Desk-top assessment of native vegetation on New Zealand sheep and beef farms

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Cover photo: Regenerating tōtara and kahikatea in farmland, Ruapehu District (all photos in this report are taken by David Norton on sheep and beef farms).

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Forest remnant, Kaipara District.

Glossary of terms

DOC – Department of Conservation.
GIS – Geographic Information System.
LCDB – Land Cover Data Base.
LENZ – Land Environments of New Zealand.
LiDAR – Light Detecting and Ranging (remote sensing tool used to measure a land surface).
LINZ – Land Information New Zealand.
LUCAS – Land Use and Carbon Analysis System (a spatial land use database).
Public conservation land – publicly owned land managed by DOC.

Regenerating shrubland and forest, Hurunui District.

Executive summary

1. This study is a desk-top assessment of the amount of native vegetation (forest, shrubland, grassland and wetland) and especially native woody vegetation (including old growth forest and regenerating forest) that occurs on sheep and beef farms in New Zealand.

Key findings

2. Sheep and beef farms contain the second most important amount of the remaining native vegetation in New Zealand after public conservation land. Specifically:

- Sheep and beef farms contain 25% of the total native vegetation remaining in New Zealand, comprising 2.8 million ha.
- Half of the native vegetation that occurs on sheep and beef farms (1.4 million ha), is woody. This represents 17% of the total native woody vegetation remaining in New Zealand.
- The native woody vegetation on sheep and beef farms is particularly important because it typically occurs in those parts of New Zealand with the least remaining native woody vegetation (and the least public conservation land), especially at lower altitudes and in drier regions.

3. The large amounts of native vegetation and especially native woody vegetation on sheep and beef farms is likely to reflect a range of factors including the areas where sheep and beef farms occur (often steeper more remote country where some forest escaped early clearance), the extensive grazing patterns that characterises much of sheep and beef farming, and the values that farmers have placed on retaining such forest.

4. Native woody vegetation on sheep and beef farms is an important resource for biodiversity conservation in New Zealand because it occurs in those areas where there is the least public conservation land.

Recommendations

5. While wetland vegetation is present across sheep and beef farms nationally, the mapping scale we were working at was too coarse to be able to draw definitive conclusions on the amount present and will require smaller-scale approaches to quantify.

6. Further work is required to quantify historic patterns of change in native vegetation cover. Apart from some fairly general large-scale analyses, and an abundance of anecdotal observations, we know little about changing native vegetation cover on sheep and beef farms through time. This work is important to understand the priorities and to support work with sheep and beef farmers to better manage the remnants of native vegetation they have on their farms.

7. Exclusion of grazing animals (farmed and feral) is the single most effective thing farmers can do to sustain and enhance the remnants of native woody vegetation on their properties.

Introduction

Beef + Lamb New Zealand, as part of the development of the environmental strategy for the sheep and beef sector, sought to gain an understanding of the current amount and type of native vegetation on sheep and beef farms across New Zealand. While public conservation land accounts for about one third of the total land area, it is biased towards upland and mountainous parts of the country (Leathwick et al. 2003). In contrast, sheep and beef farms typically occur in areas where there is less public conservation land and in some parts of New Zealand there are substantial amounts of native vegetation present on these farms.

In this study, we quantify how much and what types of native vegetation is present on sheep and beef farms. We did this using a desk-top analysis of native vegetation associated with different land use sectors at national, regional and district scales. In this report, we only present information on national and regional scales.

Forest remnant, Mangakura, Auckland.

Methods

We used land cover data derived from remote sensing to assess the amount and type of native vegetation on sheep and beef farms at two spatial scales – regions (as defined by regional council boundaries but combining Nelson and Tasman regions) and nationally for all of mainland New Zealand (Figure 1). Data from territorial authorities (district and city council boundaries) are not presented here. Within these land areas, we discriminated between public conservation land, sheep and beef farms (including pastoral lease properties) and other private land. Conservation land was defined as crown properties managed by the Department of Conservation, with LINZ-managed properties removed as they overlapped with agricultural land use layers. Conservation land also classified as farmland in Agribase was also removed (any farm type except "native" and "other miscellaneous"). Sheep and beef farms were defined by mapping farms identified as sheep, beef or sheep and beef farms in Agribase, and combining with South Island pastoral leasehold properties, obtained from crown property layers. Where land was classified neither in Agribase nor crown property layers, we used primary parcel data and LUCAS data to infer land use type. First, rivers, roads, beaches, coastal rocks and railways were removed, and areas classified as open water by LUCAS were deleted. Privately owned, non-urban, non-council land classified as high producing grassland, low producing grassland, and grassland with woody biomass was assumed to be sheep and beef grazing land. Other land use was divided into arable, dairy, forestry, horticulture, urban and other.

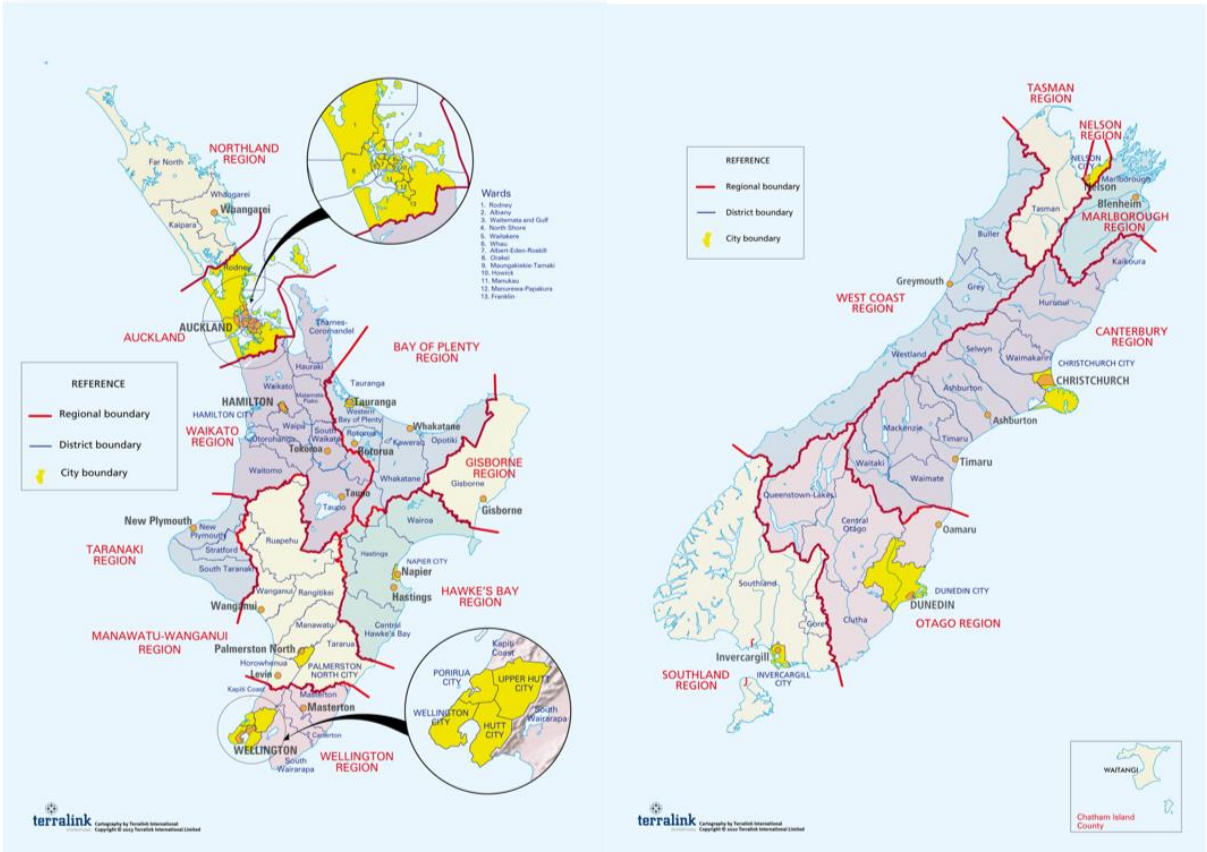


Figure 1. Regional and local authority boundaries.

There is no regional or national vegetation map available for New Zealand and we used the Land Cover Data Base (LCDB version 4.1) as a proxy for vegetation cover (derived from 2012 satellite imagery). We used 10 of these classes to define native vegetation as follows:
Class 15 – Alpine grasses/herbfield
Class 43 – Tall tussock grassland
Class 44 – Depleted grassland
Class 47 – Flaxland
Class 50 - Fernland
Class 52 – Mānuka and/or kānuka
Class 54 – Broadleaved indigenous hardwoods
Class 55 – Sub alpine shrubland
Class 58 – Matagouri or grey shrubland
Class 69 – Indigenous forest

Using GIS, we then calculated the total area of all the native vegetation cover classes on public conservation land, sheep and beef farms and other land use types.

Given that most sheep and beef farms would have been forested prior to European settlement (excepting some of those in the eastern South Island high country), we then focused on the forest and potential forest classes (mānuka/kānuka + broadleaved indigenous hardwoods + indigenous forest). As there is no mapping of individual forest types, we used the Land Environments of New Zealand (LENZ) classification as a proxy for broad forest types. At a national scale, we determined the area of each Level I land environment under native forest (as defined above) on public conservation land and on sheep and beef farms for each environment. Then at a regional scale, we did the same but this time for Level II land environments. These analyses provide an insight into how well different forest types (ecosystems) are represented on sheep and beef farms versus public conservation land.

The data presented in this report are reliant on a number of different data bases including national administrative boundaries, and the areas of covered by the different data sets we used (Agribase, LUCUS, LCDB and LENZ data sets). These treat different land/water cover types such as road, lakes and islands slightly differently from each other. While we tried to standardise our data sets as much as possible, the figures for areas might differ slightly from those published elsewhere because of this. Notwithstanding these small differences, we believe that the overall results we present are fundamentally correct.

Results and discussion

Land use

Sheep and beef farming is the most extensive land use in New Zealand, accounting for 40% of the total land area (Table 1). Public conservation land is the second most extensive at 31%. In contrast, dairy farming (10%) and plantation forestry (7%) occupy a substantially smaller area while urban areas account for <1% of the land area nationally. Regionally, sheep and beef farming accounts for a larger proportion of the regional land area than public conservation land in all regions except Bay of Plenty, Nelson/Tasman, West Coast and Southland (Table 1). In the Bay of Plenty, plantation forestry (24%) and other land uses (mainly horticulture; 28%) are unusually high, while in Nelson/Tasman, West Coast and Southland, large national parks (Kahurangi and Nelson Lakes National Parks, Paparoa, Taipoutini/Westland and Aspiring National Parks, and Fiordland and Rakiura National Parks respectively) and other areas of land managed under the Conservation Act account for the dominance of public conservation land.

Table 1. Percentage of land area in different land uses.

Region	Area (ha) of region	Percentage of region's land area in different land uses					
		PCL	Sheep & beef	Dairy	Plantation	Urban	Other
New Zealand	26,732,864	31.0	39.7	10.1	7.1	0.6	11.5
Northland	1,254,033	11.3	40.8	18.7	14.0	0.5	14.6
Auckland	491,639	6.0	34.1	11.9	9.7	8.5	29.9
Waikato	2,459,318	15.5	31.3	28.4	10.6	0.7	13.4
Bay of Plenty	1,225,530	22.4	14.0	11.5	23.7	0.8	27.6
Gisborne	835,947	9.1	62.4	0.5	19.5	0.2	8.2
Hawke's Bay	1,417,695	13.7	52.8	3.3	13.0	0.4	16.9
Taranaki	726,088	19.2	33.8	34.0	4.1	0.6	8.3
Manawatu-Wanganui	2,221,561	17.8	56.0	8.7	5.9	0.4	11.2
Wellington	812,506	16.4	52.8	5.6	7.2	1.9	16.1
Marlborough	1,049,444	27.1	52.2	2.2	7.9	0.2	10.4
Nelson & Tasman	1,007,973	63.3	11.0	5.1	12.5	0.4	7.7
West Coast	2,335,571	84.4	3.5	5.1	2.5	0.1	4.5
Canterbury	4,523,554	25.8	49.0	9.3	1.7	0.4	13.7
Otago	3,187,643	19.2	64.3	4.8	4.0	0.3	7.4
Southland	3,183,858	57.9	25.4	8.7	2.4	0.1	5.5

Based on these data it is clear that despite changes in the nature of land use over recent decades (e.g. declines in the national sheep flock and conversions to dairy farming and viticulture; MacLeod & Moller 2006, Fetzel et al. 2014), sheep and beef farming is still the predominant land use across New Zealand. Although not assessed here, we also know from other research that sheep and beef farming typically occurs at lower elevations and in regions where there is less public conservation land (Mark 1985, Awimbo et al. 1996, Norton 1999, Leathwick et al. 2003).

Native vegetation

Nationally, native vegetation (forest, shrubland, grassland and wetland) covers 43% of New Zealand (Table 2). However, much of the native vegetation present today is very different to what would have been present before human settlement, when ca. 80% of New Zealand was forested. Many of the areas that support native shrubland and grassland today occur in areas that were previously forested. Of the native vegetation present today, the majority (62%) occurs on public conservation land, although a substantial amount (25%) occurs on sheep and beef farms. This 2.8 million ha of native vegetation on sheep and beef farms accounts for about 27% of the total area (10.6 million ha) of all sheep and beef farms.

Table 2. Total native vegetation in different land uses.

Region	% region in native vegetation (area ha*1000)	Percentage of total native vegetation in different land uses					
		PCL	Sheep & beef	Dairy	Plantation	Urban	Other
New Zealand	43.0 (11,490)	61.5	24.5	1.4	2.8	0.0	9.8
Northland	31.5 (395)	31.4	29.7	7.8	7.3	0.0	23.8
Auckland	25.0 (123)	20.0	23.7	3.2	3.9	0.0	49.3
Waikato	26.4 (650)	52.4	23.0	4.3	5.7	0.0	14.6
Bay of Plenty	49.1 (602)	43.4	8.0	3.0	6.7	0.0	38.8
Gisborne	31.7 (265)	27.5	52.7	0.4	7.8	0.0	11.5
Hawke's Bay	33.7 (477)	38.7	20.0	1.1	10.5	0.0	29.7
Taranaki	39.5 (287)	47.2	33.2	4.9	5.4	0.0	9.3
Manawatu-Wanganui	32.9 (731)	51.8	26.7	0.8	3.7	0.0	17.1
Wellington	36.0 (293)	40.2	31.2	0.7	4.1	0.0	23.7
Marlborough	51.4 (540)	47.1	42.1	0.7	3.3	0.0	6.8
Nelson & Tasman	69.0 (695)	86.0	4.8	2.0	2.8	0.0	4.4
West Coast	80.0 (1,868)	93.5	1.6	1.2	1.1	0.0	2.6
Canterbury	33.2 (1,500)	47.9	48.0	0.6	0.5	0.0	3.1
Otago	37.9 (1,207)	40.5	56.1	0.2	0.8	0.0	2.5
Southland	58.3 (1,856)	87.4	8.9	0.3	0.4	0.0	3.1

These figures for native vegetation do not provide any breakdown of the type of vegetation or its quality, but they do indicate that there is still substantial native vegetation across rural New Zealand. The figures for sheep and beef farms do include some of the nearly 200,000 ha of rural New Zealand that is covenanted through the QEII National Trust (openspace.org.nz), of which 54% occurs on sheep and beef farms (about 100,000 ha). However, given that the total area of native vegetation on sheep and beef farms is nearly 3 million ha, the majority (97%) is not covenanted (although some of this might be included under other protective agreements such as through the Ngā Whenua Rāhui programme or under MPI sustainable forestry management plans and permits).

While the amount of native vegetation remaining on sheep and beef farms is impressive, this figure is influenced by the inclusion of substantial areas of native grassland, especially in the eastern South Island (Marlborough, Canterbury, Otago and Southland). Because New Zealand was predominantly forested before human arrival and because most sheep and beef

farms are located in areas that would have been forested historically, the next section focuses specifically on the extent of native woody vegetation in New Zealand as this is where sheep and beef farms can contribute most to biodiversity conservation. Native grassland, the majority of which were induced by Polynesian deforestation, is discussed later in this report.

Native woody vegetation

As a result of some 700 years of human settlement and interaction with our native forests, the area of undisturbed or old growth native forest* is now quite limited over much of New Zealand, especially in the lowlands (Ewers et al. 2006). Despite this, there are substantial areas of native woody vegetation that are in various stages of succession towards a more mature condition after previous disturbances such as logging and earlier farming (e.g. successions through kānuka shrubland on abandoned pasture). There is no consistent national mapping of native forest that allows us to confidently distinguish old growth forest from regenerating forest. The LCDB land cover class 'indigenous forest' includes both regenerating (after past human disturbances such as logging) and old growth forest. For these reasons, we have focused here on all areas of native woody vegetation that are or have the potential to develop into old growth forest which we have defined using the LCDB land cover classes of mānuka/kānuka, broadleaved indigenous hardwoods and indigenous forest. We have, however, excluded matagouri shrubland which is widespread across the eastern South Island, because there is little evidence to suggest that this vegetation type is undergoing a succession towards native forest with much of it induced by fertiliser application.

Nationally, 30% of New Zealand has a native woody vegetation cover (Table 3). This is substantially lower than the ca. 80% forest cover that is estimated to have been present when the first Polynesian settlers reached New Zealand around 1280 A.D (Ewers et al. 2006, Wilmshurst et al. 2008). Of this 8.1 million ha, 65% is on public conservation land (Table 3), 17% on sheep and beef farms and the remaining 18% on other land uses (especially plantation forestry and life-style properties). There is considerable regional variation both in the total amount of native woody vegetation present and in the proportion of this on sheep and beef farms. For example, native woody vegetation comprises only 8.3 and 10.3% of the total Otago and Canterbury land areas respectively, reflecting the widespread forest loss that occurred with Polynesian settlement (Molloy et al 1993). In contrast, the regions with the most native woody vegetation are West Coast and Nelson/Tasman with 63.7 and 60.7% respectively, reflecting the extensive areas of native forest remaining in these regions today (mainly on public conservation land). In other regions, intermediate levels of remaining native woody vegetation reflect more complex forest loss patterns from both Polynesian and European deforestation.

* Old growth refers to forests that retain a mature structure with, depending on location, large trees of beech, rimu, kahikatea, tōtara, kauri, tawa, northern rātā etc dominant.

Table 3. Total native woody vegetation in different land uses.

Region	% region in native woody vegetation (area ha*1000)	Percentage of total native woody vegetation in different land uses					
		PCL	Sheep & beef	Dairy	Plantation	Urban	Other
New Zealand	30.3 (8,106)	65.0	17.1	1.9	3.8	0.0	12.2
Northland	31.3 (392)	31.5	29.9	7.8	7.3	0.0	23.5
Auckland	24.8 (122)	20.1	23.8	3.2	3.9	0.0	48.9
Waikato	25.5 (626)	51.9	23.5	4.5	5.3	0.0	14.8
Bay of Plenty	48.8 (598)	43.5	7.8	3.0	6.7	0.0	38.9
Gisborne	31.2 (261)	27.9	52.6	0.4	7.7	0.0	11.4
Hawke's Bay	31.7 (449)	39.4	19.2	1.1	11.1	0.0	29.1
Taranaki	39.4 (286)	47.1	33.3	4.9	5.4	0.0	9.2
Manawatu-Wanganui	28.2 (627)	53.5	29.0	0.9	4.2	0.0	12.4
Wellington	34.4 (279)	38.7	31.9	0.7	4.3	0.0	24.4
Marlborough	34.2 (359)	57.4	27.3	1.0	4.8	0.0	9.6
Nelson & Tasman	60.7 (612)	85.9	4.7	2.0	3.0	0.0	4.4
West Coast	63.7 (1,487)	92.4	2.0	1.4	1.3	0.0	2.9
Canterbury	10.3 (465)	55.4	38.5	1.0	1.4	0.0	3.7
Otago	8.3 (264)	64.3	27.8	0.7	2.5	0.0	4.7
Southland	40.1 (1,277)	91.5	4.0	0.3	0.5	0.0	3.7

The proportion of remaining native woody vegetation that occurs on sheep and beef farms varies markedly across New Zealand, primarily reflecting the distribution of public conservation land. For example, in the West Coast region, native woody vegetation on sheep and beef farms accounts for only 2% (29,755 ha) of the remaining native woody vegetation, and in Nelson/Tasman region only 5% (28,756 ha), because the majority of native woody vegetation is on public conservation land (national parks, reserves etc) and sheep and beef farms make up a much smaller proportion of these regions. In contrast, sheep and beef farms contain 53% (137,189 ha) of all remaining native woody vegetation in Gisborne region, a region with relatively little native woody vegetation. But for most regions of New Zealand, the proportion of native woody vegetation on sheep and beef farms is about 20-40% of the total native woody vegetation remaining in the region.

Representativeness of woody vegetation on sheep and beef farms

The 1.4 million of native woody vegetation present on sheep and beef farms is important in of itself but only highlights part of the value of sheep and beef farms for biodiversity conservation. Ideally, we would quantify the distribution of different forest types (kauri, rimu-tawa, kahikatea, beech etc) across sheep and beef farms compared to other land uses such as public conservation land. This would provide us with valuable information on the ecological importance of native woody vegetation on sheep and beef farms as it is not the total amount of native woody vegetation that really matters but the type of native woody vegetation present that is critical. However, such national mapping is not yet available. We therefore used the LENZ classification as a proxy for broad forest types. The LENZ classification was developed using abiotic variables representing climate, soil and topography factors that are known to directly influence the distribution of native forest plants and hence

forest types (Leathwick et al. 2003). The 20 Level I land environments provide a broad summary of major ecosystem types in New Zealand and range from northern warm lowlands to the cool moist mountains of Stewart Island (Figure 2). These 20 environments fall into five groups, of which four would have been largely forested (the fifth, comprising LENZ class T, is permanent snow and ice and is not considered further here).

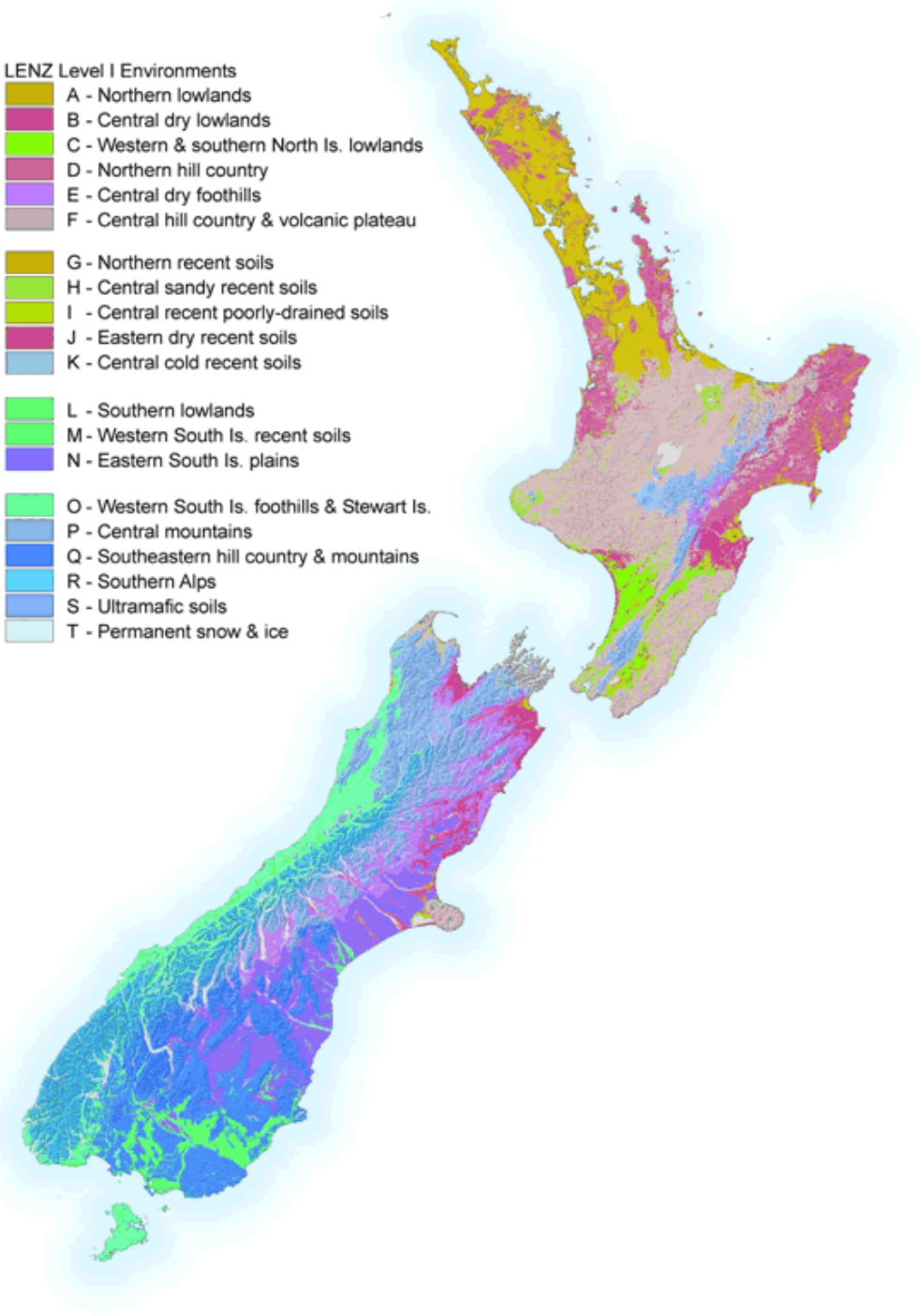


Figure 2. Geographical distribution of the twenty Level I environments (from Leathwick et al. 2003).

The distribution of native woody vegetation by land environments (Table 4) largely follows the patterns of human settlement of New Zealand with the largest proportions of native vegetation remaining in upland hill and mountains areas (e.g. Level I land environments D,

O, P, R) and the least remaining in lowland areas, especially in the east and on recent soils (e.g. Level I land environments B, I, L, M) which are the areas most conducive to primary production and settlement. Of the remaining native woody vegetation in New Zealand, there is proportionally more on public conservation land than on sheep and beef farms in eleven land environments (Table 4). The areas with substantially more native woody vegetation on public conservation land than on sheep and beef farms, are in central and southern upland areas of New Zealand (mean altitude 478 ± 48 m) with substantial amounts of native woody vegetation remaining (13.7-82.9% remaining). In contrast, within the other eight land environments (Table 4; comprising 28% of the New Zealand land area) there is proportionally more native woody vegetation on sheep and beef farms than on public conservation land. These land environments are in the northern and eastern parts of New Zealand (land environments A, B, C, E, G, I, J and N; Figure 2) and are predominantly lowland (mean altitude 147 ± 28 m). These environments also occur in the regions with the least native woody vegetation remaining (Table 3).

Table 4. Distribution of native woody vegetation by land environment across New Zealand.

LENZ class	% LENZ class in native woody vegetation	LENZ class area (ha)	% native woody vegetation on different land uses		
			PCL	Sheep & beef	Other
Northern lowland and hill country					
A	16.6	1,847,606	15.2	35.2	49.5
B	8.8	691,026	7.4	75.4	17.2
C	3.0	635,855	18.9	38.0	43.2
D	44.1	2,097,227	39.0	30.8	30.2
E	27.1	1,323,728	41.5	47.7	10.8
F	35.2	5,238,553	45.4	26.0	28.7
Northern and central recent soils					
G	7.5	336,698	17.0	32.3	50.7
H	32.5	135,198	66.6	10.1	23.4
I	0.5	120,757	8.8	50.2	41.0
J	1.8	292,822	15.7	39.6	44.7
K	9.2	160,743	57.0	17.0	26.0
Southern lowlands					
L	6.5	800,500	55.6	16.7	27.7
M	42.4	220,193	85.5	5.9	8.6
N	0.6	2,044,282	14.2	59.1	26.7
Central and southern hill country and mountains					
O	82.9	1,411,632	90.8	1.9	7.3
P	58.7	3,248,770	80.7	6.4	12.9
Q	13.7	3,271,748	64.3	23.3	12.4
R	41.1	1,925,699	99.7	0.2	0.1
S	32.2	33,458	87.0	7.0	6.0

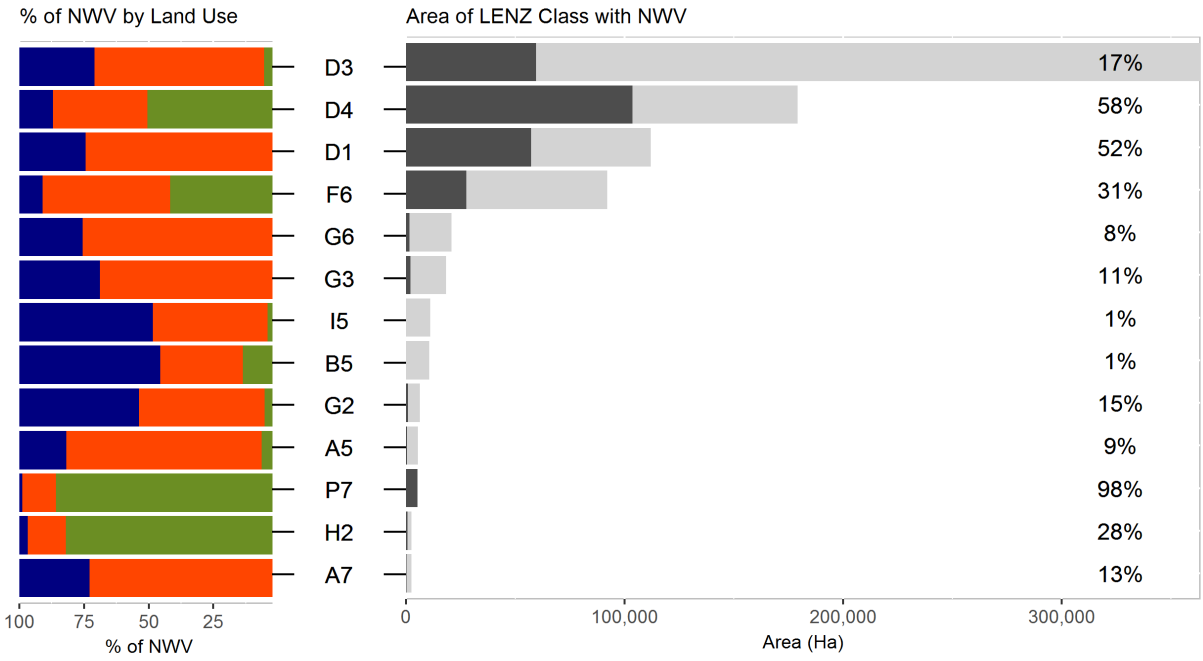
This analysis emphasises how native woody vegetation on sheep and beef farms is important not only in terms of the amount involved (1.4 million ha or 17% of all remaining native woody vegetation), but especially in terms of the types of forest involved and where they

occur. The key finding here is that not only do sheep and beef farms have substantial amounts of native woody vegetation, but this native woody vegetation includes forest types that have been most impacted (cleared) with human settlement and are very poorly represented on public conservation land. Therefore, appropriate management of native woody vegetation on sheep and beef farms is critical for sustaining the full range of forest types in New Zealand, especially in lowland areas where there is the least public conservation land.

The disproportionate importance of native woody vegetation on sheep and beef farms for representing the full range of ecosystems in New Zealand is best seen when looking at some regional examples and using the next level of the LENZ analysis (Level II). This level includes 100 classes and provides a finer-scale depiction of the major ecosystems (forest types) present in each region (which contain 9-15 Level II classes each). The Level II LENZ classes equate well with the major forest types that would have been present in a region historically, although no formal classification of these forest types against LENZ classes has been undertaken. The Gisborne (Figure 3a) and Canterbury Regions (Figure 3b) highlight the patterns at this scale, with the full data presented in the appendix.

Figure 3. *Right hand graph*: Total area (ha) of Level II LENZ land environments in each region (light grey bar) and area currently supporting native woody vegetation (NWV; dark grey bar), also expressed as percentage of the total area of each land environment. *Left hand graph*: Percentage of remaining native woody vegetation (dark grey bars on right hand graph) on public conservation land (green), sheep and beef farms (orange) and other land uses (blue).

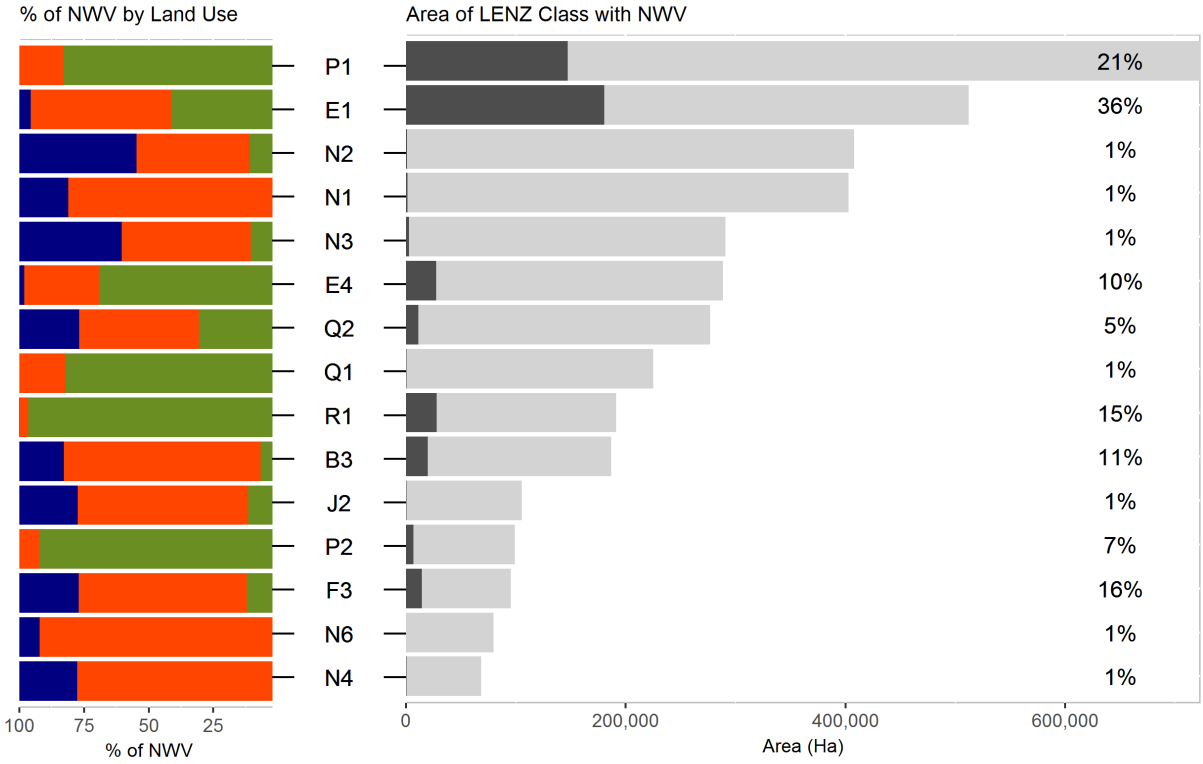
Figure 3a. Gisborne Region



While 31% (257,000 ha) of the Gisborne region (0.8 million ha) comprises native woody vegetation (Table 3), nearly twice as much is on sheep and beef farms (53%, 136,000 ha) than on public conservation land (28%, 72,000 ha). Not only is the total amount of native forest remaining variable between Level II land environments (e.g. <1% in I5 and 58% in D4), but the proportion of this remaining native woody vegetation that occurs on public

conservation land versus sheep and beef farms is also very variable. For example, of the 117,000 ha of remaining native woody vegetation on lower elevation rolling hill country (Level II land environments D3 and D1) the majority occurs on sheep and beef farms (66 and 74 %). In contrast, on higher elevation hill country along the Raukumara Range (Level II land environment D4; 179,000 ha remaining in native woody vegetation) about half of this is on public conservation land (58%) and proportionally less on sheep and beef farms (36%).

Figure 3b. Canterbury Region



Canterbury (4.3 million ha) has a smaller proportional amount of native woody vegetation remaining, comprising only 11% of the regions land area (Table 3), which reflects the long history of deforestation dating back to early Polynesian settlement (Molloy et al. 1963). Of the 0.5 million ha of remaining native woody vegetation, 55% (248,000 ha) is in the public conservation land and only 39% (171,000 ha) on sheep and beef farms. Again, the amount of native woody vegetation remaining is variable between Level II land environments (e.g. <1% in N1, N2 and N3 which occur on the plains and low hills, compared to 35% in E1 which occurs on the dry eastern hill country), as is the proportion of this remaining native woody vegetation that occurs on public conservation land versus sheep and beef farms. For example, on the mountain ranges east of the Main Divide (Level II land environment P1), the majority (84%) of the remaining 723,000 ha of native woody vegetation is on public conservation land. In contrast, on dry eastern hill country (Level II land environment E1), and especially plains and low hills (Level II land environments N1-N3), the majority of the native woody vegetation that remains occurs on sheep and beef farms.

These patterns are repeated around New Zealand (see full data in Appendix) and are supported by analyses of remaining native vegetation at smaller spatial scales (e.g. Awimbo et al. 1996). Typically, the amount of native woody vegetation remaining and the amount that is represented in the public conservation land is greater at higher elevations, on more rugged

topography and in areas with higher rainfall (lower soil moisture deficits). In contrast, at lower elevations, on less rugged topography and in drier areas, there is less native woody vegetation remaining and more of what does remain occurs on sheep and beef farms (and other types of non-public conservation land), than on public conservation land.

The data presented here strongly emphasise the importance of the native woody vegetation that is present on sheep and beef farms in substantially improving the representativeness of the full suite of ecosystems (forest types) that occurred in New Zealand prior to human settlement, especially in those parts of New Zealand with the least remaining native woody vegetation and the least public conservation land. That this woody vegetation is still present on sheep and beef farms is likely due to a range of factors including the areas where sheep and beef farms occur (often steeper more remote country where some forest escaped early clearance), the extensive grazing patterns that characterises much of sheep and beef farming, and the values that farmers have placed on retaining such forest. These factors need to be capitalised on to ensure that native woody vegetation continues to be present across New Zealand's sheep and beef farms.

Lowland forest remnant, Gisborne Region

Wetlands and grasslands

Wetlands (excluding lakes and rivers) are nationally only a minor part of the New Zealand land area, with only a very small proportion on sheep and beef farms (Table 5). Wetlands have been significantly impacted by human settlement, and wetlands are amongst the most reduced of all New Zealand ecosystems with an estimated 10% remaining today (Robertson 2016). Remaining wetlands are most common in Southland, West Coast, Canterbury and Waikato regions. The data bases used in the analyses undertaken here mean that many wetlands (lakes, rivers, estuaries etc) are allocated as 'other' because of their tenure (e.g. land managed by LINZ). In addition, LCDB underestimates the number and extent of wetlands because wetlands are often small and below the mapping resolution. Notwithstanding mapping issues and the low proportion of wetlands on sheep and beef farms, all wetlands with native vegetation have high ecological values and their conservation is a matter of national importance.

Table 5. Total wetland vegetation in different land uses.

Region	% region in wetland vegetation (area ha)	Percentage of total wetland vegetation in different land uses					
		PCL	Sheep & beef	Dairy	Plantation	Urban	Other
New Zealand	2.1 (556,050)	36.3	0.6	2.4	1.6	0.0	59.1
Northland	1.5 (18,801)	14.5	1.9	6.5	6.4	0.0	70.7
Auckland	1.0 (4,872)	24.2	2.0	6.3	1.2	0.5	65.8
Waikato	4.0 (97,846)	16.5	0.5	2.3	2.8	0.0	77.9
Bay of Plenty	2.1 (25,940)	4.0	1.7	2.2	2.6	0.1	89.5
Gisborne	0.1 (1,243)	0.9	4.1	2.1	3.0	0.0	89.8
Hawke's Bay	0.8 (11,151)	5.8	0.6	0.8	0.9	0.0	92.0
Taranaki	0.3 (2,386)	18.7	1.5	17.7	5.4	0.1	56.6
Manawatu-Wanganui	0.4 (9,880)	28.8	1.6	6.4	8.4	0.0	54.7
Wellington	1.4 (11,394)	72.7	1.1	5.7	0.2	0.1	20.2
Marlborough	0.4 (3,998)	23.9	0.8	10.4	1.2	0.0	63.7
Nelson & Tasman	0.8 (8,057)	78.2	1.0	2.0	1.2	0.0	17.6
West Coast	1.8 (41,078)	77.8	1.3	3.2	0.7	0.0	17.0
Canterbury	2.0 (89,890)	10.2	0.2	1.8	0.0	0.0	87.7
Otago	3.1 (99,158)	6.9	0.4	0.8	2.1	0.0	89.9
Southland	4.1 (130,355)	86.9	0.3	2.0	0.3	0.0	10.5

Native grasslands include both those grasslands induced by Polynesian and European burning, and subsequent grazing (O'Connor 1982, McGlone 2001), and natural (usually above the alpine treeline) grasslands dominated by snow tussocks (Mark & McLennan 2005). In total, native grasslands account for 10% of the New Zealand land area today (Table 6), with a significant proportion on sheep and beef farms (45%). Native grasslands are primarily in the South Island, and sheep and beef farms in the eastern South Island hill country and high country (Marlborough, Canterbury and Otago) contain the largest areas of native grasslands. These grasslands vary from dense short tussock dominated grasslands to extensive areas of depleted grassland with remnant short tussocks amongst a matrix of invasive grasses and forbs. Because the majority of these grasslands have been induced

through burning and pastoral management (including many decades of aerial seeding and fertiliser addition), the inter-tussock matrix is often dominated by exotic pasture species (e.g. the grasses browntop, cocksfoot and sweet vernal) and their biodiversity values can be quite low. However, in some areas, especially on young alluvial substrates and in lower rainfall areas, some important native biodiversity is associated with these grasslands. The management of native grasslands below the alpine treeline is complex, with grazing and other management inputs (fertiliser) helping to sustain some native species (such as tussocks) but leading to the loss of others (Norton et al. 2006, Day & Buckley 2013).

Table 6. Total native grassland vegetation in different land uses.

Region	**% region in native grassland vegetation (area ha)**	**Percentage of total native grassland vegetation in different land uses**					
		PCL	**Sheep & beef**	**Dairy**	**Plantation**	**Urban**	**Other**
New Zealand	10.2 (2,736,524)	36.3	44.7	0.1	0.2	0.0	18.7
Northland	< 0.1 (7)	0.0	0.0	99.4	0.0	0.0	0.6
Auckland	0.0 (0)	-	-	-	-	-	-
Waikato	0.5 (11,373)	79.3	6.1	0.0	14.0	0.0	0.6
Bay of Plenty	0.1 (646)	13.5	83.2	0.0	0.0	0.2	3.1
Gisborne	<0.1 (266)	3.5	67.6	0.0	2.7	0.0	26.2
Hawke's Bay	1.6 (23,388)	29.2	32.5	0.0	0.1	0.0	38.2
Taranaki	0.1 (751)	97.9	1.5	0.0	0.5	0.0	0.1
Manawatu-Wanganui	2.8 (62,955)	34.4	15.0	0.0	0.2	0.0	50.4
Wellington	0.5 (4,342)	90.5	2.6	0.0	0.4	0.0	6.4
Marlborough	14.3 (149,653)	27.0	72.5	0.0	0.1	0.0	0.4
Nelson & Tasman	5.9 (59,867)	98.6	0.2	0.0	0.1	0.0	1.2
West Coast	10.4 (243,846)	99.9	0.0	0.0	0.0	0.0	0.1
Canterbury	19.2 (867,887)	44.3	52.6	0.4	0.0	0.0	2.6
Otago	26.3 (836,956)	33.9	64.2	0.1	0.3	0.0	1.5
Southland	14.9 (474,587)	78.1	21.4	0.0	0.1	0.0	0.4

Limitations of the study

Accuracy of results and sources of uncertainty

As our analyses rely heavily on the accuracy of the spatial data layers we used, there is inherent uncertainty in the results. Some of this uncertainty is quantifiable, as is the case for the LCDB and LUCAS layers. The user accuracy of LCDB (i.e., the probability that the class represented on the map matches the land use on the ground) has been estimated at over 93.9% (Dunningham et. al., 2000). The main source of error in the land use data, assuming that cadastral data and Agribase are highly accurate, is likely to be the LUCAS layer. The user accuracy for LUCAS has been estimated at 95.2%. The overall user accuracy for our results, then, we estimate at 89.4% (LCDB user accuracy × LUCAS user accuracy). We expect that our area calculations of vegetation classes are accurate to within 5% of true areas (Dymond et. al., 2016). However, we note that LCDB will miss out small patches of vegetation due to the resolution of the underlying satellite data, but this is unlikely to significantly affect our national or regional results. In contrast, the accuracy of the LENZ data is harder to quantify as it is derived from numerous climatic and environmental data. The main source of error in LENZ is likely to be the underlying soil data, the accuracy of which varies by region according to the coverage of soil surveys. In general, lowland areas surrounding large settlements are the most extensively surveyed. As a result, our LENZ analyses of native woody vegetation should be used as an indicator of general trends rather than accurate predictions of site conditions. Notwithstanding these issues, we conclude that the expected accuracy of our results is high overall.

Lack of spatial and compositional information

This study did not assess either the quality or spatial arrangement of native woody vegetation on sheep and beef farms. It is likely that much of the native woody vegetation we quantified is either modified old growth forest (e.g. after early timber extraction) or successional forest (e.g. dominated by kānuka, mānuka and broadleaved species such as mahoe, lemonwood and other relatively fast-growing short-lived trees). However, with appropriate management, especially exclusion of grazing animals (farmed and feral) these areas will regenerate towards mature native forest (Dodd et al. 2011) and are therefore critical for biodiversity conservation purposes because of where they are located. Furthermore, many of the remnants of native woody vegetation on sheep and beef farms are also small, which reduces their value for biodiversity conservation in of themselves. However, as part of larger landscape level networks including public and private land and restoration sites as well as remnants, these remaining areas, even small ones, can be critical as stepping stones for mobile species such as birds. Therefore, they play a key role in contributing to landscape-level biodiversity outcomes (Norton et al. 2018).

Future research needs

Several areas that could be the focus of future research have been identified in this study. Some of these form part of the Biological Heritage National Science Challenge Project 3.3 '*Enhancing the ecological function of native biodiversity in agroecosystems'* using sheep and beef farming as its focus. The goals of this project include:

- Determining the critical social and cultural factors that influence the way native biodiversity is managed in agroecosystems.
- Quantifying the costs and benefits of retaining existing, and incorporating new, native biodiversity in agroecosystems,
- Determining how the composition and spatial arrangement of habitat in the landscape can enhance functional biodiversity in agroecosystems.

The work reported in this study has used LENZ to quantify the forest types present across sheep and beef farms, but there is an urgent need to upgrade this information to actual forest types. This is potentially best done at smaller spatial scales (e.g. catchments or districts) and could utilise remote sensing technology to help develop vegetation classifications (e.g. using LiDAR and hyperspectral imagery).

A second area where further work is needed is to quantify historic patterns of change in vegetation cover. Apart from some fairly general large-scale analyses (e.g. Wilson 1998, Cieraad et al. 2015), and an abundance of anecdotal observations, we know little about changing native vegetation cover, especially woody vegetation, on sheep and beef farms over recent decades. Having such information would be very helpful in developing strategies to work with sheep and beef farmers to better manage the remnants of native vegetation they have on their farms.

Regenerating shrubland and forest, Banks Peninsula.

Conclusions

This report presents a desk-top assessment of the amount and type of native vegetation that remains on New Zealand sheep and beef farms, focusing on native woody vegetation. While there are errors associated with the spatial data bases that we used for this analysis (Agribase, LCDB, LENZ), the general patterns that we have found are consistent with other studies and provide a good indication of the amount and type of native vegetation present.

The analyses presented here do not provide any information on either the quality of the remaining native vegetation or its spatial arrangement, but we have commented on these issues.

The main conclusions that we can draw from our results are:

- Sheep and beef farms contain 24.5% of the total native vegetation remaining in New Zealand, comprising 2.8 million ha.
- Half of the native vegetation that occurs on sheep and beef farms (1.4 million ha), is woody (old growth and regenerating forest). This represents 17% of the total native woody vegetation remaining in New Zealand.
- Moreover, native woody vegetation on sheep and beef farms is particularly important because it typically occurs in those parts of New Zealand with the least remaining native woody vegetation (and where there is proportionally less public conservation land), especially at lower altitudes and in drier regions.

Based on the results from this study a number of conclusions can be made:

- Remnants of native vegetation, especially woody vegetation, on sheep and beef farms are critical for biodiversity conservation both on the farm and for landscape-level biodiversity outcomes.
- Remnants of native woody vegetation will benefit from stock exclusion and feral animal control and will regenerate towards a more mature condition if managed accordingly.
- More research is required to further understand the actual composition of native woody vegetation on sheep and beef farms, and the way that it has changed over recent decades. This information is important for priority setting and to support work with sheep and beef farmers to better manage the remnants of native vegetation they have on their farms.

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References

Awimbo JA, Norton DA, Overmars FB 1996. An evaluation of representativeness for nature conservation, Hokitika Ecological District, New Zealand. *Biological Conservation 75*, 177-186.

Cieraad E, Walker S, Price R, Barringer J 2015. An updated assessment of indigenous cover remaining and legal protection in New Zealand's land environments. *New Zealand Journal of Ecology 39*, 309-315.

Day NJ, Buckley HL 2013. Twenty-five years of plant community dynamics and invasion in New Zealand tussock grasslands. *Austral Ecology 38*, 688-699.

Dodd M, Barker GH, Burns B, Didham R, Innes J, King C, Smale M, Watts C 2011. Resilience of New Zealand indigenous forest fragments to impacts of livestock and pest mammals. *New Zealand Journal of Ecology 35*, 83-95.

Dunningham A, Brownlie R, Firth J 2000. Classification Accuracy Assessment of NZLCDB1. *Forest Research, Rotorua*

Dymond J, Shepherd J, Newsome P, Belliss S 2017. Estimating change in areas of indigenous vegetation cover in New Zealand from the New Zealand Land Cover Database (LCDB). *New Zealand Journal of Ecology 41*, 56-64.

Ewers RM, Kliskey AD, Walker S, Rutledge D, Harding JS, Didham RK 2006. Past and future trajectories of forest loss in New Zealand. *Biological Conservation 133*, 312-325.

Fetzel T, Gradwohl M, Erb K-H 2014. Conversion, intensification and abandonment: A human appropriation of net primary production approach to analyze historic land-use dynamics in New Zealand 1860-2005. *Ecological Economics 97*, 201-208.

Leathwick J, Wilson G, Rutledge D, Wardle P, Morgan F, Johnston K, McLeod M, Kirkpatrick R 2003. *Land Environments of New Zealand.* David Bateman, Auckland, 184pp.

MacLeod CJ, Moller H 2006. Intensification and diversification of New Zealand agriculture since 1960. An evaluation of current indicators of land use change. *Agriculture, Ecosystems and Environment 115*, 201–218.

Mark AF 1985. The botanical component of conservation in New Zealand. *New Zealand Journal of Botany 23*, 789-810.

Mark AF, McLennan B 2005. The conservation status of New Zealand's indigenous grasslands. *New Zealand Journal of Ecology 43*, 245-270.

McGlone MS 2001. The origin of the indigenous grasslands of the southeastern South Island in relation to pre-human woody ecosystems. *New Zealand Journal of Ecology 25*, 1-15.

Molloy BPJ, Burrows CJ, Cox JE, Johnston JA, Wardle P 1063. Distribution of subfossil forest remains, eastern South Island, New Zealand. *New Zealand Journal of Botany 1*, 68-77.

Norton DA 1999. Forest reserves. In, Hunter ML Jr, ed, *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, Cambridge, pp 525-555.

Norton DA, Butt J, Bergin DO 2018. Upscaling restoration of native biodiversity: A New Zealand perspective. *Ecological Management and Restoration 19, S1*, in press.

Norton DA, Espie PR, Murray W, Murray J 2006. Influence of pastoral management on plant biodiversity in a depleted short tussock grassland, Mackenzie Basin. *New Zealand Journal of Ecology 30*, 335-344.

O'Connor KF 1992. The implications of past exploitation and current developments to the conservation of South Island tussock grasslands. *New Zealand Journal of Ecology 5*, 97-107.

Robertson HA 2016. Wetland reserves in New Zealand: the status of protected areas between 1990- and 2013. *New Zealand Journal of Ecology 40*, 1-11.

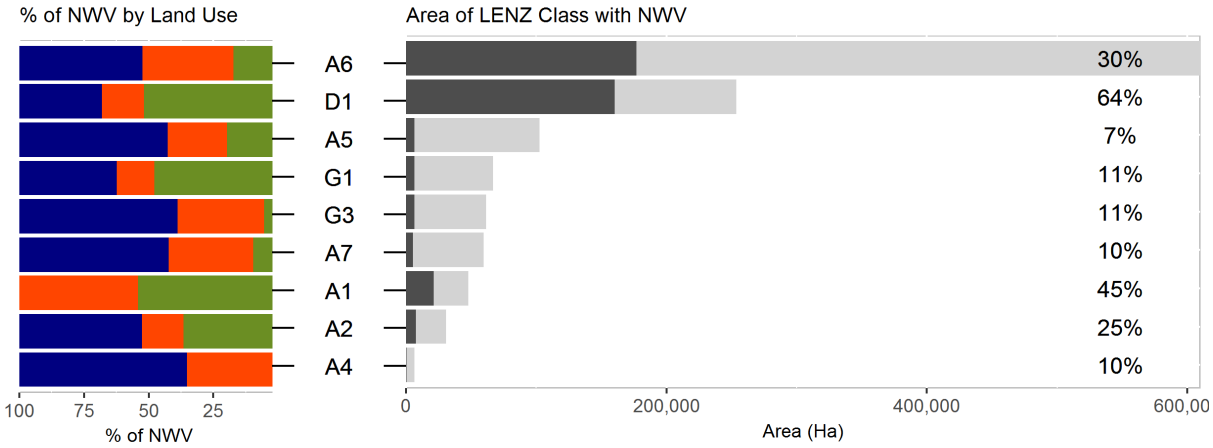
Wilmshurst JM, Anderson AJ, Higham TFG, Worthy TH 2008. Dating the late prehistoric dispersal of Polynesians to New Zealand using the commensal Pacific rat. *PNAS 105(22)*, 7676–7680.
Wilson H 1998. Living in Raoul country: the changing flora and vegetation of Banks Peninsula. In Burrows CJ, editor, *Etienne Raoul and Canterbury Botany 1840-1996*, pp.101–121. Manuka Press, Christchurch.

Regenerating and remnant shrubland and forest, Mackenzie District

Appendix

Right hand graph: Total area (ha) of Level II LENZ land environments in each region (light grey bar) and area currently supporting native woody vegetation (NWV; dark grey bar), also expressed as percentage of the total area of each land environment. *Left hand graph*: Percentage of remaining native woody vegetation (dark grey bars on right hand graph) on public conservation land (green), sheep and beef farms (orange) and other land uses (blue).

Northland Region



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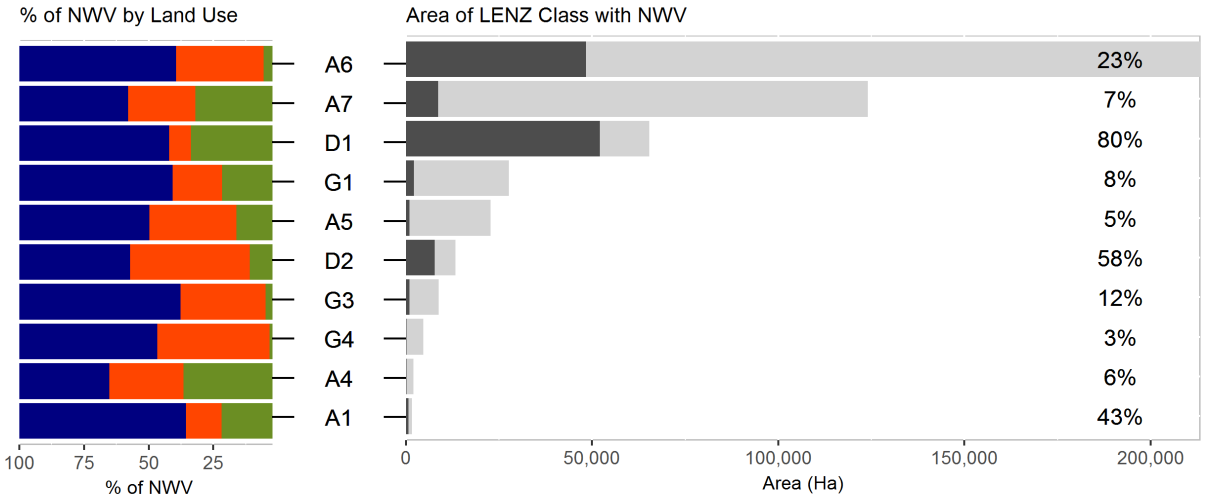

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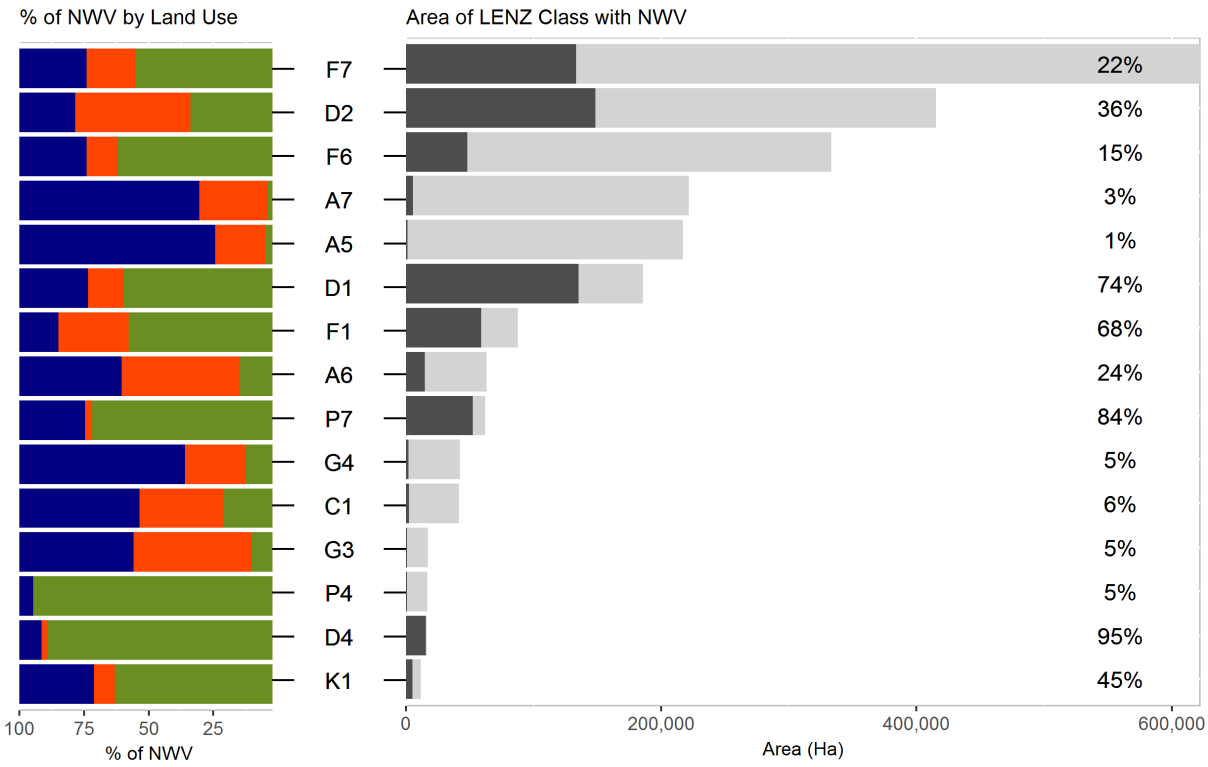
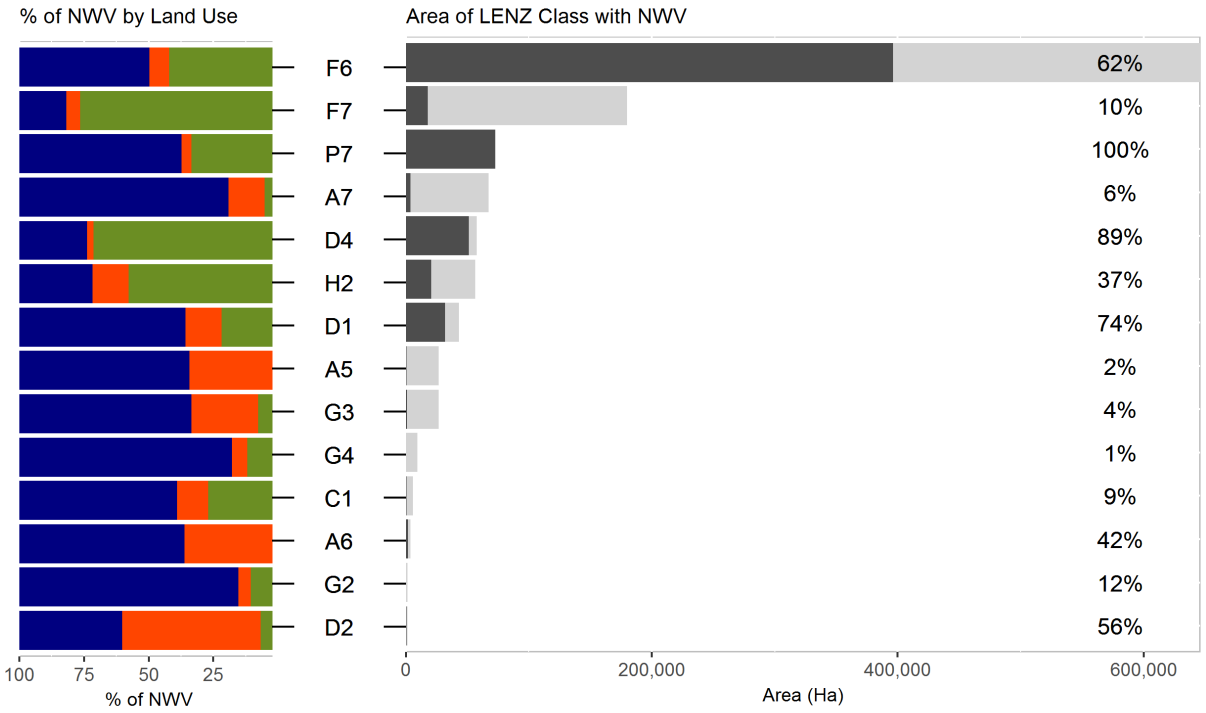
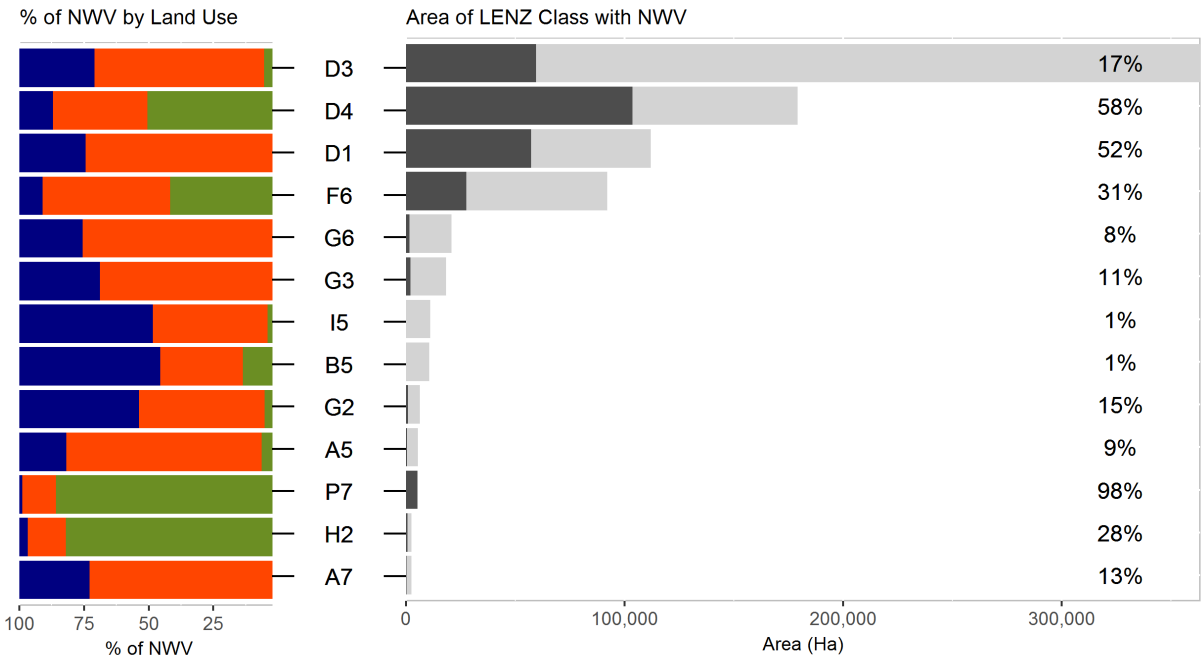


Bay of Plenty Region



Gisborne Region



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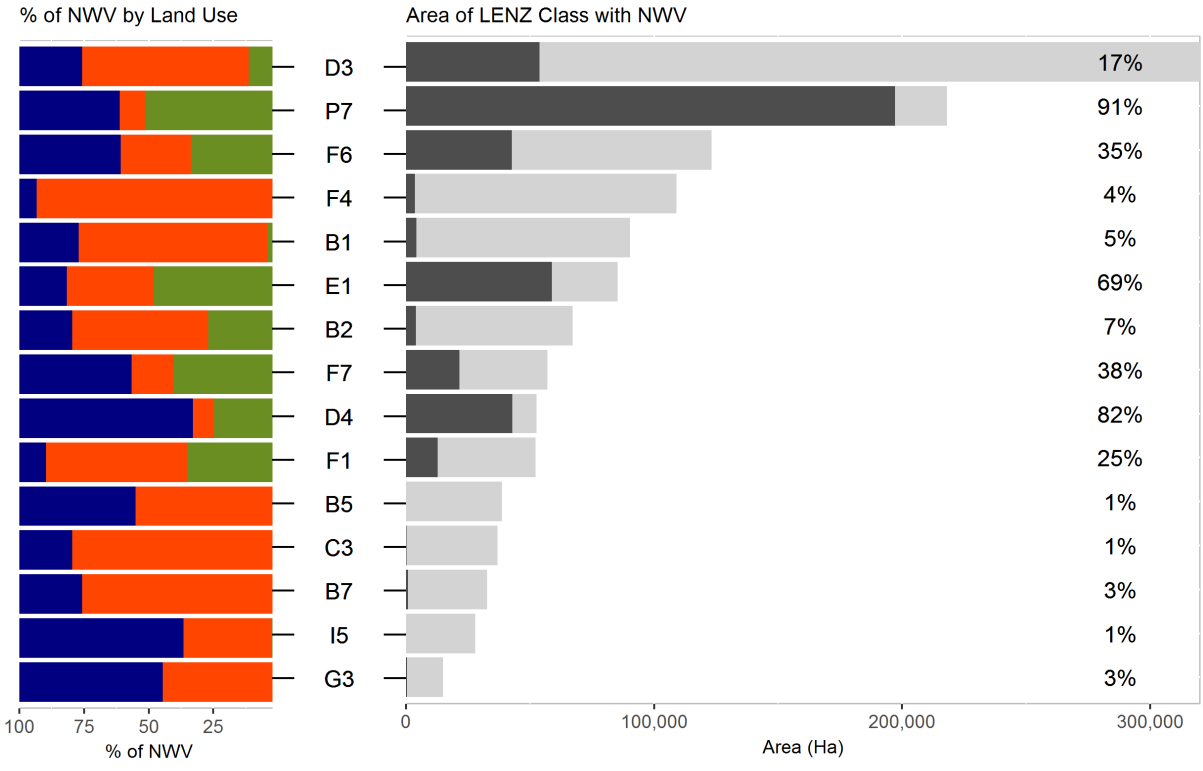

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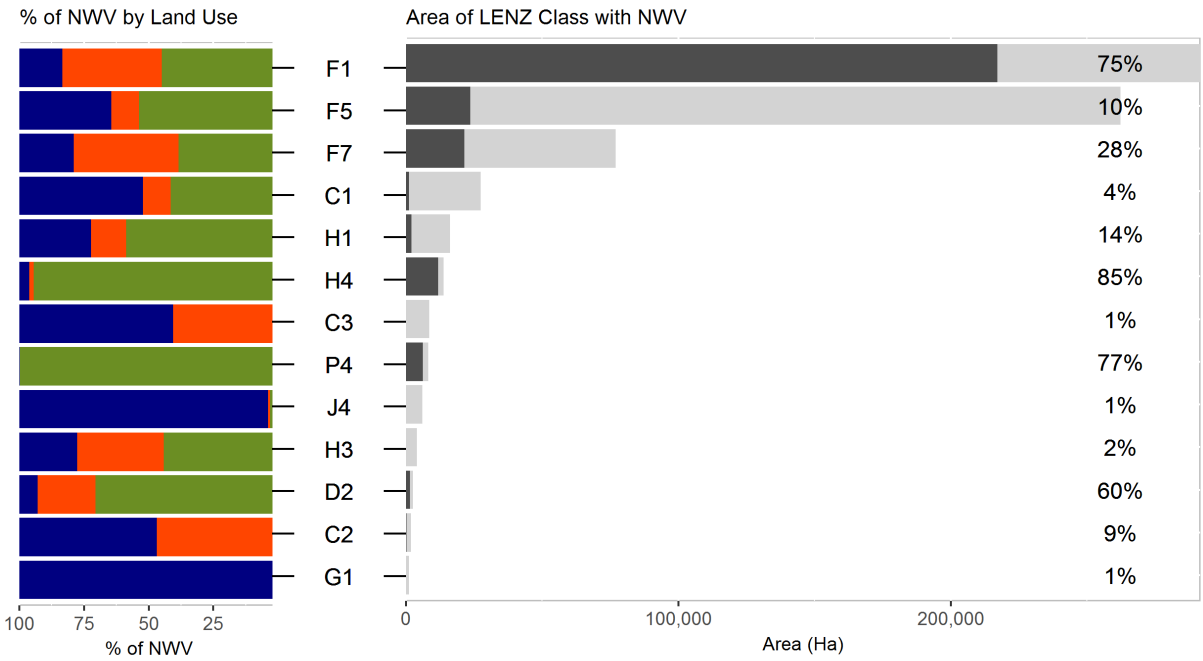
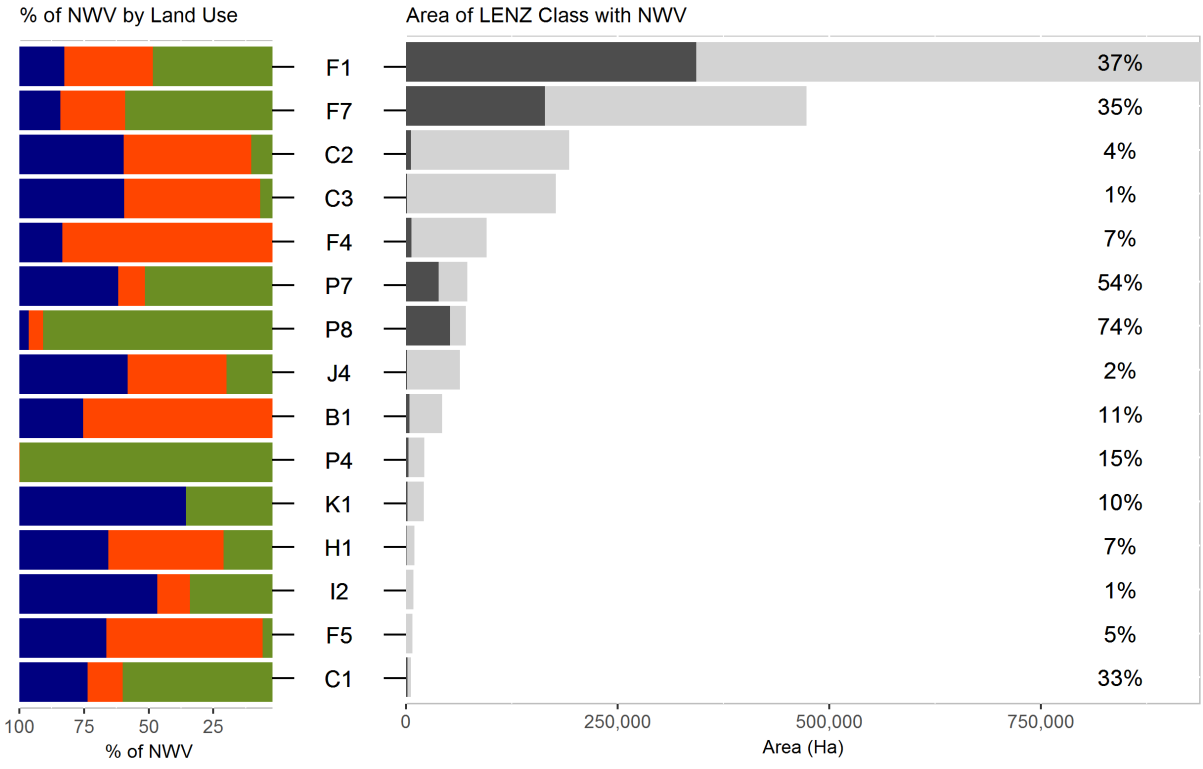
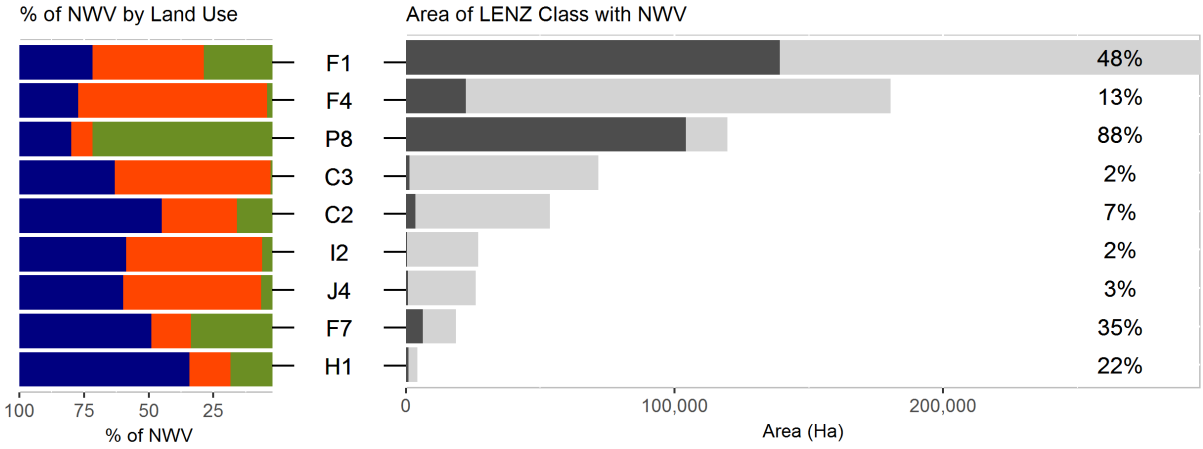


Manawatu-Whanganui Region



Wellington Region



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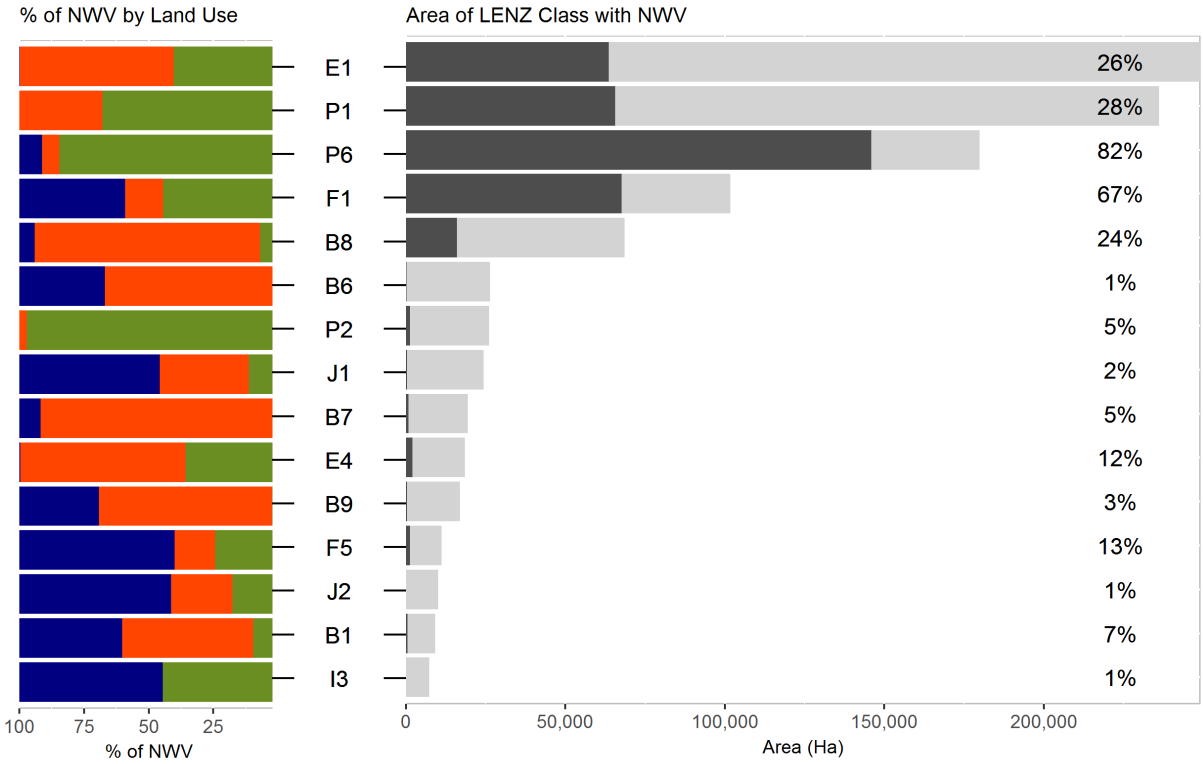
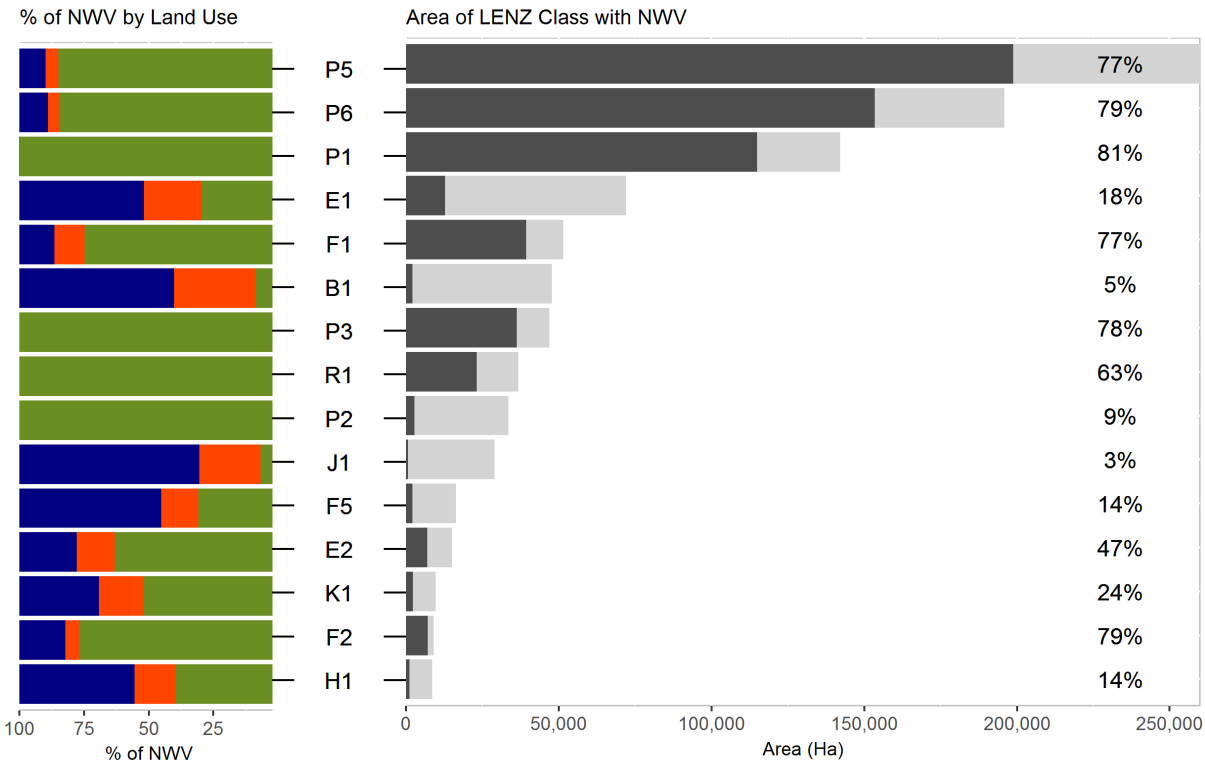
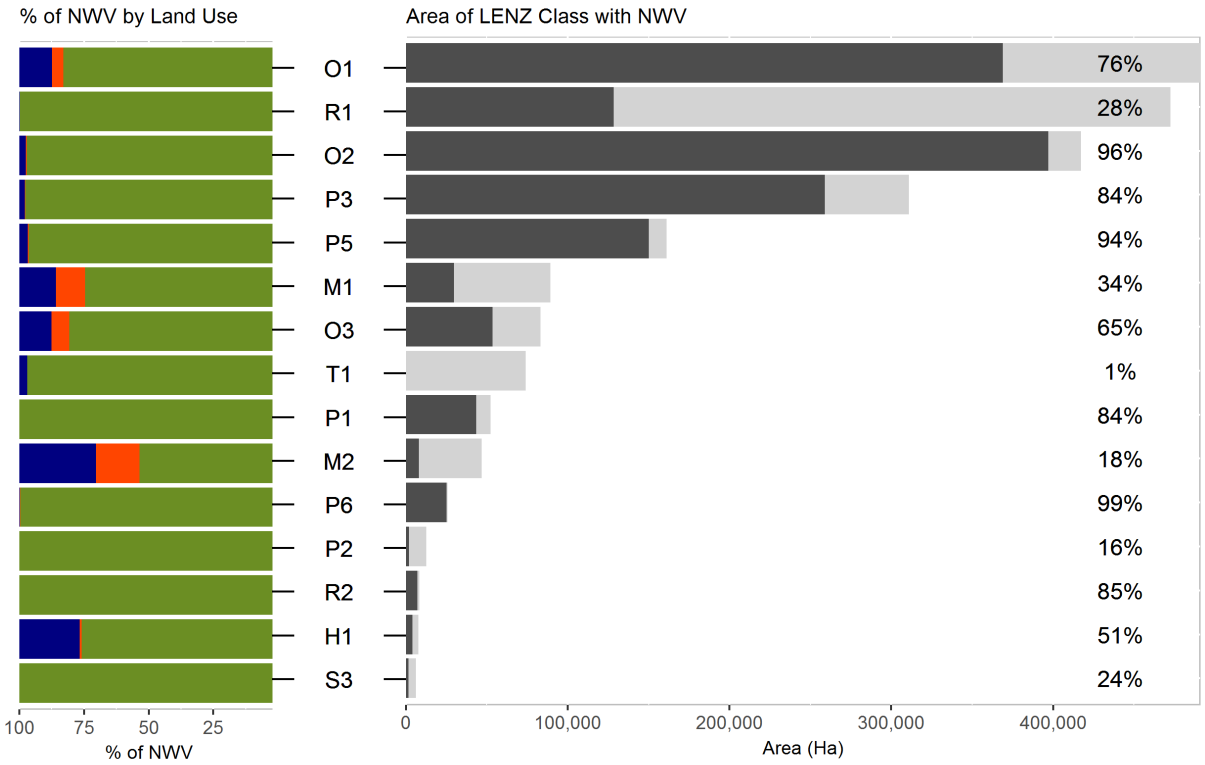


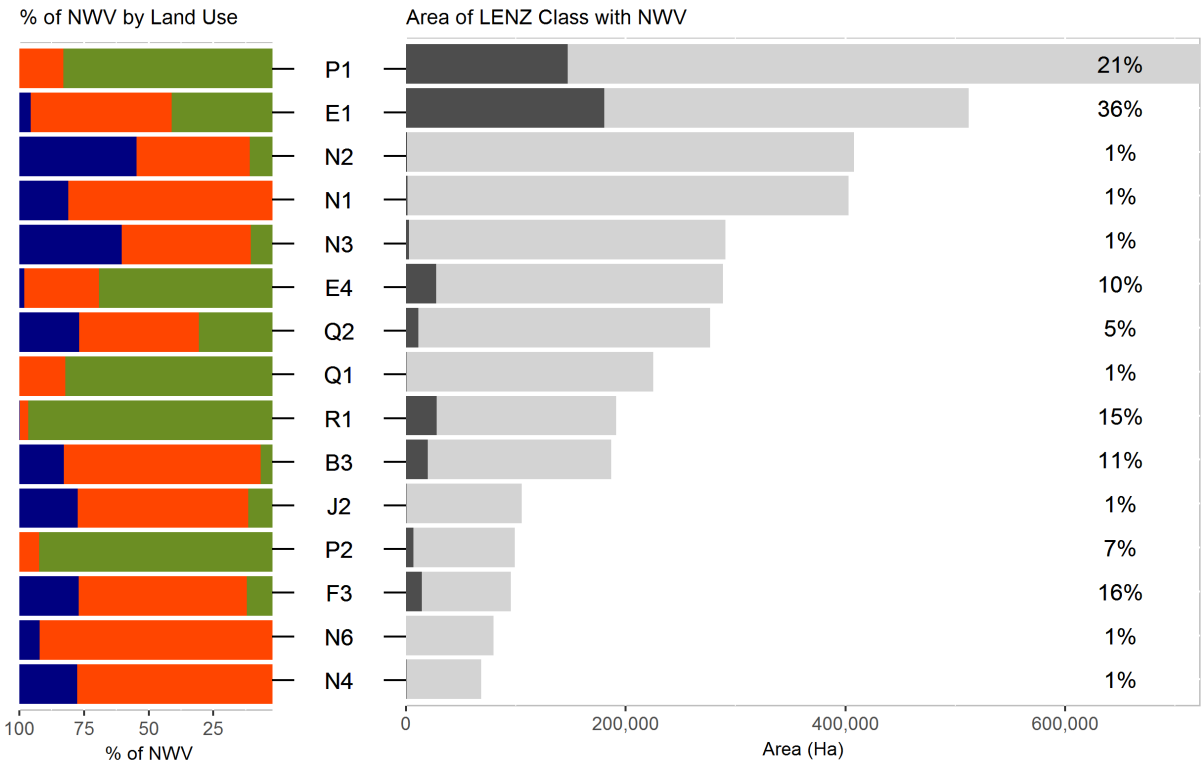
Nelson and Tasman Regions



West Coast Region



Canterbury Region



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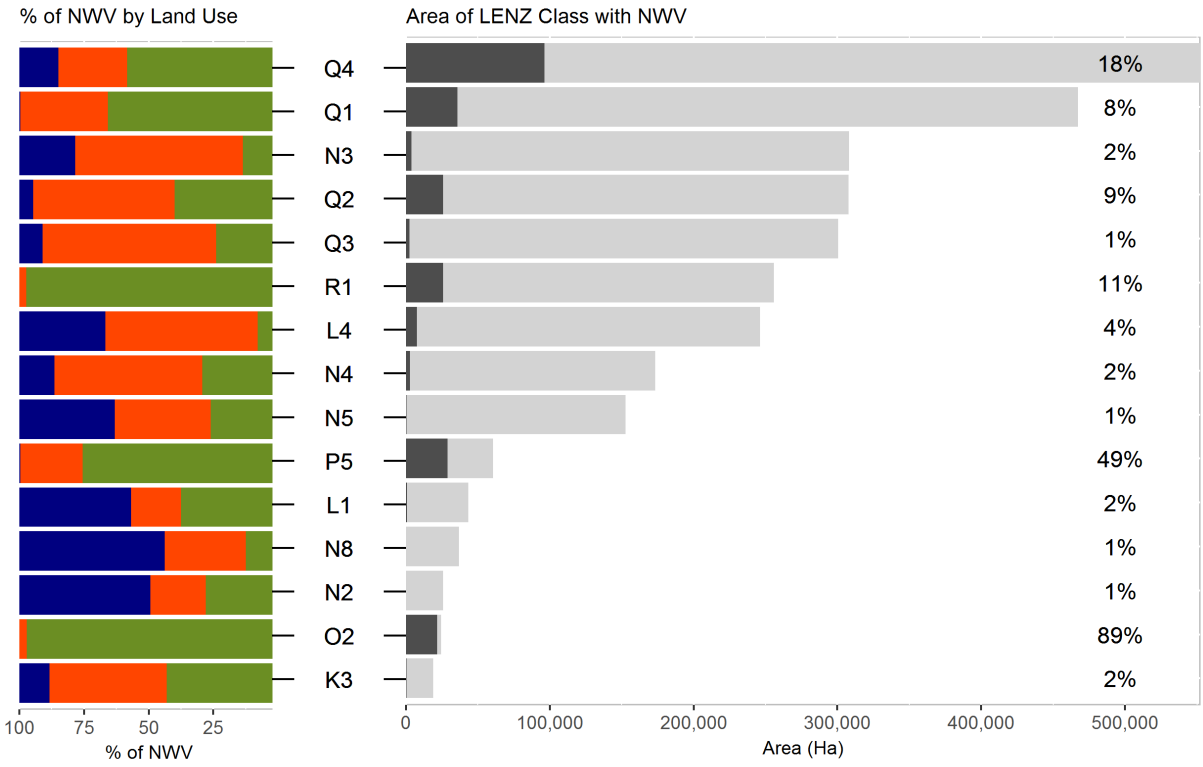

Southland Region