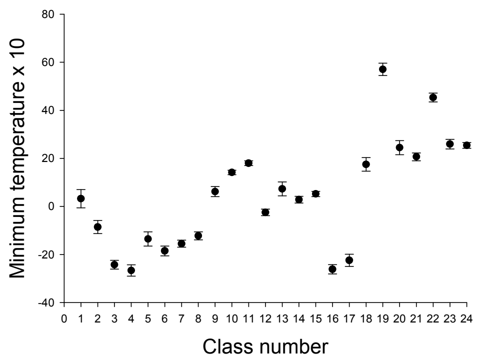
d) October vapour pressure deficit



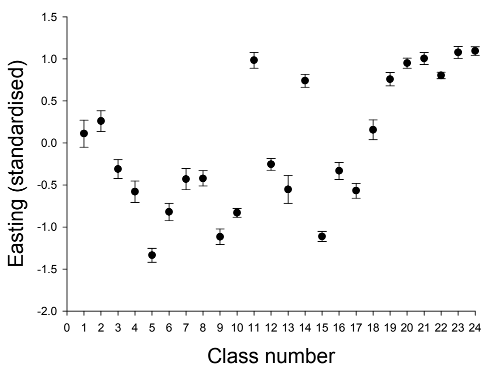
e) Mean annual temperature



f) Minimum temperature



g) Easting



h) Northing

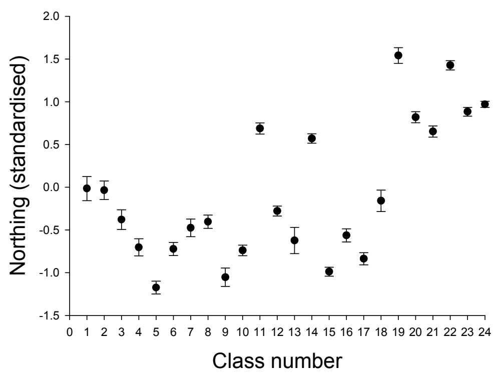


Figure 10. Environmental and site differences (means and standard errors) among the 24 forest and shrubland classes.

4.1.2 Vegetation class descriptions

SHRUBLANDS
Seven classes were designated as shrublands; one of these (class 6) grades into low forest.

Mānuka shrubland [class 1]
The Mānuka shrubland class is geographically widespread, occupying 235 000 ha of inland lowland and montane areas located primarily in the central North Island and in the north and west of the South Island (Figs 5 & 6). These shrublands occur from sea level to almost the highest altitudes sampled (i.e. >1250 m) across a wide range of slope and topographic positions, but in the central North Island are restricted to sites above 600 m (although one plot occurs by the coast near Auckland). The shrubland is dominated by mānuka (*Leptospermum scoparium*), with kānuka (*Kunzea ericoides*) and *Leptecophylla juniperina* as co-dominants in some locations. In addition to mānuka, diagnostic species in the canopy are broadleaf (*Griselinia littoralis*) and lancewood *(Pseudopanax crassifolius*) (<5 m tall), and in the subcanopy are *Leptecophylla juniperina, Leucopogon fasciculatus,* bracken (*Pteridium esculentum*) and *Dracophyllum subulatum* (in the central North Island only), and species of small-leaved *Coprosma (C. tayloriae, C. propinqua, C. microcarpa* and *C. rhamnoides*). In the ground layers diagnostic species include *Gahnia rigida* (mostly South Island), *Gaultheria antipoda*, *Gleichenia dicarpa* and *G. microphylla*, *Lycopodium fastigiatum*, *Uncinia uncinata*, and *Rytidosperma gracile*. This class varies in composition with altitude with kānuka, *Leptecophylla juniperina* and *Leucopogon fasciculatus* more important on higher altitude sites. Characteristic non-vascular species include *Ptychomnion aciculare*, *Cladia aggregata* and *Cladonia* spp.

Mean canopy height ranges from 1 to 10 m (Fig. 9a). There is usually less than 10% cover of trees and shrubs 5–10 m tall, but more than 50% cover of trees and shrubs 0.3–5 m tall. Species richness is moderate to high, with on average 36 species per plot (Fig. 9b), but compared with other vegetation classes, there are usually relatively few ferns, grasses, or exotic species present. One notable exotic species present was gorse, which occurred on 20% of the plots within the class. A relatively large number of measurable woody tree species are present (14), especially when compared with other shrubland vegetation classes.

One plot was grouped within this class (based on the occurrence of the herb *Nertera depressa*), but is very much an outlier in terms of composition, as it contains neither mānuka, kānuka, nor *Leptecophylla juniperina*. It was located on the western coast of Stewart Island. The main woody species is *Olearia oporina* and other species are herbs typically found in damp coastal turfs, such as *Nertera depressa, Selliera radicans,* and *Apium prostratum*. A finer resolution of analysis would almost certainly separate this as another shrubland class, albeit a very rare one as *Olearia oporina* was sampled only on the Fiordland coast, Stewart Island and the Chatham Islands. Seven species in the NZCMS dataset only occurred in this plot: *Apium prostratum, Blechnum banksii*, *Chenopodium glaucum*, *Crassula moschata*, *Myosotis rakiura*, *Olearia oporina* and *Poa astonii*.

***Schoenus–Dracophyllum* subalpine shrubland [class 5]**
The *Schoenus–Dracophyllum* montane shrubland class occupies 144 000 ha. It was sampled only on areas south of Arthur's Pass on the South Island and is found primarily in subalpine areas on or just east of (within 20 km) the Main Divide (Fig. 6). As such, locations have the lowest October vapour pressure deficits and lowest mean annual temperatures of any class (Fig. 10d–e). North of Mt Aspiring, these shrublands typically occur above 1000 m but

descend to 300 m on Stewart Island. Slopes are usually steep (>20°, Fig. 10b) and are on faces, or less commonly, ridges.

The shrubland is dominated by *Schoenus pauciflorus, Dracophyllum uniflorum* and *D. longifolium*, and very occasionally by silver beech <5 m tall. Other diagnostic species in the canopy are *Dracophyllum menziesii* (towards the south), *Chionochloa crassiuscula*, *Phormium cookianum* and *Astelia nervosa*. Diagnostic species in the ground layers are *Hymenophyllum multifidum*, *Anisotome haastii*, *Myrsine nummularia*, *Gentianella montana*, *Forstera sedifolia*, *Ourisia macrophylla*, *Coprosma perpusilla*, *Oreobolus impar* and *Carpha alpina*. Characteristic non-vascular species include *Dicranoloma robusta* and *Rhacocarpus purpurascens*.

Composition varies with altitude; forest species (e.g. broadleaf, black/mountain beech (*Nothfagus solandri*), silver beech (*Nothofagus menziesii*), *Myrsine divaricata*) are present on lower-altitude plots and subalpine and alpine species are present at higher altitudes (e.g. *Chionochloa pallens, Ourisia caespitosa, Ranunculus lyallii*).

Mean canopy height ranges from 0.4 to 8.5 m (Fig. 9a). There is usually less than 10% canopy cover 2–8.5 m tall, and more than 25% cover 0.3–2 m tall. Species richness is very high with on average 60 species per plot (Fig. 9b). Very few exotic species are present (range 0–3 per plot, mean = 1), the most frequent of which were *Plantago lanceolata* and *Agrostis capillaris*. Compared with other vegetation classes the proportion of woody species present is also small, comprising on average 19 species per plot, of which on average nine are measurable trees or shrubs (i.e. exceed 2.5 cm dbh).

Hard fern–*Coprosma pseudocuneata* subalpine shrubland & low forest [class 6]

The Hard fern–*Coprosma pseudocuneata* subalpine shrubland & low forest class occupies 189 000 ha and was sampled only on the South Island (south of Nelson Lakes National Park), occurring exclusively in subalpine areas on or directly east (within 40 km) of the Main Divide (Fig. 6). As such, locations typically have low October vapour pressure deficits and low annual and minimum temperatures (Fig. 10d–f). These systems can ascend as high as 1210 m north of Arthur's Pass and descend as low as 520 m in Fiordland. It typically occurs on slopes steeper than 10 degrees (Fig. 10b) on slope faces, but may also be found on terraces or in gullies.

The shrublands are dominated by hard fern (*Polystichum vestitum*), *Coprosma pseudocuneata*, *C. ciliata*, and *Olearia ilicifolia* with silver and black/mountain beech increasing in dominance in low forest. A diagnostic species in the canopy is *Hoheria glabrata*, in the subcanopy are *Hebe subalpina* and *Pseudopanax colensoi*, and in the ground layer are *Hypolepis millefolium*, *Coprosma depressa*, *Chionochloa conspicua*, *Senecio wairauensis*, *Blechnum penna-marina, Oxalis magellanica* and *Luzula picta*. Characteristic non-vascular species include *Dicranoloma robusta*, *Pyrrhobryum mnioides* and *Pseudocyphellaria homoeophylla.*

Composition changes with stand mean canopy height, which may represent a successional gradient. Tree and forest understorey species (e.g. silver beech and *Nertera villosa*) become more important in taller stands whereas shrub species (e.g. *Gaultheria crassa*, *Myrsine nummularia*, *Phormium cookianum*, *Dracophyllum longifolium*) become more important in shorter stands. Geographic gradients are of secondary importance with black/mountain beech and *Coprosma foetidissima* becoming more important in southern and western plots and

Artistotelia fruticosa and *Melicytus alpinus* becoming more important in northern and eastern plots.

Mean canopy height ranges from 1 to 20 m, but is usually less than 12 m (Fig. 9a). There is usually more than 20% cover of trees 5–20 m tall, and more than 50% cover of trees and shrubs 0.3–5 m tall. Species richness is high with on average 52 species per plot (Fig. 9b), 14 of which are measurable trees. Few exotic species are present (range 0–8 per plot, mean = 1), the most frequent of which are *Mycelis muralis* and *Hieracium lepidulum*.

Ozothamnus–Dracophyllum shrubland [class 16]

The *Ozothamnus–Dracophyllum* shrubland class occupies 235 000 ha and was sampled only on the South Island where it is found in montane areas east of the Main Divide (Fig. 6). Sites are cool but have high October vapour pressure deficits (Fig. 10d). These shrublands occur on sites occurring from 500 to 1400 m, typically on steep slopes (<30^{o}, Fig. 10b) on faces.

The shrubland is dominated by *Ozothamnus leptophyllus*, variably accompanied by *Dracophyllum uniflorum*, *Dracophyllum longifolium*, mānuka, kānuka and *Chionochloa pallens*. Diagnostic species in the subcanopy are *Aciphylla aurea* and *Gaultheria crassa*, and in the ground layer are *Festuca novae-zelandiae*, *Celmisia spectabilis*, *Wahlenbergia albomarginata*, *Brachyglottis bellidioides*, *Poa colensoi*, *Anaphalioides bellidioides*, *Blechnum penna-marina* and *Gaultheria depressa*. Characteristic non-vascular species include *Cladonia* spp., *Cladia aggregata* and *Hypnum cupressiforme*. This class varies in composition with altitude with species such as *Dracophyllum unifolium, Olearia nummularifolia, Chionochloa flavescens* and *Podocarpus nivalis* more important at higher altitudes, and species such as mānuka, kānuka, matagouri (*Discaria toumatou*), *Muehlenbeckia complexa, Galium aparine* and *Hieracium caespitosum* more important at lower altitudes.

Mean canopy height ranges from 0.3 to 7 m (Fig. 9a). There is usually less than 10% cover of shrubs 2–7 m tall and more than 25% cover of shrubs 0.3–2 m tall. Species richness is high with on average 61 species per plot (Fig. 9b). Grass species comprise a relatively high proportion of the total species present. A relatively high proportion of species (on average 11 per plot) are also exotic, the most frequent being the broadleaved species *Hieracium pilosella*, *H. lepidulum, Hypochoeris radicata*, *Cerastium fontanum* and *Crepis capillaris* and the grasses sweet vernal (*Anthoxanthum odoratum*), browntop (*Agrostis capillaris*) and Yorkshire fog (*Holcus lanatus*). Together these species comprise, on average, 10% cover in the ground tier. Few woody species are present, especially measurable trees that comprise on average just eight species per plot.

Matagouri shrubland [class 17]

The Matagouri shrubland class occupies 227 000 ha and was sampled only on the South Island where it is found in cool, dry montane areas east of the Main Divide, from southern Marlborough to central Otago (Fig. 6). Mean annual temperatures on these sites are relatively low (mean = 9^{o}) and October vapour deficits high (Fig. 10d). These shrublands are found on sites ranging from flat terraces to steep faces occurring from 185 to 900 m in altitude.

The shrubland is dominated by matagouri, sweet vernal, *Coprosma propinqua* and cocksfoot (*Dactylis glomeratus*). In addition to matagouri and *Coprosma propinqua*, diagnostic species in the canopy are *Melicytus alpinus* and *Rosa rubiginosa*, and in the subcanopy and ground layers are *Poa cita*, *Verbascum thapsus*, *Muehlenbeckia complexa*, *Arenaria serpyllifolia*, *Geranium sessiliflorum*, *Hieracium pilosella*, *Cerastium fontanum, Rumex acetosella* and the exotic grasses browntop and Yorkshire fog. Characteristic non-vascular species include *Hypnum cupressiforme* and *Teloschistes velifer*. This class varies in composition with altitude with species such as *Festuca novae-zelandiae, Ozothamnus leptophyllus* and *Poa colensoi* more important at higher altitudes, and species such as *Stellaria media* and *Trifolium arvense* more important at lower altitudes.

Mean canopy height ranges from 0.4 to 6 m (Fig. 9a). There is usually less than 10% cover of trees or shrubs over 2 m tall but more than 25% cover of shrubs 0.3–2 m tall. Species richness is moderate with on average 47 species per plot (Fig. 9b). This class is especially high in exotic species with on average 24 species per plot (half the total species richness). In addition to those already noted above *Crepis capillaris* and *Trifolium repens* are also especially common (frequency >75%). Grasses comprise a high proportion of the species present, on average 11 species per plot. Few woody species are present, especially measurable tree species, which comprise on average just four species per plot (<10% the total species richness).

Sweet vernal–Yorkshire fog successional shrubland [class 18]
The Sweet vernal–Yorkshire fog successional shrubland class occupies 469 000 ha and is the most common and widely distributed of any of the shrubland classes. It is widespread across the North Island and the east and north of the South Island, primarily in warmer and drier locations (Figs 5 & 6). These shrublands occur from sea level to 900 m on a wide range of landforms associated with flat to steep slopes.

The shrubland is dominated by woody species over swards of exotic species, particularly the grasses sweet vernal, Yorkshire fog and browntop. A large range of successional species can be present in the canopy, the most common of which are bracken, gorse (*Ulex europaeus*), kānuka, mānuka, māhoe (*Melicytus ramiflorus*), *Coprosma rhamnoides*, *C. propinqua* and *Carpodetus serratus*. Diagnostic species in the ground layer include *Hypochoeris radicata*, *Cerastium fontanum*, *Trifolium repens*, *Crepis capillaris*, *Cirsium vulgare*, *Dactylis glomerata* and *Muehlenbeckia complexa*. *Thuidium furfurosum* is a characteristic non-vascular species. This class varies in composition with slope steepness and stand mean canopy height. Species such as kānuka and *Coprosma rhamnoides* are more important in taller stands on steeper slopes, and species such as gorse and *Lotus pedunculatus* are more important on shorter stands on gentler slopes.

Mean canopy height ranges from 1 to 11 m (Fig. 9a). There is usually more than 30% cover of trees and shrubs 2–11 m tall, with a similar cover of shrubs below 2 m. Species richness is moderate with on average 46 species per plot (Fig. 9b), 10 of which are measurable trees. This class is especially high in exotic species with on average 15 exotic species per plot (one-third the total species richness).

One plot was grouped within this class, but is an outlier in terms of composition and geography. It is located in Northland, north-west of Kaitaia. Although it contains Yorkshire fog, it lacks the characteristic species of this class – sweet vernal and gorse. The main woody species are both exotics and are the subshrub *Phytolacca octandra* and the shrub/small tree *Solanum mauritianum.* Across all CMS plots, six species – *Acacia longifolia, Bromus wildenowii, Cyperus tenellus, Erechtites valerianifolia, Setaria pumila* and *Solanum chenopodioides,* all of which are exotic – only occurred in this plot.

Wheki–mānuka shrubland/low forest [class 20]
The Wheki–mānuka shrubland/low forest class was sampled only on the North Island (except for one occurrence in the Marlborough Sounds), where it is widespread south of Auckland, occupying 204 000 ha (Figs 5 & 6). These shrublands/low forests occur from lowland to montane areas ranging from 40 to 750 m, across a wide range of slope and topographic positions.

The forest/shrubland is dominated by *Dicksonia squarrosa* and mānuka in the canopy, *Blechnum novae-zelandiae* and bracken in the subcanopy, and *Lotus pedunculatus* and Yorkshire fog grass in the understorey. Other diagnostic species commonly in the canopy are kāmahi, *Pseudopanax arboreus* and *Carpodetus serratus*; and in the subcanopy are *Hebe stricta*, *Leucopogon fasciculatus*, *Geniostoma ligustrifolium*, *Clematis paniculata*, *Coprosma robusta* and *Brachyglottis repanda*; and on the ground layer are *Hydrocotyle moschata*, *Digitalis purpurea*, *Senecio jacobaea*, *Paesia scaberula*, *Uncinia uncinata* and sweet vernal grass. A large number of species grow epiphytically in this vegetation class, the most frequent being *Microsorum pustulatum*, *Asplenium flaccidum* and kāmahi. Frequent non-vascular species include *Ptychomnion aciculare*, *Thuidium furfurosum*, and *Leucobryum candidum*.

Mean canopy height ranges from 1 to 14 m (Fig. 9a). There is usually less than 30% cover of trees, tree ferns and shrubs 5–14 m tall and usually more than 50% cover of trees and shrubs 2–5 m tall. Species richness is high with on average 60 species per plot (Fig. 9b). A large proportion of these, on average 22 per plot, are measurable trees (one-third of the total species richness). This class is also high in exotic species with on average 13 exotic species per plot (almost a quarter of the total species richness). Exotic species characteristic of this class include *Prunella vulgaris* and occasionally *Erica lusitanica*.

BEECH FOREST
Four classes were designated as beech forest.

Black/mountain beech forest [class 2]
The Black/mountain beech forest class occupies 166 000 ha and is found primarily in the eastern South Island north of Lake Wanaka and in the central North Island in dry climates (Figs 7 & 8). Sites range in altitude from 340 to 820 m in the South Island and from 760 to 1140 m in the North Island. This class occurs primarily on faces and ridges, with slopes ranging from 13 to 38 degrees (Fig. 10b).

The forest canopy is dominated by black/mountain beech with *Coprosma microcarpa*, *Leptecophylla juniperina* and *Leucopogon fasciculatus* dominant in the subcanopy. Red and silver beech can be co-dominant with black/mountain beech in some stands. Other diagnostic species in the subcanopy (predominantly <2 m) are broadleaf, marbleleaf (*Carpodetus serratus*), *Coprosma linariifolia*, *C. rhamnoides*, *Elaeocarpus hookerianus*, *Pseudopanax crassifolius*, *Raukaua anomalus* and *Rubus cissoides*. In the ground layer frequent diagnostic species are *Lagenifera strangulata* and *Corybas trilobus*, and occasionally *Uncinia scabra*. This class varies in composition with latitude with *Coprosma propinqua,* and *Pseudopanax colensoi* more important in the south and red beech, silver beech, Hall's tōtara (*Podocarpus hallii*), *Blechnum vulcanicum,* and *Pyrrosia eleagnifolia* more important in the north. The most frequent epiphytes are broadleaf, *Grammitis billardierei*, *Pyrrosia eleagnifolia*, *Hymenophyllum sanguinolentum* and *Asplenium flaccidum*. Characteristic non-vascular plants include *Hypnum chrysogaster*, *Dicranoloma menziesii*, *D. billardierei* and *Ptychomnion aciculare*.

Mean canopy height ranges from 5 to 29 m (Fig. 9a). There is usually 60% cover of trees over 5 m tall, including more than 25% cover of trees 12–29 m tall. Typically there is more than 30% cover of trees and shrubs 0.3–5 m tall. Species richness is moderate with on average 33 species per plot (Fig. 9b), with over half of these (19) being measurable tree species. Ferns are relatively common in this class, comprising on average five species per plot (40% of the total species richness). The proportion of the total species richness that is exotic is typically low (mean = 1, range 0–3), with the tree Douglas-fir (*Pseudotsuga menziesii*) being the most notable exotic, and *Mycelis muralis* the most frequent. Very few graminoids are present. The proportion of the total species richness comprised of ferns species is typically low (mean = 7 per plot, range 0–13), the most frequent of which are *Grammitis billardierei*, *Blechnum procerum*, and *Asplenium flaccidum*.

Silver beech–red beech–black/mountain beech forest [class 3]
The Silver beech–red beech–black/mountain beech forest class occupies 144 000 ha (the smallest area of any forest class) and was sampled only on the South Island where it is found north of Arthur's Pass and south of Lake Wakatipu (Fig. 8). Sites range in altitude from 380 to 1200 m and occur on gentle to steep slopes on a range of topographic positions.

The forest is dominated by beeches: silver, red and black/mountain. This class is unusual in that these are the only three species that occurred in the canopy above 5 m, and these species are also the most frequently occurring species and have the highest average cover through all height tiers from 0 to 5 m. This class is characterised by a relatively high richness of fern species, the most frequent being *Grammitis billardierei*, *Asplenium flaccidum* and *Hymenophyllum villosum*, with less frequent occurrences of *Grammitis magellanica*, *Hymenophyllum sanguinolentum*, *H. multifidum*, *Blechnum procerum* and *B. discolor*. In the subcanopy there are occasional occurrences of *Coprosma colensoi*, *C. microcarpa*, *C. tayloriae* and *Cyathea colensoi*. Below 0.3 m broadleaf is the next most frequent species and occurs on 25% of the plots. The orchids *Adenochilus gracilis* and *Corybas trilobus* occur at similar frequency. Frequent non-vascular plants are *Dicranoloma billardierei*, *D. robustum Ptychomnion aciculare*, and *Bazzania adnexa*. This class varies in composition with *Blechnum discolor* and broadleaf more important on warmer sites and black/mountain beech and *Adenochilus gracilis* more important on cooler sites.

Mean canopy height ranges from 12 to 27 m (Fig. 9a). There is usually more than 40% cover of beech 12–27 m tall and more than 70% cover of beech 0.3–12 m tall. Species richness is low with on average 12 species per plot (Fig. 9b), with five of these being measurable trees. No exotic species were found on any of the plots in this class. Although species richness is low, the percentage of species that are ferns is high (39%), as noted above.

Black/mountain beech forest (subalpine) [class 4]
The Black/mountain beech forest class occupies 151 000 ha and was sampled only on the South Island where it is found east of the Main Divide from northern Southland to southern Marlborough (except in the area of the 'beech gap'; Fig. 8). Sites are cool and range in altitude from 400 m in the south to 1380 m in the north. This forest class occurs primarily on faces and ridges on steep slopes (ranging from 11 to 45 degrees) (Fig. 10b).

The forest is dominated by black/mountain beech, which has both the highest frequency and abundance through all height tiers, and is typically the only species occurring above 2 m tall. *Peraxilla tetrapetala* is the second most frequent species, occurring on almost half of the plots. In the subcanopy (0.3–2m) there are occasional occurrences of *Coprosma pseudocuneata, C. tayloriae, Phyllocladus alpinus,* silver beech, and *Podocarpus nivalis*. None of these species is particularly frequent within the class (all <25% of plots) and none has high cover. These species also frequently occur in the ground layers (<0.3 m), as well as *Blechnum penna-marina* and *Corybas trilobus*. Frequent non-vascular species are *Dicranoloma billardierei*, *D. robustum*, *Leptotheca gaudichaudii* and *Pseudocyphellaria glabra*. This class varies in composition with altitude and mapped minimum temperature with *Podocarpus nivalis* and *Phylocladus alpinus* more important on higher and cooler sites and *Blechnum penna-marina, Corybas trilobus* and *Coprosma tayloriae* more important on lower, warmer sites.

Mean canopy height ranges from 6 to 23 m (Fig. 9a). There is usually less than 20% cover of black/mountain beech 12–23m tall as well as more than 35% cover 2–12 m tall. Species richness is the lowest of any class, with on average 10 species per plot (Fig. 10b), with five of these being woody tree or shrub species. Few exotic species are found in this class (mean = 1 per plot, range 0–3), and none of the individual species were particularly frequent (the most frequent, *Mycelis muralis*, occurred on 10% of plots). Fern richness is also low, with typically only one species present on each plot.

Black/mountain beech–silver beech forest/subalpine shrubland [class 7]
The Black/mountain–silver beech forest class occupies 492 000 ha and occurs in the central North Island and on the South Island where it occurs in mountainous areas throughout (except in the area of the 'beech gap'; Figs 7 & 8). This forest class occurs on a range of landforms, from gently sloping terraces to ridges and steep (up to 54^{o}) faces, ranging in altitude from 160 to 1400 m. It grades into subalpine shrubland at higher altitudes.

The forest canopy is dominated by black/mountain and silver beech. Other diagnostic species include *Phyllocladus alpinus* and broadleaf, which also occur in the canopy (but seldom reach >5 m tall). In the subcanopy these are frequently joined by *Myrsine divaricata*, *Coprosma pseudocuneata* and *C. tayloriae*. Diagnostic species in the ground layer are *Hymenophyllum multifidum*, which typically has high cover as well as very high frequency, and *Polystichum vestitum*, *Grammitis billardierei*, *Blechnum penna-marina* and *Lagenifera strangulata*. Species most frequently occurring epiphytically are *Grammitis magellanica*, *Hymenophyllum multifidum*, *H. villosum*, *H. sanguinolentum, Grammitis billardierei*, and *Asplenium flaccidum.* Frequent non-vascular species are *Dicranoloma robustum*, *D. billardierei*, *Ptychomnion aciculare* and *Pseudocyphellaria homoeophylla*.

This class varies in composition with both mean canopy height and geography. As stands shorten *Dracophyllium unifolium, Hebe venustula* (except southern South Island), and *Podocarpus nivalis* become more important, whereas as stands increase in height red beech becomes importance, along with the forest understorey species *Asplenium flaccidum* and *Nertera villosa*. In western and southern areas *Astelia nervosa, Phormium cookianum* and *Gaultheria* spp. are more important, whereas in northern and eastern areas *Histiopteris incisa, Lagenifera pumila,* and *Viola filicaulis* are more important.

Mean canopy height ranges from 6 to 5 m, except at higher altitudes where this class includes subalpine shrublands ranging in height from 2 to 6 m (Fig. 9a). In the taller stands there is usually more than 20% cover of beech 12–25 m tall and less than 50% cover of trees and shrubs 2–12 m. Species richness is moderate with on average 30 species per plot (Fig. 9b), with 11 of these being measurable trees. The proportion of the total species richness that are exotic is typically low (mean = 1 per plot, range 0–6), the most frequent exotic being *Mycelis muralis*. The proportion of the total species richness comprised of ferns species is typically low (mean = 7 per plot, range 0–15), the most frequent of which are *Hymenophyllum multifidum*, *Grammitis billardierei*, *Polystichum vestitum* and *Blechnum penna-marina*.

BEECH–BROADLEAVED FOREST

Three classes were designated as beech–broadleaved forest.

Broadleaf forest [class 8]

The Broadleaf forest class occupies 484 000 ha and is widespread along the length of the South Island, both east and west of the Main Divide and in the North Island from the Ruahine Ranges south (Figs 7 & 8). This forest class occurs on sites ranging from sea level on Stewart Island to 1350 m in the Ruahines and on a range of landforms and slopes, ranging from 2 to 61 degrees (Fig. 10b).

The forest is dominated by broadleaf and silver beech in the canopy, and by *Coprosma foetidissima* and *C. pseudocuneata* in the subcanopy. This class varies in composition with climate and mean canopy height. In areas with lower minimum temperatures, beech species (red, silver black/mountain) become more important and stands become taller. Southern rātā (*Metrosideros umbellata*) can also occasionally co-dominate with broadleaf and silver beech. Diagnostic species in the subcanopy are *Myrsine divaricata*, *Raukaua simplex*, *Cyathea colensoi*, *Pseudopanax lineare* (South Island only) and *Pseudopanax colensoi*. Diagnostic species on the ground layer include *Uncinia filiformis*, *Blechnum fluviatile* and *Nertera villosa*. Species most frequently occurring epiphytically are *Asplenium flaccidum*, *Grammitis billardierei* and *Hymenophyllum multifidum*. Frequent non-vascular species are *Ptychomnion aciculare*, *Pseudocyphellaria homoeophylla*, *Dicranoloma robustum*, *Bazzania adnexa* and *Wijkia extenuata*.

Mean canopy height typically ranges from 5 to 26 m (Fig. 9a). There is usually more than 40% cover of trees and shrubs 5–26 m tall and more than 60% cover of trees and shrubs 0.3–5 m tall. Species richness is moderate with on average 39 species per plot (Fig. 9b), with 18 of these being measurable tree species. The proportion of the total species richness that is exotic is typically low (mean = 0.3 per plot, range 0–4). On average there are 11 fern species on each plot (range 4–27), the most frequent being *Grammitis billardierei*, *Asplenium flaccidum*, *Hymenophyllum multifidum* and *Blechnum fluviatile*.

Silver beech–red beech–kāmahi forest [class 12]

The Silver beech–red beech–kāmahi forest class is an extensive forest class, occupying 711 000 ha. It is widespread in the South Island (except for the 'beech gap') especially in Northwest Nelson and Marlborough and in western Southland (Fig. 8). It occurs in the North Island from the Ruahine Ranges south (Fig. 7). This forest class occurs on sites ranging from 130 to 980 m, across a wide range of landforms and slope steepnesses.

The forest is dominated by silver beech, kāmahi and red beech, with a dense understorey of *Blechnum discolor*. Diagnostic species in the canopy are broadleaf, marbleleaf and *Pseudopanax crassifolius* (all usually <5 m). *Quintinia serrata* or *Q. acutifolia* are occasionally co-dominant with the canopy species, as are black/mountain beech and hard beech. This class varies in composition with climate and geography with kāmahi, *Quintinia* spp., and hard beech (*Nothofagus truncata*) more important in warmer areas to the north and east, and mountain beech, *Coprosma pseudocuneata,* and *Cyathea colensoi* becoming more important in cooler areas to the south and west. Diagnostic species in the subcanopy are pepperwood, miro, *Coprosma foetidissima*, *C. rhamnoides* and *Raukaua simplex*. In the ground layer diagnostic species are *Blechnum procerum* and *Adenochilis gracilis*. Several *Hymenophyllum* species are usually present, especially *H. bivalve*. Frequent non-vascular species are *Bazzania adnexa*, *Wijkia extenuata*, *Ptychomnion aciculare*, *Rhizogonium distichum* and *Leucobryum candidum*.

Mean canopy height ranges from 7 to 32 m (Fig. 9a). There is usually more than 40% cover of trees 12–32 m tall and more than 60% cover of trees and shrubs 2–12 m. Species richness is moderate with on average 35 species per plot (Fig. 9b). Typically over half of these (18) are measurable trees and over one-third (mean = 13 per plot, range 2–27) are ferns, the most frequent of which are *Grammitis billardierei*, *Blechnum discolor*, *B. procerum* and *Asplenium flaccidum*. There are very few exotic species in this forest class.

Marbleleaf–pepperwood–wineberry forest [class 13]

The Marbleleaf–pepperwood–wineberry forest class occupies 189 000 ha, in Southland, the West Coast, and Northwest Nelson in the South Island and scattered locations to the east and north of Mt Ruapehu in the North Island (Figs 7, & 8). This forest class occurs from sea level to montane (600 m) areas in the South Island, and sites at 800–1000 m on the North Island. It is most frequent on low topographic positions (terraces and steep-sided gullies) and faces with slopes ranging from 15 to 37 degrees (Fig. 10b).

The forest is dominated by marbleleaf, pepperwood (*Pseudowintera colorata*), wineberry (*Aristotelia serrata*) and broadleaf in the canopy and *Blechnum discolor* in the understorey. Diagnostic species in the subcanopy are fuchsia, *Coprosma rhamnoides*, *C. rotundifolia*, *Pseudopanax crassifolius*, *Muehlenbeckia australis, Pennantia corymbosa* and the tree fern *Cyathea smithii*. Diagnostic species in the ground layer are *Histiopteris incisa* and *Cardamine debilis*. Frequent non-vascular species are *Ptychomnion aciculare*, *Cyathophorum bulbosum*, *Wijkia extenuata* and *Thuidium furfurosum.* This class varies in composition with altitude with silver beech, *Raukaua anomalus, Blechnum fluviatile,* and *Urtica incisa* more important in more montane areas, and *Hedycarya arborea* and the weedy species bracken, gorse and Himalayan honeysuckle (*Leycesteria formosa*) increasing in lowland forests. Stands less than 6 m tall tend to occur at lower altitudes (below 300 m) and are most likely successional stands.

Mean canopy height ranges from 4 to 30 m (Fig. 9a). There is usually less than 20% cover of trees 12–30 m tall and more than 60% cover of trees and shrubs 2–12 m. Species richness is high with on average 61 species per plot (Fig. 9b), with typically 23% of these (18) being measurable tree species. Usually, a relatively high percentage (12%) of the species are exotic, the most frequent of which are the grasses sweet vernal and browntop. The proportion of the total species richness comprised of ferns species is typically moderate (mean = 15 per plot, range 8–28), the most frequent of which are *Asplenuium flaccidum*, *A. bulbiferum*, *Blechnum discolor*, *B. fluviatile,* and *Polystichum vestitum*.

BEECH–BROADLEAVED–PODOCARP FOREST
Three classes were designated as beech–broadleaved–podocarp forest

Kāmahi–Southern rātā forest and tall shrubland [class 9]
The Kāmahi–southern rātā forest and tall shrubland class occupies 371 000 ha and was sampled only on the South Island (where it occurs in Northwest Nelson, Southland, and the West Coast south of Jackson Bay) and Stewart Island (Fig. 8). In the southern part of its range, this class occurs from sea level to 650 m; in Northwest Nelson it occurs from 600 to 1125 m. It occurs across a wide range of landforms and slope steepnesses.

The forest is dominated by kāmahi, southern rātā and black/mountain beech, with an understorey often dominated by *Gahnia procera*. Hall's tōtara, rimu and *Phyllocladus alpinus* can be co-dominant in the canopy where they occur. Other diagnostic species in the canopy are *Lepidothamnus intermedius*, *Halocarpus biformis*, *Elaeocarpus hookerianus*, and *Pseudopanax linearis*. Diagnostic species in the subcanopy are *Archeria traversii*, *Coprosma colensoi*, *C. foetidissima*, *Raukaua simplex*, broadleaf, *Pseudopanax colensoi* and *Myrsine divaricata*. On the ground layer diagnostic species are *Luzuriaga parviflora*, *Blechnum procerum* and less frequently *Libertia pulchella* and *Schizaea fistulosa*. Species occurring frequently as epiphytes include *Grammitis billardierei*, *Hymenophyllum multifidum*, *Tmesipteris tannensis* and *Ctenopteris heterophylla*. Frequent non-vascular species are *Ptychomnion aciculare*, *Bazzania adnexa*, *Dicranoloma billardierei*, *D. robustum*, *Heteroscyphus billardierei*, *Wijkia extenuata*, *Riccardia* sp. and *Schistochila nobilis*. This class varies in composition with geography and altitude (which themselves covary), with silver beech, *Dracophyllum traversii, Cyathea colensoi,* and *Coprosma pseudocuneata* more important in the northern, higher altitude areas, and mānuka, *Empodisma minus, Gleichenia dicarpa,* and *Dracophyllum longifolium* more important in southern, lower altitude areas.

Mean canopy height ranges from 3 to 19 m (Fig. 9a). Stands are low-statured on Stewart Island and in subalpine areas in the north. There is often less than 10% cover of trees 12–19 m tall and more than 70% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 44 species per plot (Fig. 9b), with 21% of these (18) being measurable trees. Very few exotic species occur in plots of this class. Typically only a moderate percentage (25%) of the species present is ferns. Exotic species are very few (mean = 0.5 per plot, range 0–2), and no individual species was particularly frequent.

Kāmahi forest [class 11]
The Kāmahi forest class occupies 371 000 ha and was sampled only on the South Island west coast north of Greymouth and on the North Island south of the Coromandel Peninsula (Figs 7 & 8). It occurs from sea level to 700 m in the South Island and from 300 to 1100 m in the North Island. It occurs across a wide range of landforms and slope steepnesses.

The forest is dominated by kāmahi, miro and the tree fern *Cyathea smithii*, with *Blechnum discolor* commonly dominating the understorey. Rimu is also occasionally co-dominant. Diagnostic species in the subcanopy are broadleaf, marbleleaf, pepperwood, *Pseudowintera axillaris*, *Coprosma grandifolia*, *C.foetidissima* and the tree ferns *Cyathea smithii* and *Dicksonia squarrosa*. Climbing rātā (*Metrosideros diffusa*) is frequent. In the ground layer diagnostic species are *Asplenium flaccidum*, *Grammitis billardierei*, *Astelia solandri*, *Microlaena avenacea*, *Microsorum pustulatum*, *Hymenophyllum demissum* and *Uncinia uncinata*. Frequent non-vascular species are *Leucobryum candidum*, *Wijkia extenuata*, *Ptychomnion aciculare*, *Bazzania adnexa*, *Cyathophorum bulbosum* and *Dicranoloma* *menziesii*. This class varies in composition with geography and altitude (which themselves covary) with *Dicksona lanata,* silver beech, *Ixerba brexioides* (North Island only), and red beech more important in the North Island, higher altitude areas and *Metrosideros fulgens, M. perforātā, Freycinetia baueriana,* hard beech and *Hedycarya arborea* more important in South Island, lower altitude areas.

Mean canopy height ranges from 6 to 30 m (Fig. 9a). There is usually more than 35% cover of trees 12–35 m tall and more than 75% cover trees and shrubs 2–12 m tall. Species richness is moderate with on average 51 species per plot (Fig. 9b), with more than half of these (26) being measurable trees. Ferns are important in this forest class, comprising on average 36% (18) of the species. Very few exotic species occur in plots of this class. Exotic species richness was low (mean = 0.4 per plot, range 0–4) and no individual species was particularly frequent.

Pepperwood–hardwood forest and successional shrubland [class 14]
The Pepperwood–hardwood forest and successional shrubland class occupies 454 000 ha, in Northwest Nelson and Marlborough in the South Island and south of the Bay of Plenty in the North Island (Figs 7 & 8). This class occurs from 300 to 1200 m across a wide range of landforms and slope steepnesses.

The class is dominated by pepperwood, broadleaf, red beech and marbleleaf, with *Microlaena avenacea* dominating the understorey. Other diagnostic species are *Rubus cissoides* in the canopy, *Coprosma foetidissima*, *C. tayloriae* and *Neomyrtus pedunculata* in the subcanopy, and *Blechnum fluviatile*, *B. procerum, B. discolor* and *Histiopteris incisa* in the ground layer. Species most frequently occurring epiphytically are *Asplenium flaccidum*, *Grammitis billardierei,* broadleaf and *Hymenophyllum sanguinolentum.* Frequent non-vascular species are *Ptychomnion aciculare*, *Wijkia extenuata*, *Dicranoloma billardierei*, *Trichocolea mollissima* and *Weymouthia cochlearifolia*. This class varies in composition with geography and October vapour pressure deficit with tawa, *Hedycarya arborea*, *Elaeocarpus dentatus* and occasional podocarps increasing in western, moister areas and kānuka, *Leucopogon fasciculatus,* and herbaceous exotics increasing in eastern, drier areas.

Mean canopy height ranges from 2 to 30 m (Fig. 9a). There is usually more than 30% cover of trees 12–30 m tall and more than 75% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 42 species per plot (Fig. 9b), with 20% of these (18) being measurable trees. A relatively large proportion of the species present are ferns, these comprising on average 32% of the total species richness (mean = 13 species per plot, range 7–23), the most frequent being *Asplenuium flaccidum*, *Grammitis billardierei* and *Blechnum fluviatile*. Exotic species richness is low (mean = 1, range 0–5), and no individual species was particularly frequent.

BROADLEAVED FOREST
Two classes were designated as broadleaved forest.

Kāmahi–hardwood forest [class 15]
The Kāmahi–hardwood forest class occupies 612 000 ha, primarily on the South Island south and west coasts (extending north to Cape Foulwind) and in the Tararua Range of the North Island (Figs 7 & 8). This class occurs from lowland to montane areas, from sea level to 820 m across a wide range of landforms and slope steepnesses.

The forest is dominated by kāmahi, broadleaf, pepperwood, and the tree fern *Cyathea smithii,* with an understorey dominated by *Blechnum discolor*. Diagnostic species in the subcanopy are marbleleaf, *Coprosma foetidissima*, *Raukaua simplex* and *Myrsine divaricata*, and on the ground layer are *Nertera villosa*, *Blechnum discolor*, *B. fluviatile*, and *Nertera depressa*. Though less frequent, the fern species *Leptopteris superba*, *Rumohra adiantiformis*, *Blechnum nigrum* and *Trichomanes colensoi* are highly diagnostic of this class, as is *Uncinia gracilenta*. Frequent non-vascular species are *Ptychomnion aciculare*, *Wijkia extenuata*, *Cyathophorum bulbosum*, and *Bazzania adnexa*. This class varies in composition with mean annual temperature, which itself varies with altitude and geography, with *Hedycarya arborea*, māhoe, supplejack and *Metrosideros diffusa* becoming more important in warmer areas and silver beech, *Coprosma pseudocuneata, C. cuneata,* and *Lagenifera strangulata* becoming more important in cooler areas.

Mean canopy height typically ranges from 6 to 36 m (Fig. 9a). There is usually more than 20% cover of trees 12–36 m tall and more than 70% cover of trees and shrubs 2–12 m. Species richness is moderate with on average 53 species per plot (Fig. 9b), with 43% of these (23) being measurable trees. A relatively large percentage of the species present are ferns, these comprising on average 21 species per plot (39% of the total species richness). Exotic species richness is low (mean = 1 per plot, range 0–3), and no individual species was particularly frequent.

Kānuka forest and tall shrubland [class 19]

The Kānuka forest and tall shrubland class occupies 393 000 ha, primarily on the North Island, becoming especially prominent north of Lake Taupo, and in a few northern South Island locations (Figs 7 & 8). This class occurs in lowland areas from sea level to 500 m. It occurs across a wide range of landforms and slopes.

The forest is dominated by kānuka in the canopy, typically with an understorey of *Coprosma rhamnoides*, *Leucopogon fasciculatus*, *Geniostoma ligustrifolia*, and silver fern. Mānuka co-dominates with kānuka in the canopy on some sites. Other diagnostic species in the subcanopy are māhoe, nīkau, *Myrsine australis*, *Hedycarya arborea*, *Phyllocladus trichomanoides* and the tree fern *Cyathea medullaris*. On the ground layer are bracken, *Uncinia uncinata*, *Oplismenus imbecillis*, *Blechnum novae-zealandiae*, *Dianella nigra*, *Microlaena stipoides, Lotus pedunculatus* and occasional *Doodia australis*.

Mean canopy height typically ranges from 1.5 to 17 m (Fig. 9a). There is usually more than 60% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 41 species per plot (Fig. 9b), with 17 of these being measurable trees. Exotic species are prominent in this class, comprising on average 20% (8) of the species, the most frequent being *Lotus pedunculatus*, *Cirsium vulgare* and *Prunella vulgaris*. Ferns are important in this forest class, comprising on average 20% of the species (mean = 8 per plot, range 0–26), the most frequent being *Pteridium esculentum* and *Blechnum novae-zelandiae*.

BROADLEAVED–PODOCARP FOREST

Five classes were designated as broadleaved–podocarp forest.

Kāmahi–podocarp forest [class 10]

The Kāmahi–podocarp forest class is the most extensively occurring forest class, occupying 794 000 ha and was sampled only on the South Island, where it occurs primarily west of the

Main Divide, in Southland and Stewart Island (Fig. 8). It occurs primarily in lowland and montane areas, from sea level to 650 m, where it is found across a wide range of landforms and slope steepnesses.

The forest is dominated by kāmahi, miro and rimu, with the understorey frequently dominated by *Coprosma foetidissima* and *Blechnum discolor*. Diagnostic species in the canopy (and subcanopy) are broadleaf, *Pseudopanax crassifolius* and the tree fern *Dicksonia squarrosa*. In the subcanopy diagnostic species are *Raukaua simplex*, *Neomyrtus pedunculata* and on the ground layer are *Nertera villosa*, *Grammitis billardierei*, *Hymenophyllum demissum*, *H. revolutum Blechnum procerum* and *Nertera depressa*. Species occurring frequently as epiphytes include kāmahi, broadleaf, *Ctenopteris heterophylla*, *Asplenium flaccidum*, *Grammitis billardierei* and *Tmesipteris tannensis* as well as several *Hymenophyllum* species. Frequent non-vascular species are *Ptychomnion aciculare*, *Bazzania adnexa*, *Wijkia extenuata*, *Schistochila nobilis*, *Dicranoloma menziesii*, *Trichocolea mollissima*, *Leucobryum candidum* and *Rhizogonium distichum*. This class varies in composition along a northeast–southwest geographic gradient with *Metrosideros diffusa, Trichomanes venosum* and *Asplenium bulbiferum* more important to the south and west, and *Phyllocladus alpinus, Myrsine salicina, Leucopogon fasciculatus* and *Dianella nigra* more important to the north and east.

Mean canopy height ranges from 4 to 35 m (Fig. 9a). There is usually more than 20% cover of trees 12–35 m tall and more than 70% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 54 species per plot (Fig. 9b), with more than half of these (26) being measurable trees. Ferns are important in this forest class, comprising on average 36% (19) of the species. Very few exotic species occur in plots of this class. Exotic species richness is low (mean = 0.8 per plot, range 0–5) and no individual species is particularly frequent.

Māhoe forest [class 21]

The Māhoe forest class occupies 393 000 ha and occurs from south of the Bay of Plenty in the North Island to Arthur's Pass in the South Island, where it occurs primarily in lowland and low montane areas, from 80 to 820 m (Figs 7 & 8). It occurs across a wide range of landforms and slope steepnesses.

The forest is dominated by māhoe, marbleleaf and the tree ferns *Cyathea smithii* and *Dicksonia squarrosa*. Other diagnostic species in the canopy are tawa and occasional kāmahi, *Hedycarya arborea*, *Schefflera digitata* and *Knightia excelsa*. In the subcanopy diagnostic species are *Coprosma grandifolia*, *Clematis paniculata*, *Geniostoma ligustrifolia, Brachyglottis repanda* and the tree fern *Cyathea dealbata*. Diagnostic species on the ground layer are *Uncinia uncinata*, *Microsorum pustulatum*, *Asplenium bulbiferum*, *Blechnum chambersii*, *B. fluviatile, Microlaena avenacea*, *Leptopteris hymenophylloides* and *Pyrrosia eleagnifolia*. Climbing rātā (*Metrosideros diffusa*) and *Ripogonum scandens* are common. Frequent non-vascular species are *Echinodium hispidum*, *Ptychomnion aciculare* and *Racopilum convolutaceum.* This class varies in composition with latitude, with tawa, miro, mataī and rimu more important to the north and *Leucopogon fasciculatus, Olearia rani,* red beech and kānuka more important to the south.

Mean canopy height typically ranges from 5 to 35 m (Fig. 9a). There is usually more than 25% cover of trees 12–35 m tall and more than 70% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 47 species per plot (Fig. 9b), with nearly half of these (22) being measurable trees. Ferns are important in this forest class, comprising on average 33% (16) of the species (range 4–25), the most common species being *Asplenium flaccidum*, *Microsorum pustulatum* and *Blechnum chambersii*. Exotic species richness is typically low (mean = 2 per plot, range 0–14) but no individual species is particularly frequent.

Silver fern–hangehange forest [class 22]

The Silver fern–hangehange forest class occupies 605 000 ha and was sampled only on the North Island, where it occurs primarily in lowland and lower montane areas, from sea level to 760 m (Fig. 7). It occurs across a wide range of landforms and slope steepnesses.

The forest is dominated by *Cyathea dealbata* (silver fern), *Geniostoma ligustrifolia* (hangehange), supplejack and *Freycinetia baueriana*. Diagnostic species in the canopy are māhoe, nīkau, *Hedycarya arborea*, and *Knightia excelsa*, with occasional *Dysoxylum spectabile*, *Beilschmiedia tarairi*, *Laurelia novae-zelandiae*, *Phyllocladus trichomanoides* and *Weinmannia silvicola*. This class varies in composition with latitude, with tawa, miro and rimu more important to the north and *Pseudopanax arboreus, Pittosporum eugenioides* and *Leucopogon fasciculatus* more important to the south. Important species in the subcanopy are *Pseudopanax crassifolius*, *Schefflera digitata*, *Coprosma grandifolia*, *Clematis paniculata*, *Myrsine australis*, *Olearia rani* and the tree fern *Dicksonia squarrosa*. On the ground layer diagnostic species are *Microsorum pustulatum*, *Uncinia uncinata*, *Astelia solandri*, *Blechnum filiforme*, and *Asplenium oblongifolium*. Climbing rātā are common, especially *Metrosideros perforata* and *Metrosideros diffusa*. Frequent non-vascular species are *Leucobryum candidum*, *Ptychomnion aciculare* and *Wijkia extenuata*.

Mean canopy height typically ranges from 6 to 28 m (Fig. 9a). There is usually less than 20% cover of trees 12–28 m tall and very high cover, usually more than 80%, of trees and shrubs 2–12 m tall. Species richness is high with on average 56 species per plot (Fig. 9b), with half of these (28) being measurable trees. Ferns are important in this forest class, comprising on average 34% of the species (mean = 19 per plot, range 6–32) the most frequent being *Microsorum pustulatum*, *Asplenium flaccidum* and *A. polyodon*. Exotic species richness is low to moderate (mean = 2 per plot, range 0–25) but no individual species is particularly frequent.

Kāmahi–silver fern forest [class 23]

The Kāmahi–silver fern forest class occupies 348 000 ha, primarily on the North Island south of the Coromandel, and in a few South Island locations in northern Marlborough (Figs 7 & 8). This class occurs in lowland and montane areas, from sea level to 760 m. It occurs across a wide range of landforms and slope steepnesses.

The forest is dominated by kāmahi, silver fern (*Cyathea dealbata*), *Leucopogon fasciculatus* and *Knightia excelsa*. Occasional tawa, rimu, miro, *Elaeocarpus dentatus* and *Pseudopanax crassifolius* are emergent or occur in the canopy and subcanopy. Diagnostic species in the subcanopy are *Hedycarya arborea*, *Geniostoma ligustrifolia, Olearia rani* and occasional *Freycinetia baueriana*, marbleleaf and māhoe, and in the ground layer are *Hymenophyllum demissum*, *H. sanguinolentum*, *Blechnum discolor*, *Microlaena avenacea* and *Astelia solandri*. Frequent non-vascular species are *Leucobryum candidum*, *Wijkia extenuata*, *Ptychomnion aciculare*, *Bazzania adnexa*, *Dicranoloma menziesii*, *D. billardierei* and *Usnea* spp. This class varies in composition with latitude with *Ixerba brexioides, Pseudowintera* *axillaris, Quintinia serrātā,* and hard beech more important to the north and black/mountain beech, *Coprosma rhamnoides* and *Pyrrosia eleagnifolia* more important to the south.

Mean canopy height typically ranges from 8 to 28 m (Fig. 9a). There is usually more than 20% cover of trees 12–28 m tall and more than 70% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 54 species per plot (Fig. 9b), with half of these (27) being measurable trees. Ferns are important in this forest class, comprising on average 30% (16) of the species. Exotic species richness is low to moderate (mean = 1.5 per plot, range 0–7) but no individual species is particularly frequent.

Tawa forest [class 24]
The Tawa forest class occupies 522 000 ha and occurs south of Auckland in the North Island and in northern Marlborough in the South Island, where it occurs primarily in lowland and lower montane areas, from 80 to 785 m (Figs 7 & 8). It occurs across a wide range of landforms and slope steepnesses.

The forest is dominated by tawa, kāmahi and *Hedycarya arborea*. Diagnostic species in the canopy are māhoe and *Knightia excelsa* and in the subcanopy are *Geniostoma ligustrifolia*, *Coprosma grandifolia* and the tree fern *Dicksonia squarrosa*. This class varies in composition with altitude and declining mean canopy height, with silver fern more important in taller stands at lower altitudes and *Ixerba brexioides, Quintinia serrata,* and the tree fern *Cyathea smithii* more important in shorter stands at higher altitudes. Diagnostic species in the ground layer are *Uncinia uncinata*, *Hymenophyllum demissum*, *Metrosideros diffusa*, *Leptopteris hymenophylloides*, *Microlaena avenacea*, *Microsorum pustulatum*, *Astelia solandri* and *Asplenium flaccidum*, the latter three of which are also very frequent epiphytes. Climbing rātā (*Metrosideros diffusa*, *M. perforata*, *M. fulgens*) are frequent. Frequent non-vascular species are *Leucobryum candidum*, *Wijkia extenuata*, *Ptychomnion aciculare* and *Camptochaete arbuscula*.

Mean canopy height typically ranges from 7 to 30 m (Fig. 9a). There is usually more than 30% cover of trees 12–25 m tall and more than 75% cover of trees and shrubs 2–12 m tall. Species richness is moderate with on average 48 species per plot (Fig. 9b), with over half of these (25) being measurable trees. Ferns are important in this forest class, comprising on average 38% (18) of the species (range 8–31), the most frequent being *Asplenium flaccidum*, *Microsorum pustulatum*, *Hymenophyllum demissum* and *Leptopteris hymenophylloides*.

4.1.3 How well do mappable environmental and spatial parameters explain the variation among plots and vegetation classes?

One plot (Q181) was shown to be an extreme outlier in terms of composition and was deleted from the analyses because it unduly influenced the results. Comparison of eigenvalues shows that the CCA analysis explained most of the variation in the plot data explained by the DCA analysis (Table 4).

The weak correlations between stand scores from the two different analyses (Table 5), however, showed that when constrained by environment, the pure compositional relationships among plots were less clearly displayed.

TABLE 4. EIGENVALUES OF DCA (UNCONSTRAINED) V. CCA (CONSTRAINED BY MAPPABLE ENVIRONMENTAL PARAMETERS) ORDINATIONS OF 1176 NZCMS PLOTS.

	DCA eigenvalue	CCA eigenvalue
Axis 1	0. 662	0.595
Axis 2	0.405	0.432
Axis 3	0.337	0.239

TABLE 5. SPEARMAN RANK CORRELATION COEFFICIENTS BETWEEN STAND SCORES GENERATED BY DCA (UNCONSTRAINED) V. CCA (CONSTRAINED BY MAPPABLE ENVIRONMENTAL PARAMETERS) ORDINATIONS OF 1176 NZCMS PLOTS. * $P < 0.05$.

	CCA		
DCA	Axis 1	Axis 2	Axis 3
Axis 1	0.027	−0.086*	−0.047
Axis 2	0.023	0.082*	0.005
Axis 3	−0.020	−0.049	0.004

All of the mappable parameters differentiated at least one of the vegetation classes from another and had an overall significance in the MANOVA of $P < 0.0001$ (Table 6). The best-performing parameters were mean annual temperature, minimum temperature, northing, and easting. These are likely to be the most useful parameters for mapping, with the others being of secondary importance. The importance of these variables is demonstrated in the DCA environmental biplot as well, where they are strongly correlated with the first ordination axis (Fig. 11). Both the DCA and MANOVA analyses demonstrate that no one mappable parameter distinguishes all the classes from each other; rather different parameters may be useful for distinguishing individual classes, or groups of classes, from the others.

TABLE 6. *F*-VALUES FOR MANOVA ANALYSIS SHOWING THE ABILITY OF MAPPABLE PARAMETERS TO DIFFERENTIATE THE VEGETATION CLASSES. PARAMETERS ARE ORDERED BY DESCENDING *F* STATISTICS AND R^2 VALUES, CORRESPONDING TO THEIR RELATIVE ABILITY TO DIFFERENTIATE THE CLASSES

Parameter	*F* stat	R^2
Mean annual temperature	173.27	0.78
Minimum temperature	125.54	0.71
Northing	101.36	0.67
Easting	80.46	0.62
Altitude	70.03	0.58
October vapour pressure deficit	67.83	0.58
Mean annual solar radiation	70.52	0.58
Water balance ratio	66.85	0.57
Water deficit	29.71	0.37
Drainage	9.77	0.16
Acid soluble phosphorus	8.32	0.14
Slope	6.27	0.11
Calcium	2.60	0.05

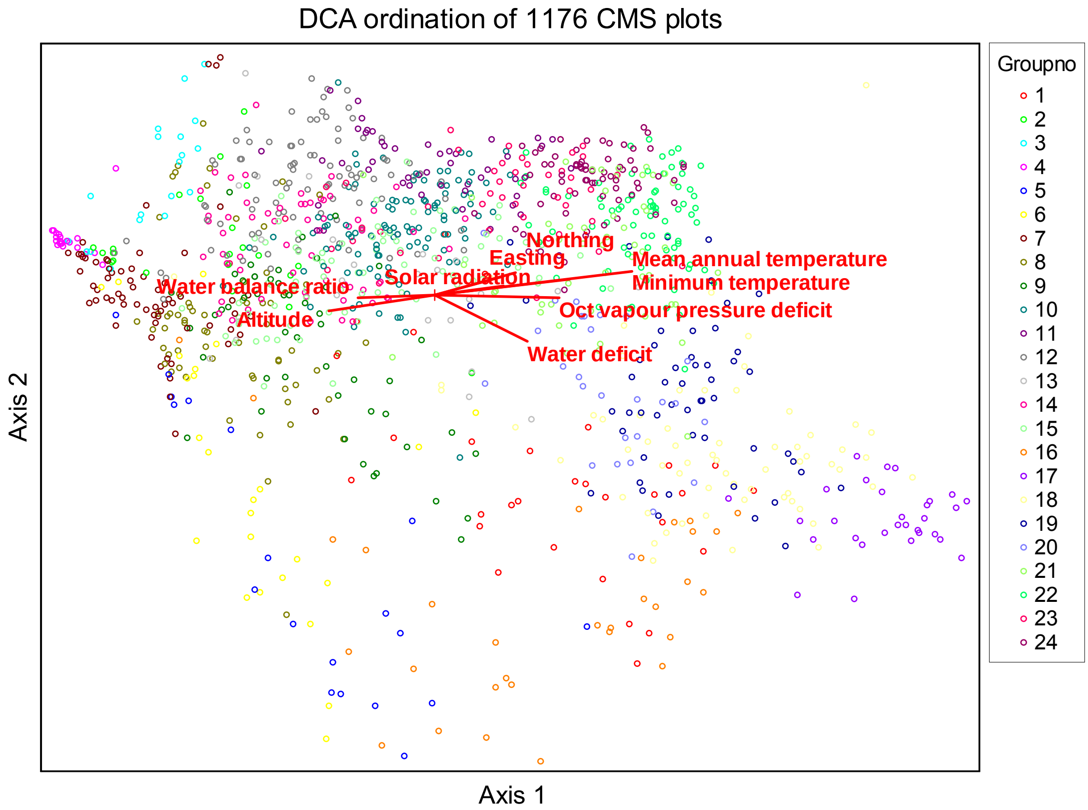


Figure 11. Biplots of DCA ordinations showing plot positions and environmental vectors. Plots are coded by vegetation class.

4.2 COMPARISON WITH PREVIOUS CLASSIFICATIONS

4.2.1 Correspondence with previously defined common and widespread types

The distinction made in our classification between forest and shrublands (or forest and non-forest) is progressively better matched to the Forest Class Maps, Vegetative Cover Map, ECOSAT woody classification, and LCDB2 (Table 7).

At a more detailed level, differences between our classification and previous classifications of New Zealand forests and shrublands can be attributed to five major aspects: the use of species groups rather than individual species in previous classifications (e.g. lumping all podocarps, all beeches, all broadleaf species together; lumping a range of shrubs into 'grey scrub'), that previous classifications relied primarily on trees, whereas we include all vascular species, the nature of the underpinning ground-based data (plot-based v. walk throughs), inferring composition from canopy appearance in aerial photos and satellite imagery, scale of the mapping, and actual changes in land cover through forest and shrubland removal or succession (Table 8). Further, all of the previous classification give disproportionate emphasis to large, canopy emergents (e.g. kauri, podocarps), which may be scattered and actually comprise a relatively low portion of total cover or basal area.

At a species-group level, our beech forest classes map well onto previous classifications, especially that of the Forest Class Maps, where 92% of the plots we classed as beech forests were located in the area mapped as beeches (Table 9). Plots in classes belonging to the species-group 'Beech–broadleaved–podocarp forest' were mapped similarly from 30%

(VCM) to 40% (Forest Class Maps) of the time. Broadleaved–podocarp plots mapped similarly from 23% (Forest Class Maps) to 36% (ECOSAT) of the time. All other species-group categories mapped similarly less than 30% of the time. The comparatively low level of correspondence with the other previous classes reflects that they tended to emphasise beeches and podocarps over broadleaved species. For the Forest Class Maps, this is because the sampling methods focused on large individuals of merchantable tree species. Several of the species that have high cover in our classes and distinguish our major groupings are broadleaved species that either are not merchantable (e.g. broadleaf, kānuka, kāmahi, māhoe) or tend to have few, if any, individuals that exceed 30.5 cm (12 inches) in diameter (e.g. horopito). For the Vegetative Cover Map this lack of matching is most likely a consequence of the mapping scale as correspondence is low across all categories and with beech forest is lower than both ECOSAT and the Forest Class Maps. For the ECOSAT woody classification, the lack of correspondence may be due to basing the classification on canopy reflectance – many broadleaved species do not have leaves in the upper canopy. It is also likely that there has been some change in forest composition since the data on which both the Vegetative Cover Map and Forest Class Maps depend were collected.

Correspondence with VCM shrubland classes was poor, with the NZCMS-based shrubland classes often corresponding to areas mapped as forest by VCM, and shrubland classes recognised by VCM frequently falling largely outside the area mapped as forest and shrubland by LCDB1 – the basis for the NZCMS sampling (Table 10). Three of the seven shrubland classes (two of these were subalpine shrublands) primarily mapped onto areas defined as 'indigenous forest' by LCDB2; this may result from the 6-m cutoff used to define indigenous forest in LCDB2 effectively including areas that floristically would be considered tall shrublands. There was good correspondence between those plots we classified as 'Mānuka shrubland' and the more broadly defined LCDB2 class 'Mānuka and/or kānuka'. There was poor correspondence, however, with our remaining shrubland classes.

Our first three pure beech forest classes corresponded well with all previous maps that recognised beech forests (Table 8); whereas our class 'Black/mountain beech–silver beech forest' corresponded with the mixed beech–podocarp classes of previous classifications. The NZCMS classification allows a finer resolution of classes within beech forest that differentiates forests comprised of different species and combinations of beech and co-occurring dominants.

TABLE 7. CORRESPONDENCE BETWEEN BROAD TYPING INTO OUR 24 CLASSES OF 1177 NZCMS PLOTS AS 'FOREST' OR 'SHRUBLAND' AND PREVIOUS CLASSIFICATION SYSTEMS.

NZCMS classes	Forest Class Maps: Series 6 (1:250 000)	Vegetation Cover Map	Ecosat	LCDB2
Shrublands		71% located within area mapped as shrubland*		71% located within area mapped as shrubland
Forest	79% located within area mapped as forest	87% located within area mapped as forest*	88% located within area mapped as forest	90% located within area mapped as forest

*Shrubland in VCM includes those classes designated as scrub, grassland forest, or grassland scrub; forest includes those areas designated as forest or forest-scrub.

TABLE 8. REASONS FOR DIFFERENCES IN NZCMS-BASED CLASSIFICATION VERSUS PREVIOUS CLASSIFICATIONS.

	NZCMS classes	Forest Class Maps: Series 6 (1:250 000)	Vegetation Cover Map	Ecosat	LCDB2
Used individual species v. species groups	Individual species	Species groups	Species groups	Species groups	Species groups
Relied on woody plants v. all vascular species	All vascular species	Woody plants over 30-cm diameter	Woody plants	Woody plants in the canopy	Woody plants in the canopy
Nature of data sources	1177 plots on an 8-km grid	Aerial photos, vegetation plots, walk throughs	Aerial photos, walk throughs	Satellite imagery, Limited ground truthing	Satellite imagery, Limited ground truthing

TABLE 9. CORRESPONDENCE BETWEEN OUR 17 FOREST CLASSES GENERALISED INTO FIVE SPECIES-GROUP CATEGORIES AND PREVIOUS CLASSIFICATION SYSTEMS. WE LIST THE CLASSES OF THE PREVIOUS CLASSIFICATIONS THAT INCLUDE A TOTAL OF AT LEAST 10% OF THE PLOTS FROM THE CORRESPONDING NZCMS SPECIES-GROUP-BASED CATEGORY. BOLD FONT INDICATES THE PREVIOUS CLASSES THAT ROUGHLY MATCH THE SPECIES-GROUP-BASED CATEGORIES IN TERMS OF COMPOSITION.

NZCMS classes	Forest Class Maps: Series 6 (1:250 000)	Vegetation Cover Map	Ecosat
Beech forest	**Beeches (92%)**	**Beech (68%)**	**Beech forest (84%)**
Beech–broadleaved forest	Beeches (61%)	Beech (46%)	Beech forest (50%)
	Rimu–Beeches (20%)	Lowland podocarp–broadleaved–beech (23%)	Beech/podocarp–broadleaved (24%)
Beech–broadleaved–podocarp forest	Beeches (37%)	**Lowland podocarp–broadleaved–beech (30%)**	Beech forest (35%)
	Rimu–Beeches (29%)	Beech (30%)	**Beech/podocarp–broadleaved (22%)**
	Highland Softwoods–Beeches (11%)	Lowland podocarp–broadleaved (12%)	**Podocarp–broadleaved/Beech (11%)**
			Podocarp–broadleaved (16%)
Broadleaved forest	Beeches (33%)	Beeches (25%)	Beech forest (24%)
	General Hardwoods (26%)		Beech/podocarp–broadleaved (12%)
	Rimu–Beeches (14%)		**Broadleaved (12%)**
			Podocarp–broadleaved (13%)
Broadleaved–podocarp forest	**Rimu–Tawa (23%)**	**Lowland podocarp–broadleaved (31%)**	**Podocarp–broadleaved (36%)**
	Rimu–Beeches (13%)	Lowland podocarp–broadleaved–beech (25%)	Podocarp–broadleaved/Beech (22%)
	Rimu–Tawa–Beeches (11%)		

Our three ‘beech–broadleaved’ classes mapped onto some areas designated as ‘beech forest’ by Forest Class Maps, VCM and ECOSAT, some areas mapped as ‘Beeches/General Hardwoods’ in the Forest Class Maps, and some areas mapped as including beeches, broadleaved species and podocarps by ECOSAT (Table 8). Of our three beech–broadleaved–podocarp forest classes, the kāmahi–southern rātā forest had the best general correspondence with VCM (mapped as lowland podocarp–broadleaved forest); otherwise correspondence is relatively weak. Our two broadleaved forest classes generally corresponded poorly with previous classifications. Of the five broadleaved–podocarp classes, four (māhoe forest, silver fern–hangehange forest, kāmahi–silver fern forest, and tawa forest) mapped to broadleaved–podocarp classes in Forest Class Maps; three (māhoe forest, silver fern–hangehange forest, and tawa forest) mapped to broadleaved–podocarp classes as designated by ECOSAT, and two (māhoe and kāmahi–silver fern forests) mapped to broadleaved–podocarp classes as designated by VCM.

The Leathwick (2001) potential vegetation maps classes are species-based. Overall, we found poor correspondence between our classes and Leathwick’s. Only five of our classes had more than 50% of their plots in an individual potential vegetation map class, and no one of these had more than 56% of its plots in this class. These are as follows:

- NZCMS class Silver beech–red beech–black/mountain beech forest = Potential vegetation map Silver beech forest
- NZCMS class Kānuka forest = Potential vegetation map Kauri/taraire/kohekohe–tawa forest
- NZCMS class Silver beech–red beech–kāmahi forest = Potential vegetation map Rimu–miro/kāmahi–red beech–hard beech forest
- NZCMS class Wheki–mānuka shrubland = Potential vegetation map Rimu/tawa–kāmahi forest
- NZCMS class Tawa forest = Potential vegetation map Rimu/tawa–kāmahi forest

For these five classes, this may provide some ideas about potential successional trajectories or elements missing from our forest classes owing to existing partial harvesting (particularly of podocarps).

TABLE 10. CLOSEST CORRESPONDENCE BETWEEN 24 CLASSES BASED ON 1177 NZCMS PLOTS AND PREVIOUS CLASSIFICATION SYSTEMS. WE LIST THE CLASSES OF THE PREVIOUS CLASSIFICATIONS THAT INCLUDE A TOTAL OF AT LEAST 50% OF THE PLOTS FROM THE LISTED NZCMS CLASS. 'N/A' INDICATES WHERE MOST OF THE NZCMS PLOTS FOR THE CLASS FELL OUTSIDE THE AREA MAPPED IN THE PREVIOUS CLASSIFICATION.

Mapped woody classes → NZCMS classes ↓	Forest Class Maps: Series 6 (1:250 000)	Vegetation Cover Map	Ecosat	LCDB2
Shrublands				
1. Mānuka shrubland	n/a	Plots fell across a range of structural types	n/a	Mānuka and/or kānuka
5. *Schoenus–Dracophyllum* subalpine shrubland [SI]	Beeches	Beeches	Beech forest	Indigenous forest
6. Hard fern–*Coprosma pseudocuneata* subalpine shrubland and low forest [SI]	Beeches	Forest	Beech forest	Indigenous forest
16. *Ozothamnus–Dracophyllum* montane shrubland (steep) [SI]	n/a	Plots fell across a range of structural types	n/a	Plots fell across a range of classes
17. Matagouri shrubland (open canopy–dry) [SI]	n/a	Plots fell across a range of structural types	n/a	Mānuka and/or kānuka
18. Sweet vernal–Yorkshire fog successional shrubland (open canopy)	n/a	Plots fell across a range of structural types	n/a	Plots fell across a range of classes
20. Wheki–mānuka shrubland/low forest [mostly NI]	Rimu–Tawa/Kauri–Softwoods–Hardwoods	Forest	Podocarp–broadleaved forest/Kauri forest	Indigenous forest
Beech forest				
2. Black/mountain beech forest	Beeches	Beeches	Beech forest	Indigenous forest
3. Silver beech–red beech–black/mountain beech forest [SI]	Beeches	Beeches	Beech forest	Indigenous forest
4. Black/mountain beech forest (subalpine) [SI]	Beeches	Beeches	Beech forest	Indigenous forest
7. Black/mountain beech–silver beech forest	Beeches/Highland Softwood–Beeches	Plots fell across a range of classes	Beech–Podocarp–broadleaved forest/Beech forest	Indigenous forest
Beech–broadleaved forest				
8. Broadleaf forest	Plots fell across a range of classes	Plots fell across a range of classes	Podocarp–broadleaved–beech forest/Podocarp–broadleaved forest	Indigenous forest
12. Silver beech–red beech–kāmahi forest	Beeches	Beeches	Beech forest	Indigenous forest
13. Marbleleaf–pepperwood–wineberry forest	Beeches/General Hardwoods	Plots fell across a range of classes	Beech forest/Beech–podocarp–broadleaved forest	Indigenous forest
Beech–broadleaved–podocarp forest				
9. Kāmahi–rātā forest [SI]	Rimu–Beeches/Beeches	Lowland podocarp–broadleaved forest	Plots fell across a range of classes	Indigenous forest
11. Kāmahi forest	Beeches/ Rimu–Beeches	Plots fell across a range of classes	Plots fell across a range of classes	Indigenous forest
14. Pepperwood–hardwood forest	Beeches/General Hardwoods–Beeches	Grassland–Scrub	n/a	Plots fell across a range of classes

Broadleaved forest				
15. Kāmahi–hardwood forest	n/a	Grassland–Scrub	n/a	Plots fell across a range of classes
19. Kānuka forest	Plots fell across a range of classes	Plots fell across a range of classes	Plots fell across a range of classes	Indigenous forest
Broadleaved–podocarp forest				
10. Kāmahi–podocarp forest [SI]	Beeches	Beeches	Beech forest	Indigenous forest
21. Māhoe forest	Rimu–Tawa–Beeches/Rimu–Tawa	Lowland podocarp–broadleaved forest	Podocarp–broadleaved–beech forest	Indigenous forest
22. Silver fern–hangehange forest (short) [NI]	Rimu–Tawa/ Rimu–Tawa–Beeches	Plots fell across a range of classes	Podocarp–broadleaved forest/ Podocarp–broadleaved–beech forest	Indigenous forest
23. Kāmahi–silver fern forest	Rimu–Tawa–Beeches/Rimu–Tawa	Lowland podocarp forest	Podocarp–broadleaved beech forest	Indigenous forest
24. Tawa forest	Rimu–Tawa/Rimu–Tawa–Beeches	Plots fell across a range of classes	Podocarp–broadleaved forest/Podocarp–broadleaved beech forest	Indigenous forest

4.2.2 Representation of previously defined rare types

What classes in the previous classification are poorly represented by NZCMS plots? The most narrowly distributed NZCMS-based classes (*Schoenus–Dracophylllum* subalpine shrubland and silver beech–red beech–black/mountain beech forest) each comprise 19 (1.6%) of the 1177 plots measured, which represents an area of 144 000 ha (i.e. c. 1.6% of the total area of 8.9 million hectares defined as forest or shrubland by LCDB1). This means that we expect all of our classes to describe forest classes that have an extent greater than 144 000 ha. Rarer forest classes will have either been missed by the plot sampling entirely, or have been sampled but classed within a more broadly defined class. Here we define previously mapped classes as poorly represented by the NZCMS plots if they overlapped in position with less than 1% (fewer than 12) of the NZCMS plots.

Forest Class Map types that were poorly represented by NZCMS plots include Kauri, Kauri–Softwood–Hardwoods–Beeches, Rimu–Taraire–Tawa, and Taraire–Tawa, all of which had mapped extents < 41 000 ha (Table 11). There were no dense kauri stands sampled by the NZCMS plots; the one plot that fell within that mapped area (CQ31) was dominated by kānuka and has <5% cover of kauri. The Kauri–Softwood–Hardwoods–Beeches class is common only on the Hunua Ranges and the southern end of the Coromandel and is characterised by abundant, small kauri with hard beech as a subdominant. The lack of plots in these forest types could have also resulted from the undersampling of Northland (see section 2.1) in comparison with the rest of the country. No NZCMS plots were sampled that contained both kauri and hard beech. Both the Rimu–Taraire–Tawa and the Taraire–Tawa forest classes mapped onto NZCMS plots assigned to 'Silver fern–hangehange forest'. Rimu, taraire and tawa all are frequent in this forest class and co-occur on scattered plots. These results strongly suggest that all seven NZCMS plots were in fairly early successional versions of those types defined by the Forest Class Maps.

All of the forest and shrubland classes of the Vegetative Cover Map that were poorly represented by NZCMS plots had been reported by Newsome to cover <100 000 ha. The majority of the NZCMS plots that fell within the area mapped as podocarp forest fell within the only NZCMS class, 'Kāmahi–podocarp forest', that has podocarps (usually rimu) as major canopy dominants. The NZCMS plots that fell within the area mapped as 'Highland-podocarp–broadleaved forest' all contained broadleaved species such as broadleaf and kāmahi, and scattered individuals of podocarp species that occur at higher altitudes (e.g. Hall's tōtara, mountain toatoa). These plots are among the 16% of plots in the NZCMS class 'Broadleaf forest' that do not contain any beech species but do contain the other associates. Later work may find this to be an association within a more broadly defined alliance. None of the NZCMS plots that fell within the class mapped as 'Beech–broadleaved forest and scrub' had beech as a canopy dominant; rather they had other hardwoods prominent such as hīnau, broadleaf, marbleleaf and māhoe with silver fern. As a consequence, they were classed in five different NZCMS classes. The VCM classes 'Subalpine scrub and indigenous forest' and 'Subalpine scrub' are based more on stand structure and height and position in the landscape than on composition. Dominant species can vary greatly from location to location and accordingly plots that fell within these classes were distributed across multiple NZCMS classes. The VCM class 'Gorse scrub' was both rare on the landscape (20 000 ha) and due to the scale of mapping appears to have included forested areas. The one NZCMS plot (BS101) that fell within this mapped area was classed as Tawa–māhoe forest, is 7 m tall, and it is unknown whether it may have succeeded from gorse in the 30 years since the data that underpins VCM were collected.

Only one of the woody classes mapped by ECOSAT was poorly represented by NZCMS plots (Table 11). This was the class 'Coastal forest', which has a mapped extent of 5199 ha. Only one NZCMS plot fell within this area. This plot was assigned to the class 'Māhoe forest'.

Four of the shrubland classes defined by LCDB2 were poorly represented by NZCMS plots (Table 11). These were Fernland, Gorse and broom, Grey scrub and Matagouri. As defined by LCDB2 Fernland, Grey scrub and Matagouri would all have an extent < 73 000 ha, but LCDB2 had difficulty distinguishing different shrubland classes and shrublands from grasslands. For example, LCDB2 estimates total coverage of Matagouri shrubland to be <30 000 ha compared with our coverage by this class of 227 000 ha. Only 10% of the plots we classed as 'Matagouri shrubland' fell within this mapped area; more typically they mapped as 'Low producing grassland'.

TABLE 11. CLASSES DEFINED IN PREVIOUS CLASSIFICATIONS THAT ARE POORLY REPRESENTED BY NZCMS PLOTS.

Map and Class	Extent (acc. to original map) (ha)	No. of NZCMS plots mapped into class	NZCMS class assigned
Forest Class Maps			
Kauri	2 722	1	Kānuka forest
Kauri–Softwood–Hardwoods–Beeches	10 872	0	
Rimu–Taraire–Tawa	40 846	4	Silver fern–hangehange forest
Taraire–Tawa	11 894	2	Silver fern–hangehange forest
Vegetative Cover Map			
Podocarp forest	43 000	7	Kāmahi–podocarp forest and one plot in each of three other classes
Highland podocarp–broadleaved forest	51 000	5	Broadleaf forest and one plot in each of two other classes
Beech–broadleaved forest and scrub	48 000	8	Five classes assigned
Subalpine scrub and indigenous forest	88 000	8	Four classes assigned
Subalpine scrub	96 000	7	Three classes assigned
Gorse scrub	20 000	1	Māhoe forest
ECOSAT woody classes			
Coastal forest	5199	1	Māhoe forest
LCDB2 woody classes			
Fernland	51 710	3	*Ozothamnus–Dracophyllum* montane shrubland/ Sweet vernal–Yorkshire fog successional shrubland
Gorse and broom	203 089	11	Sweet vernal–Yorkshire fog successional shrubland, and one plot in each of two other classes
Grey scrub	72 402	4	Matagouri shrubland and one plot in *Ozothamnus–Dracophyllum* montane shrubland
Matagouri	29 535	3	Matagouri shrubland
Leathwick (2001)			
Kahikatea–mataī/tawa–māhoe forest	Not available	6	
Kahikatea–pukatea–tawa forest	Not available	11	
Mataī–kahikatea–tōtara forest	Not available	4	

Three potential vegetation classes (Leathwick 2001) were poorly represented by NZCMS plots: Kahikatea–mataī/tawa–māhoe forest, Kahikatea–pukatea–tawa forest, and Mataī–kahikatea–totara (Table 11). These are all described as conifer–broadleaved forests of warm climates and are restricted to the North Island.

4.3 COMPARISON WITH CLASSIFICATIONS BASED ON WOODY SPECIES ONLY AND INCLUDING NON-VASCULAR SPECIES

For the woody species only based classification the optimal partition was achieved with 22 clusters. For the vascular and non-vascular combined classification the optimal partition was achieved with 23 clusters.

Using woody species maintained the broad species groupings of classes, except that the broadleaved forest and broadleaved–podocarp forest classes were combined with each other and with the Wheki–mānuka shrubland class (Table 12). Within broad species-based groupings, two shrubland classes were resolved in a similar way (Hard fern–*Coprosma pseudocuneata* shrubland and Matagouri shrubland), whereas others were split. The classes within beech forests and beech–broadleaved–podocarp forests were resolved in much the same manner as using all species, whereas the classes within beech–broadleaved forests were rearranged (Table 12).

Adding non-vascular species maintained the assortment of classes into broad species-based groupings that was based on the vascular-species-only classification (Table 13). Three classes within the shrubland group were defined differently: Mānuka shrubland, *Schoenus–Dracophyllum* shrubland and *Ozothamnus–Dracophyllum* shrubland. The circumscription of three beech forest classes changed slightly (silver beech–red beech–black/mountain beech forest, black/mountain beech forest, and black/mountain beech–silver beech forest), as did two of the beech–broadleaved forest classes (silver beech–red beech–kāmahi forest and kāmahi–hardwood forest) and both broadleaved–podocarp forest classes (Table 13).

TABLE 12. CONCORDANCE BETWEEN THE CLASSIFICATION BASED ON ALL VASCULAR SPECIES AND WOODY SPECIES ONLY. BLACK SHADING INDICATES WHERE >50% AND MEDIUM GREY WHERE 25–50% OF PLOTS FROM THE VASCULAR CLASES FELL WITHIN THE SPECIFIED CLASS OF THE WOODY-SPECIES-BASED CLASSIFICATION.

CMS woody classes → CMS vascular classes ↓	18	12	13	17	14	16	20	21	9	7	10	11	8	3	6	4	5	1	2	22	15	19
Shrublands																						
1. Mānuka shrubland	[grey]																					
5. *Schoenus–Dracophyllum* shrubland		[grey]	[grey]																			
6. Hard fern–*Coprosma pseudocuneata* shrubland		[black]																				
16. *Ozothamnus–Dracophyllum* shrubland			[black]	[grey]																		
17. Matagouri shrubland					[black]																	
18. Sweet vernal–Yorkshire fog successional shrubland						[grey]																
20. *Wheki*–mānuka shrubland/low forest							[black]	[grey]														
Forests																						
2. Black/mountain beech forest									[black]						[grey]							
3. Silver beech–red beech–black/mountain beech forest										[black]												
4. Black/mountain beech forest											[black]											
7. Black/mountain beech–silver beech forest												[black]										
8. Broadleaf forest													[grey]			[grey]						
12. Silver beech–red beech–kāmahi forest																			[grey]			
13. Marbleleaf–pepperwood–wineberry forest														[grey]								
14. Pepperwood–hardwood forest															[black]							

15. Kāmahi–hardwood forest																						
9. Kāmahi–Southern rātā forest																						
10. Kāmahi–podocarp forest																						
11. Kāmahi forest																						
23. Kāmahi–silver fern forest																						
19. Kānuka forest																						
22. Silver fern–hangehange forest																						
21. Māhoe forest																						
24. Tawa forest																						

TABLE 13. CONCORDANCE BETWEEN THE CLASSIFICATION BASED ON JUST VASCULAR SPECIES AND BOTH VASCULAR AND NON-VASCULAR SPECIES. BLACK SHADING INDICATES WHERE >50% AND MEDIUM GREY WHERE 25–50% OF PLOTS FROM THE VASCULAR CLASSES FELL WITHIN THE SPECIFIED CLASS OF THE WOODY-SPECIES-BASED CLASSIFICATION.

CMS vascular & non-vascular classes →	21	13	19	12	18	20	23	16	15	17	14	4	6	5	3	2	1	7	11	22	10	8	9
CMS vascular classes ↓																							
Shrublands																							
1. Mānuka shrubland	▒		▒																				
5. *Schoenus–Dracophyllum* shrubland		▒		▒																			
6. Hard fern–*Coprosma pseudocuneata* shrubland		■																					
16. *Ozothamnus–Dracophyllum* shrubland			▒	■																			
17. Matagouri shrubland					■																		
18. Sweet vernal–Yorkshire fog successional shrubland						■																	
20. *Wheki*–mānuka shrubland/low forest							■																
Forests																							
2. Black/mountain beech forest								■															
3. Silver beech–red beech–black/mountain beech forest									■	▒													
4. Black/mountain beech forest										■													
7. Black/mountain beech–silver beech forest											▒												
8. Broadleaf forest											■												
12. Silver beech–red beech–kāmahi forest												▒											
13. Marbleleaf–pepperwood–wineberry forest													■										
14. Pepperwood–hardwood forest														■									

15. Kāmahi–hardwood forest																							
9. Kāmahi–Southern rātā forest																							
10. Kāmahi–podocarp forest																							
11. Kāmahi forest																							
23. Kāmahi–silver fern forest																							
19. Kānuka forest																							
22. Silver fern–hangehange forest																							
21. Māhoe forest																							
24. Tawa forest																							

4.4 EFFECTS OF SAMPLING INTENSITY ON CLASSIFICATION RESULTS

We use Recce plots (Allen & McLennan 1983) established for the SWMEP programme to assess the effect of sampling intensity. To obtain a representative sample of Recce descriptions from this survey, we wrote computer algorithms that selected plots closest to systematic grid points that we specified. To derive alternate selections of plots with different sampling intensities, we altered our specified grid spacing to select plots on averages of 4-mile, 2-mile and 1-mile grid spacing. These resulted in datasets containing 158, 608, and 2226 plots respectively.

OPTIMCLASS specified that the optimal partition of 158 SWMEP plots positioned on a 4-mile grid was a one using flexible beta clustering with a Bray–Curtis distance measure and Recce class values as importance values (Fig. 12). The optimal partition was that resulting in 13 vegetation classes (Fig. 12). These classes had distinct sets of dominant and diagnostic species (Fig. 13). Five classes were forest, four were shrubland, and the remaining four supported low vegetation dominated by graminoids or ferns. Four classes (totalling 121, or 77%, of the plots) were dominated by kāmahi, co-occurring with different combinations of emergent podocarps, tree ferns, hardwoods, and ground ferns. One class, comprising 14 plots, was dominated by silver beech.

a) b)

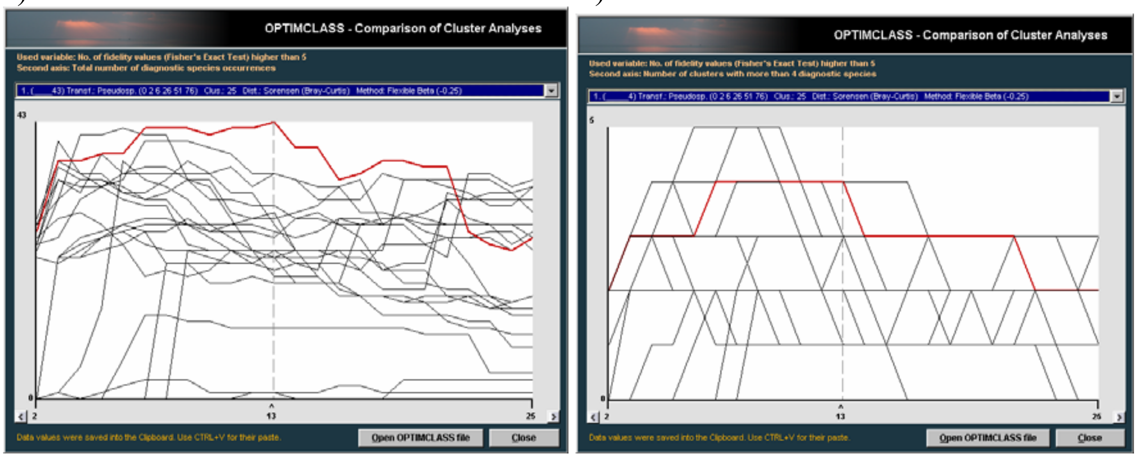


Figure 12. OPTIMCLASS analysis of partitions of 158 SWMEP plots located on a 4-mile grid based on diagnostic species having fidelity values as determined by *P*-values of Fisher's exact test greater than 5. The horizontal axis represents partitions with 2, 3, 4,…25 clusters. The vertical axis for (a) is the number of diagnostic species occurring over all the clusters in the given partition. The vertical axis for (b) is the number of clusters with more than four diagnostic species. Each line represents the results for individual partitions; the red line shows the partition that is optimal at the top of the curve.

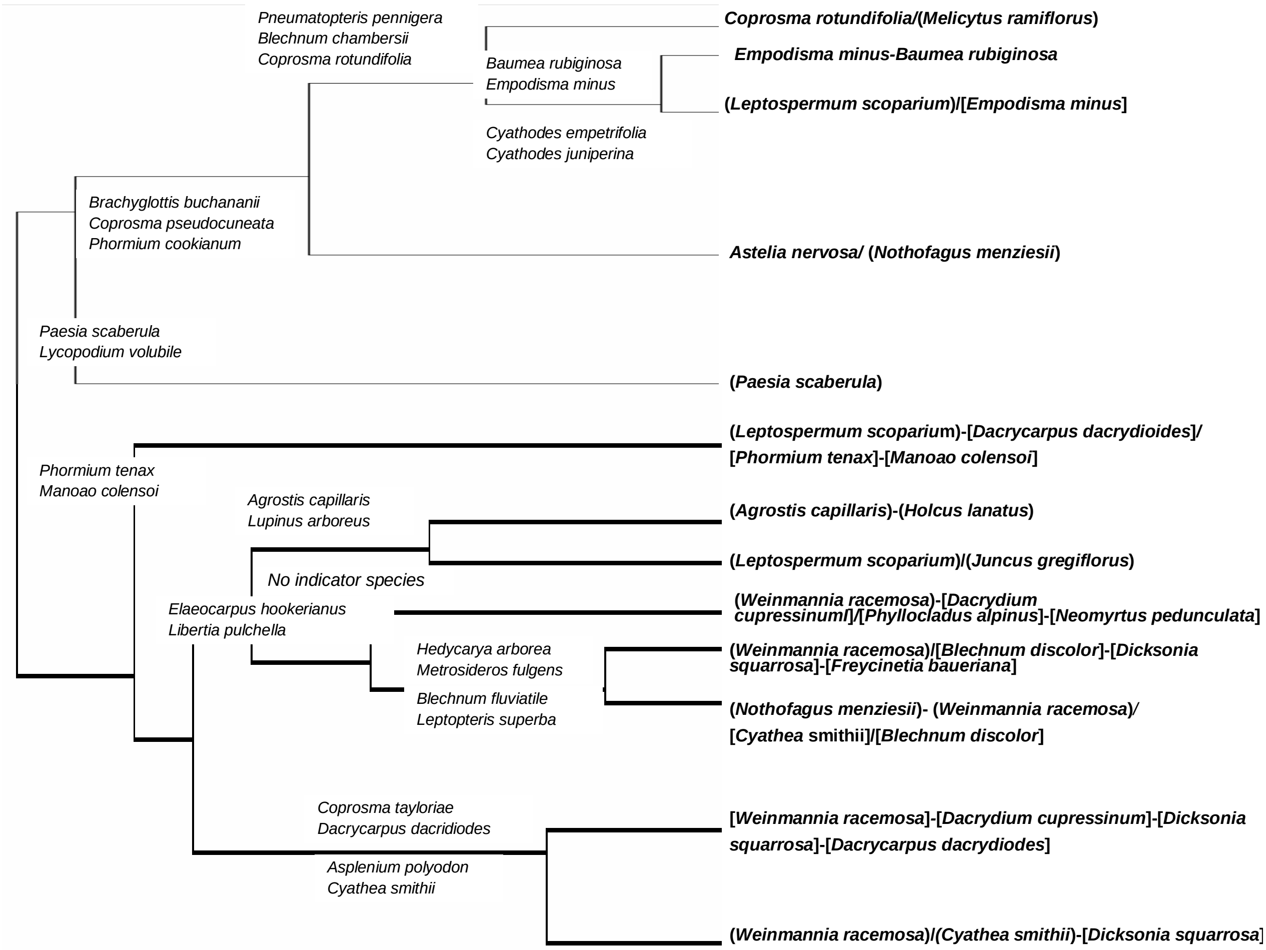


Figure 13. Tree diagram based on flexible beta clustering with a Bray–Curtis distance measure and Recce class values as importance values of 158 SWMEP plots positioned on a 4-mile grid. Atkinson names (reflecting dominance) and diagnostic species are indicated.

In comparison, plots from six NZCMS classes occurred in the area sampled by SWEMP (Fig. 8). Of these, four were dominated by kāmahi (as in the SWMEP classification); one by silver beech (again similar to SWMEP), and a final type dominated by marbleleaf, pepperwood and wineberry (similar to one of the SWMEP shrubland classes). In the SWMEP classification, mānuka dominated three shrubland classes (comprising a total of 12 plots), co-occuring with either kahikatea, manoao (*Manoao colensoi*), flax (*Phormium tenax*), wire rush (*Empodisma minus*), ferns or graminoids. An additional shrubland class was recognised comprising five plots dominated by *Coprosma rotundifolia*, māhoe, wineberry and hard fern. In contrast, the NZCMS-based classification only recognised one, rather than three, mānuka-dominated classes. The remaining five SWMEP classes comprised only one or two plots each and so their characterisation by dominant and indicator species may not be widely applicable across the region.

4.4.1 Concordance of classifications generated from datasets of varying resolution

Concordance between the classification based on 158 plots arrayed along a 4-mile grid and that based on 608 plots arrayed along a 2-mile grid and that based on the 2226 plots arrayed along a 1-mile grid is displayed in Table 14.

TABLE 14. CONCORDANCE BETWEEN THE CLASSIFICATION BASED ON 158 PLOTS ARRAYED ALONG THE 4-MILE GRID AND THOSE BASED ON (A) 608 PLOTS ARRAYED ALONG A 2-MILE GRID, (B) 2226 PLOTS ARRAYED ALONG A 1-MILE GRID. BLACK SHADING INDICATES WHERE >50%, MEDIUM GREY WHERE 25–50% OF PLOTS FROM THE 4-MILE GRID CLASS FELL WITHIN THE SPECIFIED CLASS OF THE NEW CLASSIFICATION.

(a)

2-mile grid → 4-mile grid ↓	1	2	9	3	4	5	13	6	7	10	11	12	8
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													

(b)

1-mile grid → 4-mile grid ↓	6	7	9	10	11	13	4	2	1	12	3	5	8
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													

The majority of plots in each of the large, kāmahi-dominated classes (classes 1, 2, 4 & 5) from the 4-mile-grid classification fall in an individual class in the classifications generated from the finer resolution grids, but some plots were moved to another, very similar class. The majority of plots in the beech-dominated class (class 3) were grouped together in the classification generated from the 2-mile grid, but were distributed across more classes in that generated from the 1-mile grid. The plots in the mānuka-dominated classes (6, 8 & 11) and the minor classes (7, 9, 10, 12 & 13) typically remained in distinct classes in classifications generated from finer resolution grids.

4.4.2 Recognition of rare classes

The rarest community classes from the 4-mile-grid classification comprised one plot, or 0.6% of the sampled landscape. When a classification with the optimal number of classes is produced based on a dataset created from a finer resolution grid, if classes are recognised that include none of the plots from the 4-mile grid, they could be too rare on the landscape to be picked up by the 4-mile grid.

The optimal classification of the 2-mile-grid-based dataset recognised 15 classes based on 608 plots, compared with the 13 classes recognised by the classification of 158 plots positioned on a 4-mile grid. All 15 classes contained at least one of the original 158 plots (Table 14). This means that the finer resolution grid is providing the ability to detect subdivisions within the 4-mile-grid-based classification. There are no classes, however, comprised solely of plots from rare vegetation classes that were only detected by the finer resolution grid.

The optimal classification of the 1-mile grid (26 classes across 2226 plots) produced similar results (Table 14). All 26 classes contained at least one of the original 158 plots.

The optimal classification of all SWMEP plots (38 classes across 5023 plots) distinguished six classes that contained none of the 158 plots from the 4-mile grid. Dominant and indicator species of these classes are detailed in Table 15. The first class is unique in being dominated by kahikatea, with kāmahi being a very minor element. The next two classes share major dominants with classes defined using the 4-mile-grid-based dataset (i.e. wire rush (*Empodisma minus*), mānuka), whereas the most abundant species in the three smallest classes (*Leptocarpus similis*, *Ulex europaeus* and *Brachyglottis rotundifolia* were never dominants in the 13 classes defined by the 4-mile grid.

Overall, grids of 1-mile and 2-mile allowed finer divisions within classes based on a 4-mile grid to be recognised. Including all plots from the survey identified six classes that contained none of the 158 plots from the 4-mile grid. This demonstrates how finer resolution data stored in the NVS Databank might be used to refine the NZCMS-based classification of forests and shrublands.

TABLE 15. DOMINANT AND INDICATOR SPECIES IN SIX VEGETATION CLASSES THAT CONTAINED NO PLOTS FROM THE 4-MILE GRID.

No. of plots	Dominant species	Indicator species
125 (2.5%)	*Dacrycarpus dacrydioides*	*Dacrycarpus dacrydioides*
	Myrsine divaricata	*Pseudowintera colorata*
	Blechnum novae-zelandiae	
	Pseudowintera colorata	
114 (2.3%)	*Empodisma minus*	*Empodisma minus*
	Gleichenia dicarpa	*Gleichenia dicarpa*
	Leptospermum scoparium	
	Dracophyllum longifolium	
70 (1.4%)	*Leptospermum scoparium*	*Phyllocladus alpinus*
	Phyllocladus alpinus	*Lagarostrobos colensoi*
	Lagarostrobos colensoi	*Leptospermum scoparium*
	Dacrydium cupressinum	
33 (0.7%)	*Leptocarpus similis*	*Leptocarpus similis*
	Coprosma propinqua	
	Phormium tenax	
	Centella uniflora	
14 (0.3%)	*Ulex europaeus*	*Ulex europaeus*
	Fuchsia excorticata	
	Histiopteris incisa	
	Phormium tenax	
11 (0.2%)	*Brachyglottis rotundifolia*	*Cortaderia richardii*
	Blechnum novae-zelandiae	
	Phormium tenax	
	Cortaderia richardii	

4.5 VEGETATION MAPPING PLAN

Classification and Regression Tree (CART) analysis will be used to develop relationships between mappable parameters and the results of the classification based on the NZCMS data. This will allow the classification to be mapped across New Zealand. We will map the distribution of the forest classes across the area mapped as indigenous forest or shrubland by LCDB2 or any updated version. As boundaries between forest and shrublands and other cover types are known to contain error, vegetation classes of plots that occur outside of this mapped area will be represented by points designating their location only.

CART analysis may be thought of as a variant of decision trees. A training set is derived from a set of pre-classified plots (the response variable) that are used to determine the structure of the tree. Multiple predictor variables can be used and these can be either continuous (regression tree analysis) or categorical (classification tree analysis). CART models are non-parametric and so can handle non-linear relationships between predictor and dependent variables. A binary tree is generated through a process of binary recursive partitioning of the dependent variable (i.e. the pre-classified plots) into increasingly homogenous subsets by splitting the data based on critical thresholds of individual predictor variables. In other words, rather than estimating a mean value for a range of environmental variables associated with the vegetation classes (as with most parametric techniques), CART analyses identify specific thresholds of predictor variables above or below which a vegetation class can be found. The resulting tree can be displayed graphically as a series of if/then conditions.

The option of 'aggregated boosting' also has been shown to improve accuracy of classifications (reviewed by De'ath 2007). Boosting creates additional CART analyses by resampling with replacement from the initial dataset. Each additional classification-tree tries to correct the predictions from the previous classification-tree by preferentially selecting observations that have been misclassified in the previous model over those that were not. The algorithm then produces a final model prediction based on the multiple regression-tree predictions.

Since the tree is produced from a training dataset it usually suffers from overfitting (i.e. it is 'explaining' random, idiosyncratic elements of the training dataset that are unlikely to be features of future, independent datasets) and will result in poor performance with these future data. To address this problem it is pruned with either an independent validation dataset or by using the technique of v-fold cross-validation (Breiman et al. 1984). Tree 'pruning' is analogous to variable selection in regression (Miller & Franklin 2002).

As a first stage, we will use CART analysis to derive a tree from a training set containing 70% of the pre-classified NZCMS forest and shrubland plots. The validation dataset will contain 30% of the pre-classified plots. Separate models will be developed for each vegetation class with the response variable being the presence/absence of that class.

Four classes of predictor variables would be used: climate variables, topographic variables, SPOT 5 satellite imagery, spatial layers representing disturbance (e.g. earthquake frequency). The use of environmental variables follows the predictive vegetation modelling approach of other authors (e.g. Franklin 1995; Guisan & Zimmerman 2000) that has been demonstrated to predict tree distributions in New Zealand (Leathwick 2001). The values of some environmental and site variables will be taken from the plot observations themselves (e.g. altitude, slope, aspect) whereas others will come from existing spatial layers (e.g. climate variables, soil types). The modelling approach will include a spatial constraint following Miller & Franklin (2002). This helps account for known spatial dependencies in vegetation pattern.

Accuracy and error of the modelled forest and shrubland class map will be assessed using the proportion of correctly classified units (PCC), kappa, and omission and commission errors, following Blackard et al. (2008).

We also expect that there will be a certain degree of uncertainty in our predicted mapped distributions. Uncertainty may arise in this exercise for a range of reasons (see Blackard et al. 2008; Vogiatzakis & Griffiths 2006) including (a) spatial characteristics of a vegetation class that make it hard to model, (b) poor quality predictor data, (c) weak relationships between the predictor variables and the forest classes, (d) bias in the geographic representation of the NZCMS data because of the inability to obtain permission to sample forests and shrublands on private land, (e) the existence of transitional vegetation classes, and (f) high spatial heterogeneity. We will explore a range of approaches to produce uncertainty maps including (a) mapping the probability of prediction of the particular forest class that was mapped for a pixel, (b) producing percent error maps following Blackard et al. (2008), and (c) indicating 'fuzzy boundaries' where pixels are predicted to represent more than one forest/shrubland class. We expect this last map will be especially useful. It is well recognised that species are distributed individualistically along environmental gradients and so do not occur in discrete, sharply bounded community classes. We classify vegetation as 'classes' to provide an aid to understanding the nature of species co-occurrence patterns across the landscape, as many co-occurrence patterns are repeated. At the same time we recognised that boundaries between communities are artificial and arbitrary human constructs. The depictions of fuzzy boundaries thus allow communities to be mapped, but make maps more ecologically realistic.

CART analysis has been most widely used in ecology to predict distribution patterns of individual species, and less frequently to predict fire occurrence. Although not a frequent application of CART analysis, the approach has been used successfully for extending plot-derived forest classifications to mapped areas in the interior west (Arizona, New Mexico, Wyoming) of the United States (Ruefenacht et al. 2004), and a 38 500-ha area in the White Mountains of Crete (Vogiatzakis & Griffiths 2006).

Higher resolution data (i.e. data from existing vegetation plots stored in NVS, previous regional classifications developed by the NZ Forest Service, PNAP programme, DSIR; Regional Vegetation Maps (e.g. Tongariro National Park, Stewart Island)) can be used to refine the classification to provide better resolution for different forest classes. CART analysis can be used to apply the NZCMS classification to the tens of thousands of existing plots with data stored in the NVS Databank. The predictor variables will be the abundances of different species that occur on these plots. The CART algorithm will then be applied to plots in the NVS Databank that contain plant abundance data. The plots in NVS will require 'taxonomic scrubbing' to ensure that consistent nomenclature is used. NVS plots that are well predicted to belong to a forest/shrubland class will be used to more clearly resolve and describe variation within the class and to depict its geographic location. Plots that are poorly predicted may represent classes that were too rare to be depicted by the NZCMS classification (e.g. kauri forest), as we discovered in doing the fine-scale analysis of the SWEMP data. Further analysis of NVS data may be required to define these classes.

A pilot project should be done to map a finer resolution classification for (a) the central North Island and (b) western Southland using the techniques outlined above.

This work will also allow the error in the forest and shrubland class map we produce to be assessed with plot data.

5. Conclusions

New Zealand needs a systematic framework for reporting upon the range of biodiversity and ecosystem indicators (Lee et al. 2005). We present a robust vegetation classification based on summed cover in 1177 vegetation plots systematically located in New Zealand forest and shrublands. These data were collected as part of the New Zealand Carbon Monitoring System.

The OPTIMCLASS routine identified the beta-flexible clustering method (computed using PC-ORD) using a Manhattan (Sorenson's) distance measure and Recce class values as importance values, as the clustering method that maximised the number of diagnostic species occurrences in the classification. In total, 24 forest and shrubland classes were recognised, each comprising 19–105 plots from the total of 1177 NZCMS plots analysed.

We provide detailed information to interpret the resulting classification. We based our names on the system advocated by the International Vegetation Classification. We produced a tree diagram to illustrate the clustering pattern. We produced a synoptic table to summarise species distributions and abundance across the classes. We graphed means and standard errors of a range of environmental parameters collected with the plot data (altitude, slope, mesotopographic index) and derived from GIS layers (mean annual temperature, minimum temperature, October vapour pressure deficit), and features of the vegetation (mean canopy height). We used ArcView to produce maps showing the geographic distribution of the vegetation classes. We then described each vegetation class.

We recognised seven shrubland classes. These range from successional classes to montane and subalpine shrublands.

We grouped the forest classes into species-group types to allow ready comparison with previous classifications. Four classes were designated as beech forest, five as beech–broadleaved forest, four as beech–broadleaved–podocarp forest, two as broadleaved forest and two as broadleaved–podocarp forest.

DCA, CCA and MANOVA analysis showed the mappable parameters of mean annual temperature, minimum temperature, northing, and easting to be most strongly related to the compositional variation among the 1177 NZCMS plots. These are likely to be the most useful parameters for mapping, with the others being of secondary importance.

Differences between our classification and previous classifications of New Zealand forests and shrublands can be attributed to five major aspects: the use of species groups rather than individual species in previous classifications (e.g. lumping all podocarps, all beeches, or all broadleaf species together, lumping a range of shrubs into 'grey scrub'), the nature of the underpinning ground-based data, inferring composition from canopy appearance in aerial photos and satellite imagery, scale of the mapping, and actual changes in land cover through forest and shrubland removal or succession; our classes may vary in the relative proportion of the grouped species. Further, all of the previous classification give disproportionate emphasis on large, canopy emergents (e.g. kauri, podocarps), which may be scattered and actually comprise a relatively low portion of total cover or basal area.

The distinction made in our classification between forest and shrublands (or forest and non-forest) is progressively better matched by the Forest Class Maps, Vegetative Cover Map, ECOSAT woody classification and LCDB2 (Table 7). At a species-group category level, our beech forest classes map well onto previous classifications; whereas there are more discrepancies with the other groups.

Classes that were recognised in previous classifications that are rare according to their representation in the NZCMS plots are Kauri, Kauri–Softwood–Hardwoods–Beeches, Rimu–Taraire–Tawa, and Taraire–Tawa (Forest Class Maps). Podocarp forest, Highland-podocarp–broadleaved forest (Vegetative Cover Map), Coastal forest (ECOSAT) and Kahikatea–mataī/tawa–māhoe forest, Kahikatea–pukatea–tawa forest, and Mataī–kahikatea–tōtara (Leathwick 2001).

A classification that incorporated non-vascular species had closer correspondence to the vascular-species-based classification than one based on woody species alone.

Grids of different sizes were superimposed on data collected in the SWMEP study to examine the influence of scale of resolution on the classification. The classification based on the 4-mile grid provided very similar results to the NZCMS-based classification in forest class recognition and provided finer resolution within the Mānuka shrubland class recognised by

NZCMS. Grids of 1 mile and 2 mile allowed finer divisions within classes based on a 4-mile grid to be recognised. Including all plots from the survey identified six classes that contained none of the 158 plots from the 4-mile grid. This demonstrates how finer resolution data stored in the NVS Databank might be used to refine the NZCMS-based classification of forests and shrublands.

Finally, an approach based on the use of Classification and Regression Tree (CART) analysis is outlined to both map the classification across New Zealand and refine it using additional data stored in the NVS Databank.

6. Recommendations

With the classification based on the 1177 NZCMS plots completed, the next phase is to map this classification. This would be most effectively done using boosted regression trees to develop relationships between the presence and absence of each forest/shrubland class and mapped predictor variables. Four classes of predictor variables would be used: climate variables, topographic variables, SPOT 5 satellite imagery, spatial layers representing disturbance (e.g. earthquake frequency). A spatial constraint will be included. The area mapped will be that defined as forest or shrubland by LCDB2. This should be funded by DOC as a joint DOC–Landcare Research collaboration.

It will be important to quantify the error of the resultant maps. This should be done in four ways:

- Map cumulative error in predictor variables
- Map where boundaries between classes are fuzzy, i.e. locations where more than one class is predicted to occur above a threshold level of probability
- Map areas where no class is predicted to occur above a threshold level of probability
- Map areas where existing data (plot data in the NVS Databank) differ in composition from the predicted mapped class.

Additional statistics should be calculated for each of the forest/shrubland classes including those that utilise other data collected by the NZCMS. These will include (a) stand basal area and density; (b) basal area and density of dominant tree species; (c) size class distribution of dominant tree species; (d) threatened species based on Hitchmough et al.'s (2007) recently updated list; (e) relevant indicators as outlined by Lee et al. (2005). These statistics will be used to ensure that the broad categorisation of the classes into groups such as 'Beech forest' or 'Beech–broadleaved–podocarp' forest is accurate This should be jointly funded by DOC and MAF.

Higher resolution data (i.e. data from existing vegetation plots stored in NVS, previous regional classifications developed by the Forest Service, PNA programme, DSIR; Regional Vegetation Maps–e.g. Tongariro National Park, Stewart Island) should be used to refine the classification to provide better resolution for (a) kauri forest, (b) beech forest, (c) forests containing *Libocedrus,* (d) beech forest in western Southland, and (e) beech forest in the central North Island. These areas have been chosen because they are of high interest to MAF for underpinning indigenous forest management. The NVS data component will involve using boosted regression trees to best predict class membership of NVS plots on indicator species for the NZCMS-derived forest/shrubland classes. This should be jointly funded by DOC and MAF.

NVS plots that are well predicted to belong to a forest/shrubland class will be used to more clearly resolve and describe variation within the class and to depict its geographic location. Plots that are poorly predicted may represent classes that were too rare to be depicted by the NZCMS classification (e.g. kauri forest). Further analysis of NVS data may be required to define these classes.

A comparison, such as that undertaken on a national scale, with regional vegetation maps (e.g. Tongariro National Park (Atkinson 1985) and Stewart Island (Wilson 1994)) should be made to determine how well the national classification performs at a regional scale.

A pilot project should be done to map a finer resolution classification for (a) the central North Island and (b) western Southland using the techniques outlined above.

A consideration of whether an 8-m cutoff to assign classes to forest versus shrubland is needed. We followed Atkinson (1962), which resulted in a generous assignment of classes to shrubland. In contrast LCDB and several regional councils frequently use a cutoff height of 6 m.

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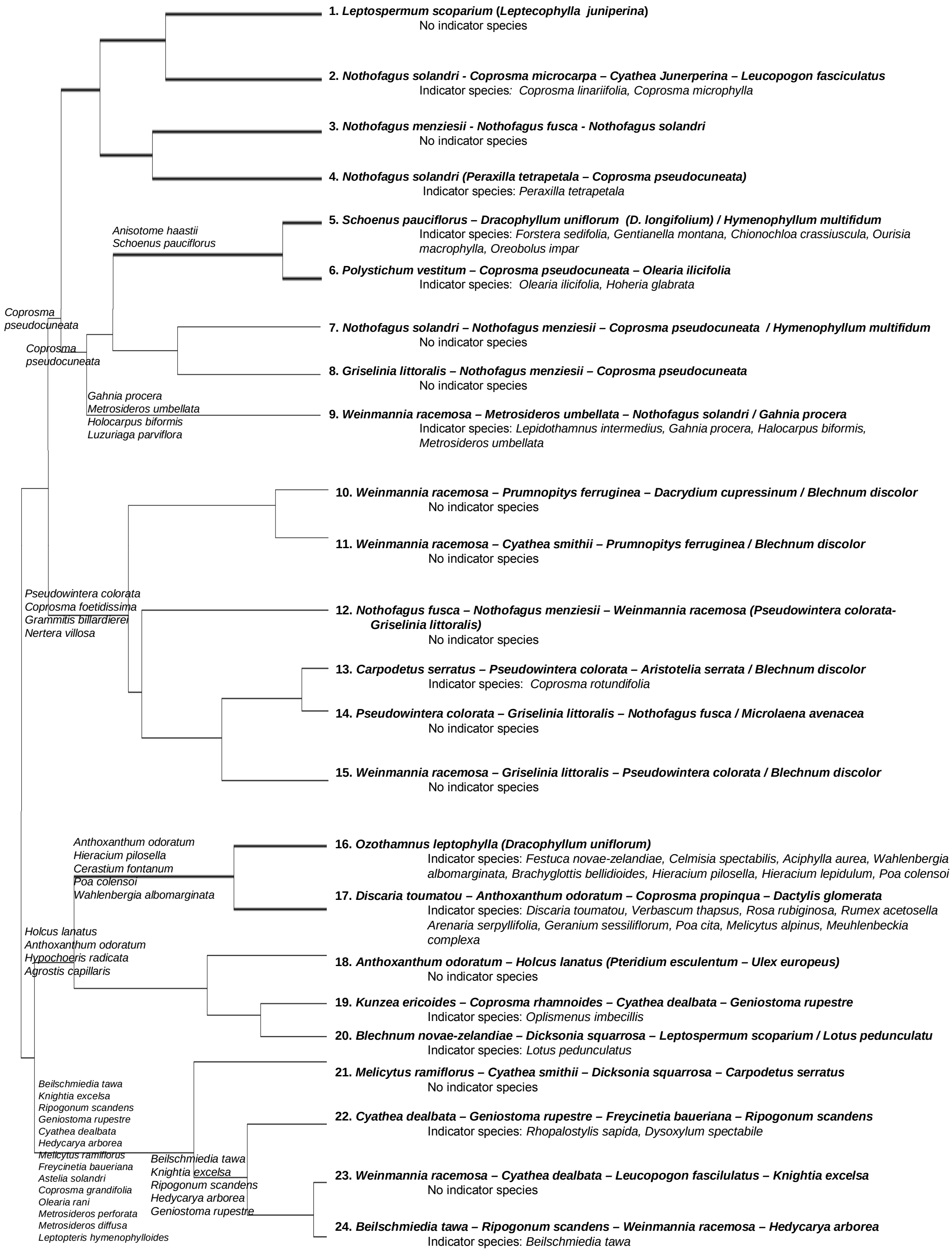
Appendix 1

Tree diagram for the classification of 1177 CMS plots into 24 classes, showing scientific names and indicator species



Appendix 2

Synoptic table summarises species distributions and abundance across the 24 classes based on 131 species that have high dominance, constancy, or diagnostic value. Classes are ordered to most clearly display the transitions is species composition among the classes.

Appendix 2. Synoptic table summarises species distributions and abundance across the 24 classes based on 131 species that have high dominance, constancy, or diagnostic value. The mean cover (calculated across all plots within each type) is shown followed by the constancy of the species within the class (i.e. the percentage of plots in the class where the species was present). Average cover values ≥ 5% are highlighted purple, and constancy values ≥ 50% yellow. All species shown have cover ≥ 5% in any one or more classes, or have constancy ≥ 30% in one or more classes, or were considered a diagnostic species for a class. Diagnostic utility was determined from the combined constancy and fidelity ranks, with preference for those species distributed across fewer classes. '+' indicates the species was present but had cover <1% and constancy <30%.

Vegetation class→	Ozothamnus–Dracophyllum montane shrubland (steep) [South Island] 16	Schoenus–Dracophyllum subalpine shrubland [South Island] 5	Matagouri shrubland [South Island] 17	Kānuka forest and tall shrubland 19	Sweet vernal–Yorkshire fog successional shrubland 18	Mānuka shrubland 1	Wheki–mānuka shrubland [mostly North Island] 20	Black/mountain beech forest 2	Black/mountain beech forest (subalpine) [South Island] 4	Silver beech–red beech–black/mountain beech forest [South Island] 3	Hard fern–Coprosma pseudocuneata subalpine shrubland and low forest [South Island] 6	Black/mountain beech–silver beech forest and subalpine shrubland 7	Broadleaf forest 8	Kāmahi–Southern rātā forest and tall shrubland [South Island] 9	Kāmahi–podocarp forest [South Island] 10	Kāmahi forest 11	Silver beech–red beech–kāmahi forest 12	Pepperwood–hardwood forest and successional shrubland 14	Kāmahi–hardwood forest 15	Matbleaf–pepperwood–wineberry forest 13	Kāmahi–silver fern forest [mostly North Island] 23	Tawa forest [mostly North Island] 24	Māhoe forest 21	Silver fern–hangehange forest (short) [North Island] 22
Dracophyllum uniflorum	10 55	8 79	.	.	.	+	.	.	.	.	2	+	.	+	.	.	.	.	.	.	.	.	.	.
Ozothamnus leptophyllus	4 74	+ 37	+	+	+	+	+	+	.	.	.	+	+	+	.	.	.	.	+	+	+	.	.	+
Festuca novae-zelandiae	2 74	.	6 47	.	+	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.
Celmisia spectabilis	2 55	.	+	.	+	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Aciphylla aurea	1 55	+	1 13	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia albomarginata	+ 84	+ 32	+ 50	.	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.	.
Brachyglottis bellidioides	+ 52	+	+	.	.	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium lepidulum	2 74	.	4 33	.	+	+	.	+	+	.	+	+	+	.	.	.	.	.	.	+	.	.	.	.
Poa colensoi	3 84	+ 47	1 50	.	+	+	.	+	.	.	+	+	.	+	.	.	.	.	+	.	.	.	.	.
Hieracium pilosella	3 84	.	11 73	.	+	+	+	+	.	.	.	+	+	.	.	.	.	.	.	+	.	.	.	.
Cerastium fontanum	+ 65	.	2 87	+	+ 61	+	+	.	.	.	+	+	.	.	.	+	+	.	.	+	.	.	+	+
Schoenus pauciflorus	2 29	11 84	+	.	+	.	.	.	.	.	+ 44	+	+	+	.	.	.	.	+	.	.	.	.	.
Dracophyllum longifolium	5 32	6 68	.	.	.	+	.	.	+	.	6 48	+	2 30	4 69	+	.	.	+	+	+	.	.	.	.
Chionochloa crassiuscula	.	6 58	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Dracophyllum menziesii	.	3 58	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.
Anisotome haastii	+	2 68	.	.	.	.	.	.	.	.	+ 36	+	.	.	.	.	.	.	.	.	.	.	.	.
Myrsine nummularia	+	2 84	.	.	.	.	.	.	+	.	+ 32	+	+	.	.	.	.	+	.	.	.	.	.	.
Gentiana montana	+	+ 79	.	.	+	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.
Forstera sedifolia	+	1 74	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Ourisia macrophylla	+	1 74	.	.	.	+	.	.	.	.	+	+	+	.	.	.	.	+	.	.	.	.	.	.
Coprosma perpusilla	+	+ 58	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	+
Oreobolus impar	+	+ 53	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.
Carpha alpina	.	+ 53	.	.	.	+	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.
Discaria toumatou	+	.	29 90	.	2 10	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coprosma propinqua	4 45	+	11 83	+	6 36	+ 36	+	+	+	.	.	+	+	.	+	+	+	+	+	3 44	+	.	+	.
Rosa rubiginosa	+	.	6 77	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis capillaris	1 71	+	10 77	+	4 68	+	2 33	+	+	.	+	+	.	.	+	.	.	+	.	+ 36	+	.	.	+
Verbascum thapsus	+	.	+ 63	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rumex acetosella	+ 45	.	1 80	+	+	+	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Arenaria serpyllifolia	+	.	+ 50	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Geranium sessiliflorum	+	+	+ 53	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa cita	+ 32	.	7 70	.	+	+	.	.	+	.	+	+	.	.	.	.	.	.	+	+	.	.	.	.
Melicytus alpinus	+ 48	+	2 77	.	+	+	.	.	.	.	+	+	+	.	.	.	.	.	+	+	.	.	.	.
Muehlenbeckia complexa	+	.	1 63	+	+	+	.	+	.	.	.	.	.	.	+	+	+	.	+	1 12	+	+	.	+
Anthoxanthum odoratum	3 77	+	9 100	1 25	10 76	+	3 74	+	+	.	+	+	+	.	.	.	.	+	.	+ 44	+	.	+	+
Holcus lanatus	+ 52	+	3 97	+	7 92	+	10 82	.	.	.	+	+	.	.	+	.	.	.	.	+ 44	+	.	+	+
Ulex europaeus	.	.	.	6 27	19 39	3 19	2 22	.	.	.	.	.	+	.	+	+	.	.	.	4 20	.	.	+	+
Coprosma rhamnoides	+	.	.	8 75	6 45	+ 45	+ 37	3 86	+	+	+	+	+	+	+ 56	+	1 67	+ 37	1 52	2 84	1 35	+	+ 39	1 30
Dactylis glomerata	+ 39	+	6 83	2 25	4 57	+	3 37	.	.	.	+	.	.	.	.	.	.	.	.	+	+	.	+	.
Kunzea ericoides	6 29	.	+	31 92	9 39	21 48	6 56	5 32	.	.	.	+	+	+	+	+	.	+	.	+	1 15	+	5 21	4 20
Oplismenus imbecillis	.	.	.	3 52	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+ 30
Doodia australis	.	.	.	3 37	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Leptospermum scoparium	10 29	8 32	+	10 58	6 32	21 71	31 78	+	+	+	+	+	+	12 53	2 18	.	.	+	+	3 8	+	+	+	+
Leptecophylla juniperina	+	+	.	+	+	10 58	+	6 82	+	+	+	+	+	3 65	+	.	+	+	+	+	1 20	+	+	+
Gaultheria antipoda	+	+	.	+	+	2 48	+ 37	1 32	+	+	+	1 25	+	+	+	+	+	+	+	+	+	+	.	+
Pteridium esculentum	4 19	.	2 10	4 62	7 45	+ 52	18 70	+	.	.	.	.	.	+	+	+	+	+	.	2 36	+	+	+	+
Pseudopanax arboreus	.	.	+	1 25	+	1 3	12 63	+	.	.	.	.	.	.	.	+	+	+	+	+	1 26	+	+	2 31
Lotus pedunculatus	.	.	+	1 39	2 40	+	6 93	.	.	.	.	.	.	.	+	+	.	.	.	+ 36	+	.	+	+
Hebe stricta	.	.	.	+	+	+	2 63	+	.	.	.	+	.	.	.	.	.	+	.	.	+	.	+	+
Hydrocotyle moschata	.	.	.	+	+	+	+ 63	+	.	.	.	+	.	.	.	+	.	+	.	+ 32	+	.	+	+
Digitalis purpurea	+	.	+ 33	+	1 48	+	1 63	.	.	.	.	.	.	.	.	.	.	+	.	+ 32	+	+	+	+
Senecio jacobaea	+	.	+	+	+ 32	.	1 52	.	.	.	.	.	.	.	.	+	.	+	+	+	+	+	+	+
Paesia scaberula	.	.	.	2 33	2 26	+	2 67	+	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+
Dicksonia squarrosa	.	.	.	1 31	2 26	+	12 85	.	.	+	.	+	+	+	6 86	5 71	1 34	+ 35	5 65	4 44	5 54	10 75	9 67	7 73
Blechnum novae-zelandiae	+	+	.	3 46	2 18	3 32	10 93	.	.	.	+	+	+	1 20	4 51	1 65	+	+ 30	2 38	2 48	3 67	+ 39	+	2 48
Leucopogon fasciculatus	.	.	.	8 73	+	8 48	5 59	11 73	+	+	+	+	+	+	1 22	2 61	2 48	3 42	.	+	8 91	+	2 25	1 44
Coprosma microcarpa	+	+	+	+	+	+ 32	.	7 96	+	+	+	1 22	+	+	+	+	+	+	.	+	+	.	+	+
Coprosma linariifolia	+	.	.	.	+	.	.	3 73	+	.	.	+	+	+	+	+	+	+	+	+	+	.	+	.
Elaeocarpus hookerianus	.	.	.	.	+	+	+	1 59	.	+	.	+	+	4 49	1 43	+	+ 34	2 50	+	+	+	+	+	.
Nothofagus fusca	.	.	.	+	.	+	.	23 55	2 5	46 90	+	6 12	10 28	+	3 14	16 47	33 69	27 63	1 7	16 44	3 9	+	2 12	.
Adenochilus gracilis	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	.	.	.	.
Nothofagus menziesii	.	9 37	.	.	.	+	.	9 36	+	52 100	21 48	28 65	36 77	10 63	6 38	8 49	25 82	28 55	25 62	22 64	2 4	.	+	+
Nothofagus solandri	1 13	4 16	.	+	2 2	+	+	56 100	76 100	29 63	10	45 80	6 27	16 69	3 15	+	9 30	4 18	2 10	4 16	13 37	+	+	.
Podocarpus nivalis	4 32	+	+	.	.	+	.	.	3 20	.	5	+	+	.	.	.	.	+	.	.	.	.	.	.
Peraxilla tetrapetala	.	.	.	.	.	.	.	+	+ 40	.	.	+	+	+	.	+	+	.	+	+	.	.	.	.
Phormium cookianum	3 36	3 74	+	+	+	+	+	.	.	.	6 56	+	+ 30	+ 31	+	.	+	+	+	+	+	.	+	+
Polystichum vestitum	2 58	1 42	+ 30	+	+ 37	+	+	+	+	+	30 96	2 68	5 59	+	+	+	+	2 48	3 63	3 76	+	+	+	+
Olearia ilicifolia	+	+	.	.	+	.	.	.	.	.	6 64	+	+	.	+	.	+	+	+	.	.	.	.	.
Coprosma ciliata	2 39	2 37	+	.	+	.	.	+	+	.	4 68	+ 42	1 56	+ 31	+ 49	+	+	+	2 68	2 48	.	.	.	.
Hoheria glabrata	.	+	.	.	+	.	.	.	.	.	5 60	+	+	.	+	.	.	.	+	+	.	.	.	.
Senecio wairauensis	+	+	.	.	+	.	.	.	+	.	+ 44	+	.	.	.	.	.	.	+	+	.	.	.	.
Chionochloa conspicua	+	+	.	.	+	.	.	.	.	.	1 48	+	+	+	+	.	+	+	+	.	.	.	.	1 3
Blechnum penna-marina	1 74	+ 47	+	.	+	+	.	+	+	+	1 60	+ 59	+	+	.	.	+	+	+	+	+	+	+	.
Coprosma pseudocuneata	+	2 53	.	.	.	+	.	+	+ 35	+	6 88	6 75	5 81	+	+	.	+	+	+	.	.	.	.	.
Hymenophyllum multifidum	+	5 74	.	+	+	+	+ 30	+	.	+	3 52	8 71	4 67	1 71	+ 65	+ 57	1 45	2 57	2 65	+ 36	2 67	+ 33	+	+
Phyllocladus alpinus	1 13	+	.	.	+	1 36	.	+	+	.	1	3 59	1 48	7 51	4 48	+	+	2 32	+	.	.	.	.	+
Lagenifera strangulata	+	.	+	.	+	+ 32	.	+ 59	+	.	+ 40	+ 54	+	.	.	.	+	+	+	+ 40	.	.	+	.
Griselinia littoralis	2 45	1 21	+	+	2 24	1 71	+	4 86	+	+	2 44	3 59	11 92	3 86	4 94	3 90	3 90	7 93	9 95	4 84	+ 33	2 42	2 46	+
Coprosma foetidissima	.	+ 32	.	+	+	1 26	.	1 36	.	+	+ 40	2 42	5 92	4 98	5 96	1 69	2 78	4 67	4 90	+	+	+	+	+
Raukaua simplex	.	+	.	+	+	+	+	+ 36	.	+	+ 32	+ 49	3 89	3 88	2 77	+	1 62	2 58	4 80	+	+	+	+	+
Uncinia filiformis	.	+	.	.	.	.	+	.	.	+	+ 44	+	1 63	+ 41	+	+	+	+	+ 33	+	+	+	+	+
Pseudopanax linearis	.	+	.	.	+	+	.	.	.	.	+	+	1 56	2 57	+	.	+	+	+	.	.	.	.	.
Metrosideros umbellata	.	+	.	+	+	+	.	.	.	.	+	+	6 38	13 94	8 66	.	2 21	+	7 49	+	+	.	.	.
Gahnia procera	.	+	.	+	.	1 3	.	.	.	.	.	.	+	8 71	2 17	+	+	+	.	.	+	.	.	+
Lepidothamnus intermedius	.	+	.	.	.	+	.	.	.	.	.	.	.	17 57	+	.	.	.	.	.	.	.	.	.
Halocarpus biformis	.	2 16	.	.	+	2 3	.	.	.	.	.	+	1 13	7 61	+	.	.	+	+	.	.	.	.	.
Luzuriaga parviflora	.	+	.	.	.	.	+	.	.	.	.	+	+ 31	1 76	+ 54	+	+	+ 35	+ 32	+	.	.	+	.
Archeria traversii	.	+	.	.	.	.	.	.	.	.	3 36	1 17	4 48	4 57	+	+	+	.	+	.	.	.	.	.
Coprosma colensoi	.	+	.	.	+	+	.	1 27	+	+	+	+	2 69	3 90	1 63	1 41	+ 43	2 40	1 65	+	+	+	+	+
Dacrydium cupressinum	.	.	.	+	.	+	+ 30	+	.	.	.	.	+	5 47	15 94	7 74	+ 30	1 22	+	+	3 59	3 45	3 23	2 34
Pseudopanax crassifolius	+	.	.	+	+	1 48	2 59	2 96	+	+	+	+	+	+ 33	2 90	2 51	1 73	1 45	1 56	1 80	3 78	1 52	+ 48	3 59
Prumnopitys ferruginea	.	.	.	+	+	+	.	+	.	.	.	+	+	+ 33	9 98	6 92	2 51	1 43	1 43	+ 32	2 61	2 65	3 31	2 43
Blechnum discolor	+	.	.	+	+	+	4 48	5 36	.	+	+	+	+	3 49	19 86	23 94	36 94	6 62	17 85	13 76	9 74	7 70	1 39	2 41
Weinmannia racemosa	.	.	.	1 15	+	3 26	8 70	1 14	.	.	+	+	3 28	15 96	33 100	33 98	24 72	4 45	22 88	3 36	19 91	18 88	2 48	4 28
Quintinia acutifolia	.	.	.	.	.	+	.	.	.	.	.	.	+	1 8	11 44	+	7 20	.	3 15	+	.	.	+	.
Ixerba brexioides	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	15 51	.	+	.	.	4 33	3 26	+	1 11
Pseudowintera axillaris	.	.	.	.	.	.	+	.	.	+	.	.	+	.	+	6 74	+	+	+	.	1 33	3 54	+	+
Myrsine salicina	.	.	.	+	.	1 7	+	+	.	.	.	.	+	+	4 33	7 63	2 15	2 17	+	+	2 11	+	+	+
Astelia solandri	.	.	.	+	.	+	+	+	.	.	.	+	+	.	+	1 82	+	+	+	+	1 76	1 73	+ 42	1 73
Dicksonia lanata	.	.	.	.	.	.	.	3 9	.	.	.	.	.	.	+	6 35	+	7 22	.	.	.	+	.	+
Nothofagus truncata	.	.	.	+	+	.	.	+	.	.	.	+	.	+	4 12	9 22	12 25	+	.	2 4	13 35	1 3	.	+
Carpodetus serratus	+	.	.	+	2 36	+	4 67	4 82	.	.	+	+	+	+	2 50	4 76	2 63	5 72	5 80	5 84	1 59	1 51	7 77	2 35
Aristotelia serrata	.	.	.	+	+	.	+	+	.	.	3	+	+	+	+	+	+	1 30	1 42	7 76	+	+	4 39	+
Fuchsia excorticata	+	.	+	+	+	.	+	+	.	.	+	+	+	.	+	+	+	2 17	3 53	6 72	+	+	+	+
Coprosma rotundifolia	.	.	.	+	+	+	.	.	.	.	.	+	+	+	+	+	+	+	1 28	3 80	+	.	+	+
Muehlenbeckia australis	+	.	+	+	+ 32	.	+	+	.	.	+	+	+	.	+	+	+	+	+	2 60	+	+	+	+
Pennantia corymbosa	.	.	.	+	+	.	+	.	.	.	.	+	.	.	+	+	+	+	+	1 36	+	+	2 39	+
Cyathea smithii	.	.	.	+	1 13	+	4 56	.	.	+	+	.	+	+	7 69	11 74	2 46	2 47	19 83	6 72	3 33	12 71	8 75	5 39
Pseudowintera colorata	.	.	.	.	+	2 13	1 7	+ 50	+	+	+	+	4 53	1 35	2 65	5 67	3 66	30 97	10 93	8 76	+	+	5 31	+
Microlaena avenacea	.	.	.	+	+	+	2 44	+	.	+	+	+	2 28	+	2 57	3 76	+	13 75	2 54	1 56	1 70	3 77	4 64	2 51
Neomyrtus pedunculata	.	.	.	.	+	+	.	2 32	.	+	.	+	+	+ 43	5 77	+	+ 34	8 58	+	1 48	+	.	+	.
Nertera villosa	.	+	.	.	+	+	+	+	.	.	+ 36	+	+ 63	+ 41	1 85	+	+ 50	1 37	2 94	1 48	+	+	+	.
Nertera depressa	.	+	.	+	+	+	+ 30	+	.	.	.	+	+	+ 37	1 69	+	+	+	1 79	+ 48	+	+	+	+
Melicytus ramiflorus	.	.	.	4 67	3 39	+	2 70	+	.	.	.	.	+	.	+	3 47	+	+	4 30	5 28	2 54	9 96	22 100	12 90
Beilschmiedia tawa	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	10 41	+	+	.	.	13 63	42 99	25 56	17 73
Pyrrosia eleagnifolia	.	.	.	+	+	+	+	+	.	.	.	.	.	.	+	+	+	+	+	+	+ 35	+	+ 56	+ 39
Cyathea dealbata	.	.	.	8 69	+	.	6 37	+	.	.	.	.	.	.	+	2 35	+	+	+	.	12 83	17 70	5 62	23 89
Freycinetia baueriana	.	.	.	+	+	.	+	.	.	.	.	.	.	.	5 20	4 18	+	.	+	+	4 48	10 67	+	17 85
Rhopalostylis sapida	.	.	.	3 39	+	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	+ 30	+	+	12 84
Geniostoma rupestre	.	.	.	7 75	+	.	2 82	.	.	.	.	.	.	.	.	+	+	+	.	.	5 74	2 86	2 54	10 95
Dysoxylum spectabile	.	.	.	1 14	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	8 51
Blechnum filiforme	.	.	.	+	+	.	+	.	.	.	.	+	.	.	.	+	.	.	+	.	+	2 44	+	3 70
Asplenium oblongifolium	.	.	.	+	+	.	+	.	.	.	.	.	+	.	.	+	.	+	+	+	+	+ 44	+	+ 61
Metrosideros perforata	.	.	.	+	+	.	+ 37	.	.	.	.	.	.	.	2 25	2 18	+	.	+	.	2 50	3 70	+	3 74
Laurelia novae-zelandiae	.	.	.	+	+	.	+	.	.	.	.	.	.	.	+	+	.	.	.	.	+	1 23	+	5 44
Knightia excelsa	.	.	.	1 23	+	.	2 52	.	.	.	.	.	.	.	.	+	+	.	.	.	10 83	6 75	3 60	8 83
Olearia rani	.	.	.	+	+	.	2 59	+	.	.	.	.	.	.	.	+	+	+	.	.	3 72	4 52	1 27	5 61
Hymenophyllum sanguinolentum	.	.	.	+	.	+	+ 30	+ 32	.	+ 32	+	+ 31	+ 33	+	+ 36	1 55	+	2 60	+	+ 32	1 70	+ 39	+ 33	+ 38
Ripogonum scandens	.	.	.	+	+	+	1 33	+	.	.	.	+	.	+	2 65	2 59	+	+	1 24	+	2 80	13 99	8 69	9 94
Hedycarya arborea	.	.	.	2 44	+	+	+ 44	+	.	.	.	.	.	.	2 43	2 53	+	+	2 24	1 20	1 76	12 94	6 69	9 93
Lastreopsis hispida	.	.	.	.	.	.	+	.	.	.	.	+	.	.	+	+	+	+	+	+	+	+ 57	+	+ 49