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How does Changing Land Cover and Land Use in New Zealand relate to Land Use Capability and Slope?

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Abstract

Land cover and use are critical for climate change, water quality and use, biodiversity and soil conservation as well as important drivers of rural economic activity and the evolution of rural communities. The Land Use in Rural New Zealand (LURNZ) model is a simulation model that predicts overall shifts in land use at a national scale and then allocates those changes spatially. We create a new dataset that allows us to consider fine scale land cover and use on private rural land and land characteristics associated with those land covers and uses. Second, we produce some summary statistics on the land cover transitions that were observed from 1996 to 2002. We find some evidence that supports our simple model of the relationship between land use changes and observable land quality, and the use of Land Use Capability and slope in rules to simulate the location of changes in land use and cover and also identify some directions for future work.

JEL classification
R14, Q50, Y1

Keywords
Land use, climate change, water, soil, land use capability, LURNZ, New Zealand, spatial modelling

Table of Contents

1 Introduction 1

2 Land Cover and Land Use Data 3

3 Other Data 4

4 Descriptive Statistics 4

4.1 2002 Land Cover 6

4.2 Change from 1996 to 2002 17

4.2.1 Pasture Transitions 19

4.2.2 Scrub Transitions 24

5 Summary 29

6 Directions for future research 31

Appendix A: 33

Appendix B: Dataset References 34

References 35

Table of Tables

Table 1 Aggregation of LCDB2 land cover categories......................................5

Table 2 Slope statistics on private land by 2002 land cover 9

Table 3 Comparison between LCDB and Statistics New Zealand Land cover data 17

Table 4 Pastureland transitions on private land from 1996 to 2002.................19

Table 5 Private, non-Maori land moving into pasture by land cover and new farm type 21

Table 6 Pasture statistics from Statistics New Zealand...................................21

Table 7 Slope statistics for transitions of more than 50 hectares between rural uses involving pasture on private, non-Maori land.............................23

Table 8 Transitions into bare ground from other land cover types by LCDB2 categories...26

Table 9 Slope statistics for transitions of more than 50 hectares between rural uses involving scrub and native forest on private, non-Maori land 27

Table 10 Transitions between land cover (1996) and land cover/use (2002) on private land...33

Table of Figures

Figure 1 Prior assumptions about interaction of land quality and land use 2

Figure 2 Distribution of private land in New Zealand by land cover and LUC class in 2002 6

Figure 3 Another visualisation of private land by land cover and LUC class in 2002 7

Figure 4 Proportions of LUC class by land cover type 8

Figure 5 Histograms of average slope within each polygon by land cover, weighted by polygon area 10

Figure 6 Distribution of different farm types on private pastureland in 2002 by LUC 13

Figure 7 Another visualisation of private pastureland by farm type and LUC class in 2002 13

Figure 8 Proportions of LUC class by 2002 pastoral farm type 14

Figure 9 Dairy farms: Histogram of average slope weighted by polygon area 14

Figure 10 Sheep/Beef intensive: Histogram of average slope weighted by polygon area 15

Figure 11 Sheep/Beef Hill Country: Histogram of average slope weighted by polygon area 15

Figure 12 Area of private land in scrub and native cover categories by Island .. 16

Figure 13 Area of private land in scrub and native cover categories by LCDB2 class 16

Figure 14 Distribution of private land in scrub and native cover by LUC class. 17

Figure 15 Area of new pastureland by LUC class and animal type 20

Figure 16 Proportional distribution of land moving out of pasture across LUC class 22

Figure 17 Histograms comparing average slope of pasture that did not change with pastureland that converted to forest, weighted by polygon area 23

Figure 18 Area of land moving out of scrub and native forest by new land cover type 25

Figure 19 Proportional distribution of scrub and native forest transitions across LUC class 26

Figure 20 Histograms comparing average slope of scrub and native forest that did not change with scrub and native forest that converted to plantation forestry or pasture, weighted by polygon area 28

1 Introduction

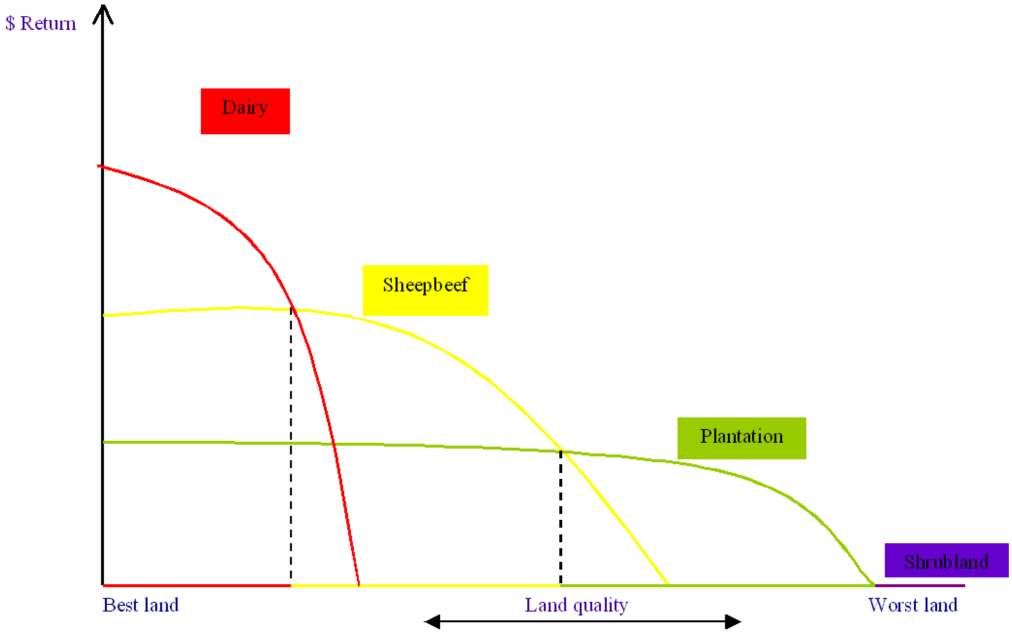
Land cover and use are critical for climate change, water quality and use, biodiversity and soil conservation as well as important drivers of rural economic activity and the evolution of rural communities. This paper aims to contribute to our understanding of the drivers of rural land use in New Zealand.

We create a new dataset that allows us to consider fine scale land cover and use on private rural land and land characteristics associated with those land covers and uses. Second, we produce some summary statistics on the land cover transitions that were observed from 1996 to 2002.

The Land Use in Rural New Zealand (LURNZ) model is a simulation model that predicts overall shifts in land use at a national scale and then allocates those changes spatially. Figure 1 shows how we expect land use and land quality to interact when farmers apply their land to the use that will yield the highest return. Dairy farming will occur on the highest quality land, and sheep and beef farming, plantation forestry and scrub will occur on progressively lower quality land. In the first version of LURNZ we model land use on a 25 ha grid and use expert judgement to create a ranking of land quality Hendy et al (2007). Going forward, we will provide an empirical basis for the rankings we use and also model land cover (and use) change at the sub-farm level. These sub-farm shapes represent different types of land within a farm and are the best measure in the available data of the level at which landowners make land-use decisions.

The LURNZ spatial allocation rules are deterministic. They minimise the number of grid cells that need to change use to match the national level changes in shares while re-allocating land uses optimally within this constraint. In this framework, we would not expect land in plantation forestry, for example, to transition directly to dairy land. More likely, we would see forestry convert to sheep and beef farming and some sheep and beef land transition into dairy. In reality, there is uncertainty in the relationship between simple measures of land quality and land use; many factors influence an owner’s land use decision. For example, if dairy prices are high enough, and land of reasonable quality is in plantation forest for historical reasons (as it is in New Zealand because of a shortage of cobalt in some soils) then some forest or scrub land will probably convert directly to dairy farming.

Figure 1. Prior assumptions about interaction of land quality and land use



We can examine the validity of some of our assumptions and hypotheses by looking at historical land use and land cover transitions. We primarily use Land Use Capability (LUC) as an indicator of land quality because it is a measure of the land's versatility, its potential for agricultural production and constraints on its use. We also examine slope, one of the factors included in LUC, in more detail and present summary statistics for both measures across different categories of land use and land cover. We expect to find pasture on high quality land, and particularly dairy on the highest quality pasture. Pastureland should be relatively flat or gently rolling, not on steep slopes. Scrub should be located on land in low quality LUC classes, potentially with steep slopes. Additionally we can compare the land that transitions out of a particular land cover with the land that stays in the original land cover. For example, we would expect the land that transitions from scrub into pasture or forestry to be of higher quality on average than the land that remains in scrub.

We find some evidence that supports our simple model and the use of LUC and slope in rules to simulate the location of changes in land use and cover and also identify some directions for future work.

2 Land Cover and Land Use Data

The New Zealand Land Cover Database version 2 (LCDB2) is satellite imagery from 1996/1997 and 2001/2002 that has been classified into 42 different land cover classes (MfE and Terralink International, dataset, 2005).[1] It is derived from Landsat satellite imagery that is collected in 30 metre pixels. When the 2001/2002 data were collected and classified, the 1996/1997 data were quality checked and updated so that the two datasets would be consistent. This allows land cover change analysis because the two observations in time can be directly compared.

Agribase is primarily survey data collected from farm owners by AsureQuality. The database contains attributes reported by the farmer such as primary land use, farm area and stocking rates. The dataset that we are working with was created by Landcare Research by intersecting Agribase farm boundaries and information with 2001/2002 land cover from LCDB2. This dataset is also known as Land Use of New Zealand (LUNZ), and was developed as a part of the CLUES project Woods et al (2006). The intersection results in sub-farm shapes, which identify different land cover types within farm boundaries and link to land use information, critically for our purposes, it identifies whether the farm is predominantly dairy or sheep/beef.

In order to examine land cover/use change at the sub-farm level, 1996/1997 land cover was assigned to the sub-farm shapes in LUNZ. This was done by layering the Agribase polygons over the LCDB2 polygons and joining the 1996/1997 land cover from LCDB2 to the Agribase polygons (Todd, dataset, 2003).[2] (Table 10 in the Appendix shows the types of land cover/use changes we are able to identify with the data thus created).

[1] Data references provide details on the location of the exact dataset used and also documentation relevant to that dataset.

[2] About 40 hectares of gorse and broom that did not change from 1996 to 2002 are present in LCDB2 but missing from the Agribase dataset. This area corresponds to a hole in the Agribase dataset in the Gisborne District.

3 Other Data

Land Use Capability (LUC) is a polygon dataset that is part of the New Zealand Land Resource Inventory (NZLRI) (Froude and Beanland, 1999). LUC consists of a three-part index that describes the ability of land to provide sustained agricultural production. We focus on the broadest measure of land quality, the LUC class, which ranges from class I (highest quality) to class VIII (lowest quality.) Generally, land in classes I through IV is considered to be arable while land in classes V through VIII are not arableMinistry of Agriculture and Forestry (2000). These classes were intersected with sub-farm shapes and are presented as proportions and areas of LUC classes within each shape (Landcare Research and MAF, dataset, 2002).

The slope dataset which is part of Land Environments New Zealand (LENZ) is a raster of average slope over a grid of $25m^2$ pixels (Landcare Research, dataset, 2003). In order to examine slope on the LUNZ sub-farm shapes, the raster data were summarised over each polygon. This process produced summary statistics on slope within each polygon, including mean, standard deviation, minimum and maximum of the pixels covered by the polygon (Todd, dataset, 2009).

Ownership data were used to reduce the dataset to only privately owned land. We are not interested in modelling land cover and use on public land because the use of public land is driven by different mechanisms than land use decisions on private land. The ownership dataset was put together by Landcare Research and identifies publicly owned land (such as DOC or local government) as well as privately owned land that may have some use restrictions (for example, Maori land or private reserves.) By joining this information onto Agribase, each polygon can be identified as being public land, private or privately owned land with some potential restrictions on use (Landcare Research, dataset, 2008).

4 Descriptive Statistics

The LUNZ dataset, modified as described above, provides LCDB2 land cover data for 1996 and 2002 and land use data collected from landowners for 2002. This chapter present descriptive statistics in two sections. First, in section 4.1, we focus on the land cover and use data for 2002. In section 4.2, we examine land cover changes that occurred from 1996 to 2002. The 42 land cover classes in LCDB2 have been aggregated in the LUNZ dataset (by Landcare Research) to broader land cover categories, shown in Table 1. Both the aggregated categories and the more detailed LCDB2 land cover categories are used throughout this chapter.

Table 1. Aggregation of LCDB2 land cover categories

Label	Land Cover	LCDB2 Land Cover Categories
AAA	Pasture	Alpine Grass-Herbfield, Depleted Tussock Grassland, High Producing Exotic Grassland, Low Producing Grassland, Tall Tussock Grassland
ARA	Arable	Short-rotation Cropland
FOR	Forest	Afforestation (imaged, post LCDB 1), Afforestation (not imaged), Forest Harvested, Other Exotic Forest, Pine Forest - Closed Canopy, Pine Forest - Open Canopy
HOR	Horticulture	Orchard and Other Perennial Crops, Vineyard
NAT	Native	Deciduous Hardwoods, Indigenous Forest, Mangrove
OTH_ART	Artificial Surfaces	Built-up Area, Dump, Surface Mine, Transport Infrastructure, Urban Parkland/ Open Space
OTH_BRG	Bare Ground	Alpine Gravel and Rock, Coastal Sand and Gravel, Landslide, Permanent Snow and Ice, River and Lakeshore Gravel and Rock
OTH_SCR	Scrub	Broadleaved Indigenous Hardwoods, Fernland, Gorse and Broom, Grey Scrub, Major Shelterbelts, Manuka and or Kanuka, Matagouri, Mixed Exotic Shrubland, Sub Alpine Shrubland
OTH_WAT	Water	Estuarine Open Water, River
OTH_WET	Wetlands	Flaxland, Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Lake and Pond

4.1 2002 Land Cover

Figure 2 below shows the distribution of the privately owned New Zealand land base by LUC class. About one third of this land is in LUC class VI. Fewer than 500 thousand hectares of privately owned land are LUC class VIII because much of the really low quality land in New Zealand is publicly owned. The chart also shows the distribution of the New Zealand land base by land cover category in each LUC class. Some general patterns are evident in this chart. For example, scrub and native forests tend to be located on land in the lower quality LUC classes while arable land is in the higher quality LUC classes. However there is significant overlap between forest, pasture and other land cover types in the LUC II to LUC VII range (this reflects unobservable differences, and could also be a manifestation of high transition costs, or uncertainty associated with switching land use), making it difficult to develop hard and fast rules about which uses would likely be located on which LUC.

Figure 2. Distribution of private land in New Zealand by land cover and LUC class in 2002

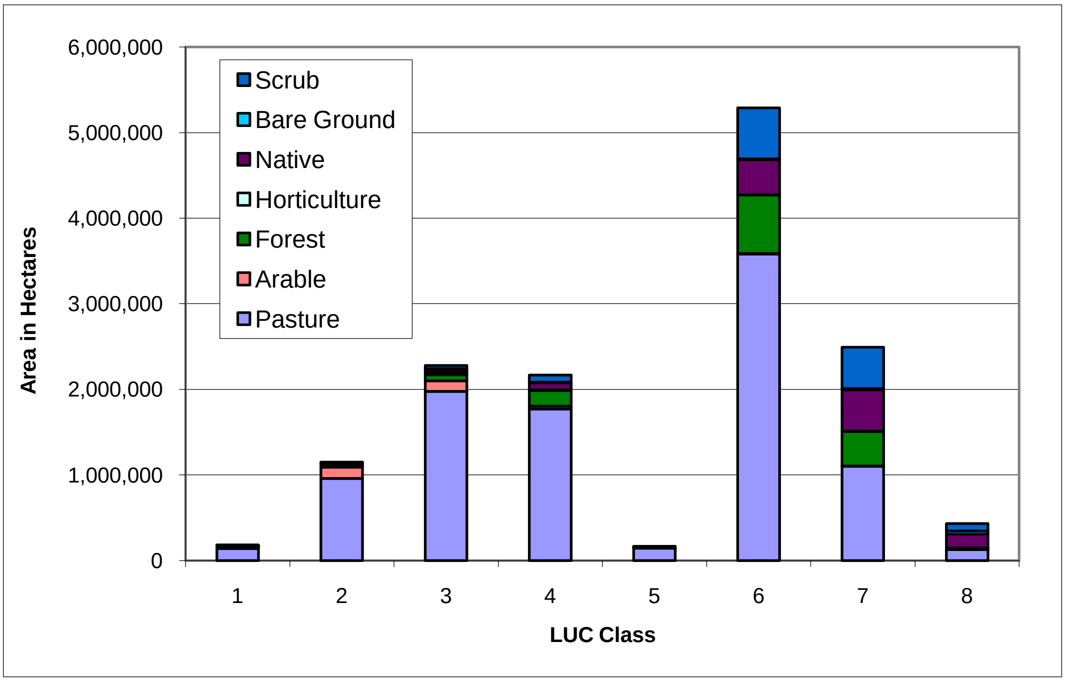
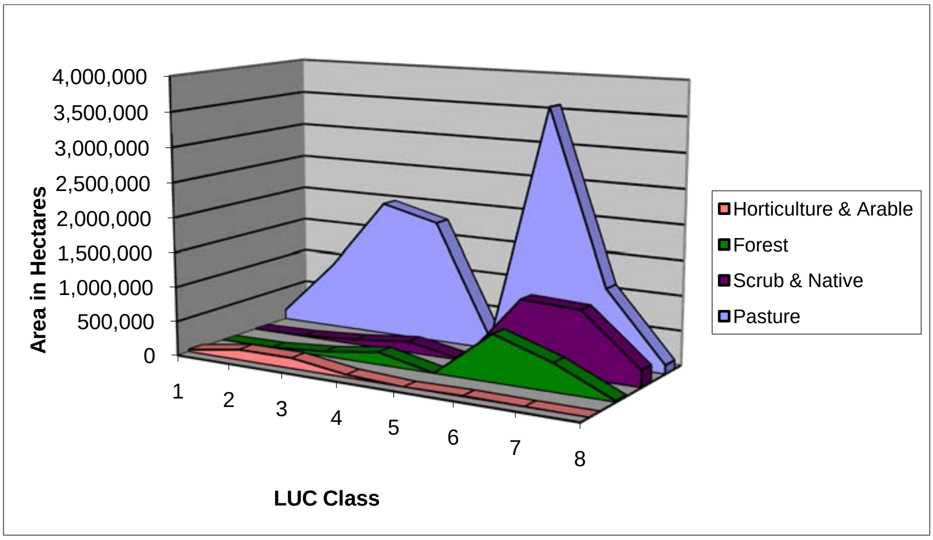


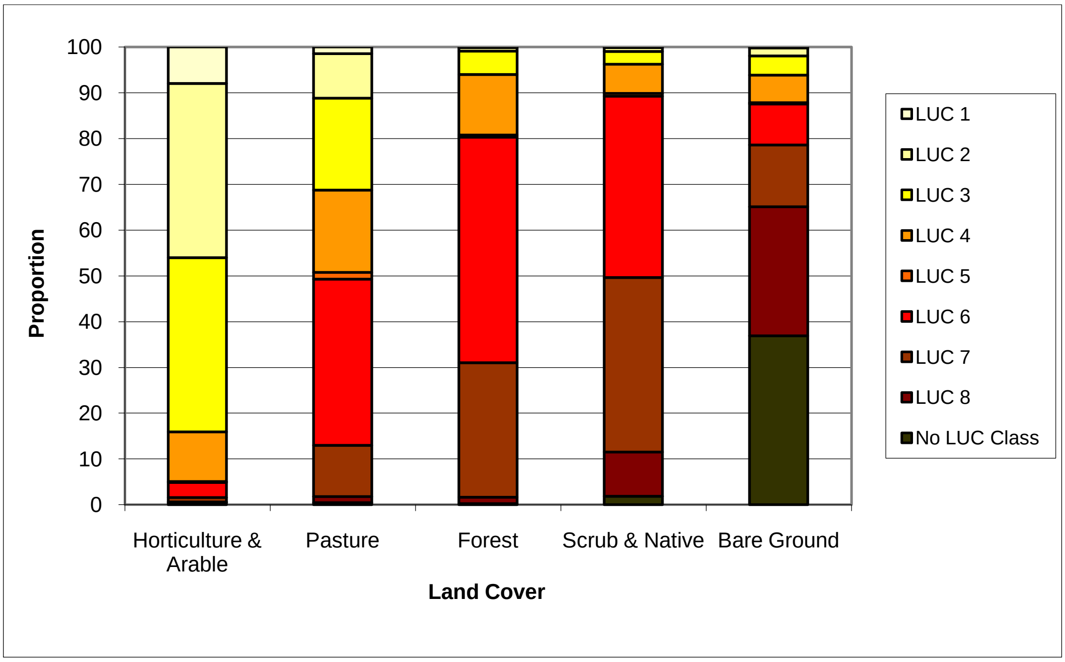
Figure 3 is another illustration of the data shown in Figure 2. The relationships between land cover and LUC described above are a bit clearer in this figure. Here we have grouped together horticulture and arable land because they are similar land cover types falling on similar land. We have also grouped together scrub and native forest for the same reasons.

Figure 3. Another visualisation of private land by land cover and LUC class in 2002



We can reverse the images shown above and examine LUC class within each land cover type. In Figure 4, land cover is shown on the horizontal axis in the order of decreasing expected land quality from left to right. We expect to find horticulture and arable use on the highest quality land, and this is supported by the fact that more than 80 percent of this land cover type is found on land in LUC class III or better. Bare ground is likely to be located on the lowest quality land and it clearly falls on the lowest average quality land of the categories shown here. About 38 percent of bare ground has not been assigned an LUC class and this indicates that either the area was not evaluated at all or it has been assigned a value like “lake”, “river” or “quarry” in the LUC data. This is not surprising since river and lake shores and coastal sand and gravel are considered to be bare ground.

Figure 4. Proportions of LUC class by land cover type



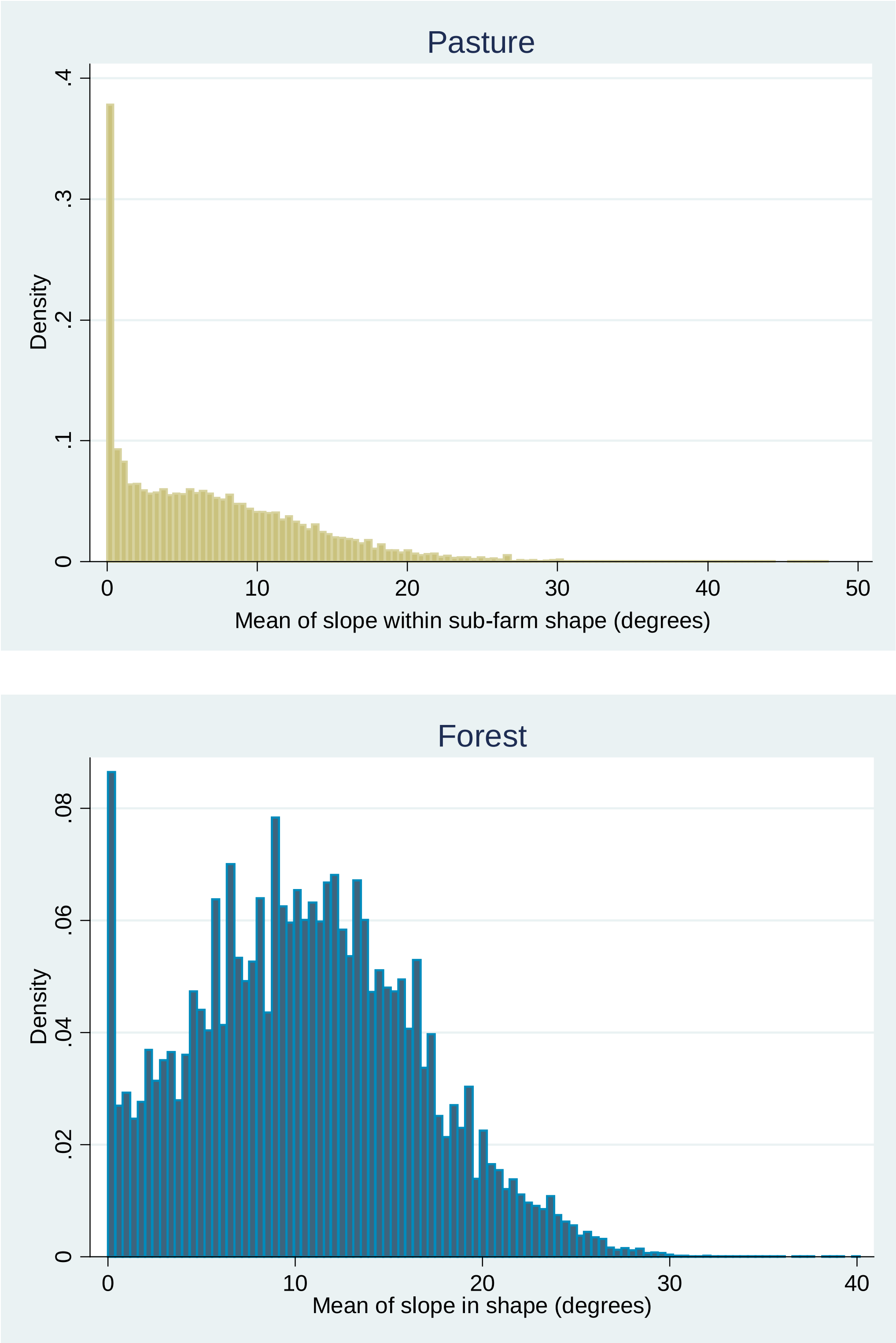
While slope is one of the geophysical characteristics that are incorporated into LUC, it is an important factor on its own that impacts different land uses in different ways. Slope statistics, aggregated by 2002 land cover, are shown in Table 2. Each sub-farm polygon has a set of statistics including mean and standard deviation. The average shown in the table below is a weighted average by area of the polygon averages. The standard deviation statistics give an idea of the variability of slope on land in each land cover category. The minus one standard deviation statistic was calculated by first subtracting one standard deviation from the mean for each polygon. Then the polygon statistics were averaged using polygon areas as weights, for each land cover type. Similarly, the plus one standard deviation statistic is a weighted average within land cover types of the mean plus one standard deviation for each polygon.

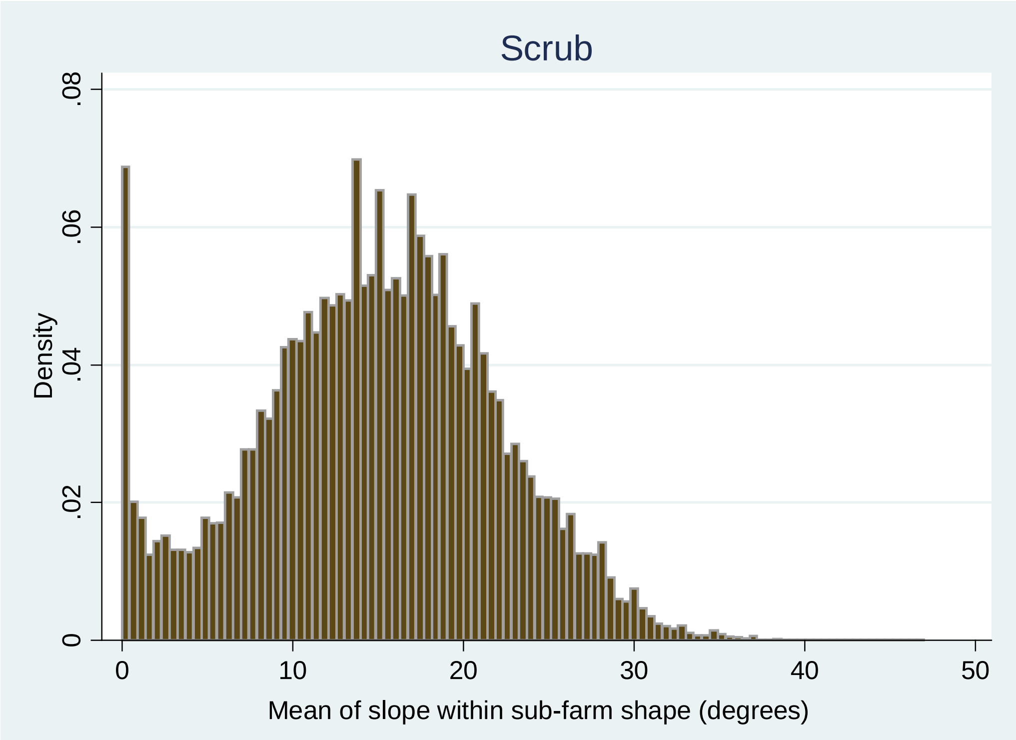
Table 2. Slope statistics on private land by 2002 land cover

2002 Land Cover	Total area (hectares)	Minus one standard dev	Average	Plus one standard dev
Horticulture	80,940	1	1	2
Arable	324,800	0	1	1
Pasture	9,856,000	4	7	10
Forest	1,383,000	7	11	15
Native	1,214,000	11	15	20
Artificial Surfaces	189,100	0	2	4
Bare Ground	132,500	7	10	13
Scrub	1,312,000	11	15	19
Water	257,800	0	1	3
Wetland	45,010	0	1	2

The slope statistics meet some of our expectations about slope and land use/cover. The land cover types that are generally considered to be non-productive from an economic perspective, native forest and scrub, are located on steeper land with more variation in slope. The land uses requiring the highest quality land, arable and horticulture, are located on the flattest land with little variability in slope. Pasture is located on land with an average slope of 7 degrees while forested land has an average slope of 11 degrees. The histograms in Figure 5 illustrate the distribution of mean slope for three different land cover types. These figures focus on means within polygons so they do not capture the slope variability within sub-farm shapes, but they do capture the variability between sub-farm shapes. Nearly 40 percent of pastureland is within a sub-farm that has an average slope near zero. Slope on scrub and forested land exhibits more variability and scrubland tends to be steeper than forested land, as noted in the table above.

Figure 5. Histograms of average slope within each polygon by land cover, weighted by polygon area





In addition to land cover, we can also examine the land use data that is reported in Agribase and incorporated in LUNZ. For farms that are mostly in land cover identified as pasture, the dataset includes the primary farm enterprise indicated by the farmer. These farm types include dairy (DAI), deer (DEE), other animals (OAN), sheep and beef – hill country (SBH), and sheep and beef – intensive (SBI). In the South Island, there are also merino wool farms (SMO). For this analysis, pastureland is identified using the land cover data from LCDB2, as opposed to using the farmer stated information in Agribase. The Agribase survey data provide valuable information about the whole farm, but little information about the use of particular pieces of land within the farm (i.e. the "sub-farm"), which we are interested in. For example, the survey data may identify a farm as being pasture because that is the farmer's primary enterprise while LCDB2 indicates that the farm is 60 percent pasture and 40 percent forest. For this analysis, we would like to focus on the land within the farm that is actually being used as pasture.

Within the area of pasture identified by land cover, we examine the physical characteristics of land in the different farm types described above. Some farms have multiple pastoral uses, for example dairy and sheep/beef on different bits of pasture on the same farm. However, here we are assigning the primary pastoral use to all pasture on the farm. A blank animal type indicates that pasture is likely a small proportion of the total farm area and there is no information about the pasture in Agribase. For example, most of the farm might be plantation forestry with small areas of pasture that the landowner did not bother to report to Agribase.

Figure 6 shows the distribution of different pastoral farm types across LUC class. Dairy farming clearly tends to occur on land in higher quality LUC classes, while hill country sheep and beef farms are located on land in lower quality LUC classes. Some dairy farming shows up on land in LUC classes VI and VII where we would not expect it, and there are at least two possible explanations for this. The first is that it is not actually dairy land, but another pastoral use such as sheep and beef grazing on a farm that is otherwise mostly dairy. It is also possible that the major limitation captured by its LUC rating of the land is water availability and dairy farming can take place there with the help of irrigation. Intensive sheep and beef farming occurs across a wide range of land quality from LUC class I to class VIII. Similar to the situation with dairy, we would not expect to see intensive sheep and beef farming on land in LUC classes VII and VIII. It is possible that these areas are identified incorrectly because they are located on a farm that is mostly intensive sheep and beef farming. Merino wool farms tend to be located at high elevations on low quality land in LUC classes VI, VII and VIII as expected. Figure 7 just provides another visualisation of the relationship between LUC and land cover.

Figure 6. Distribution of different farm types on private pastureland in 2002 by LUC

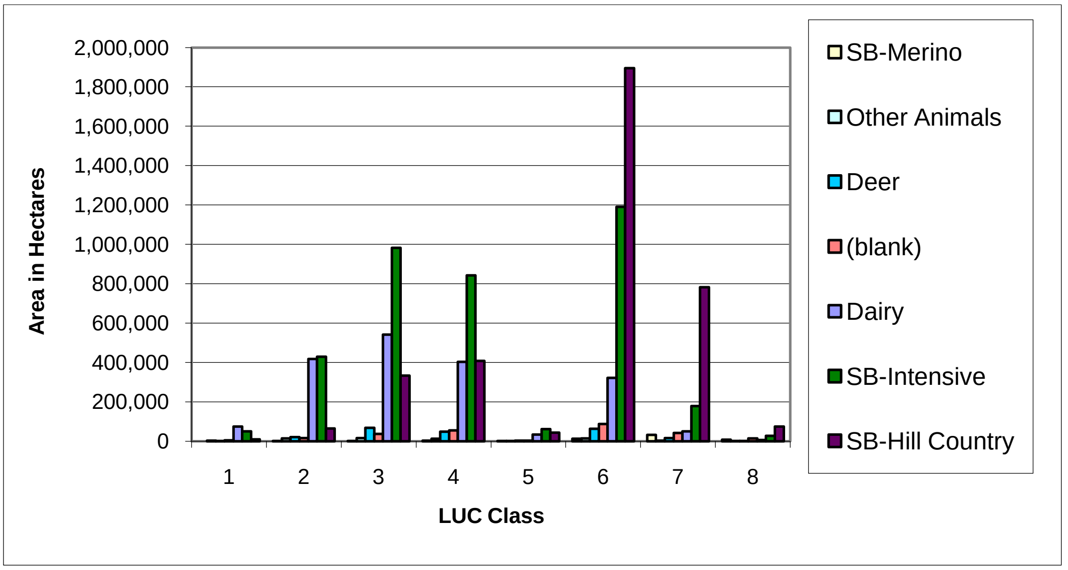
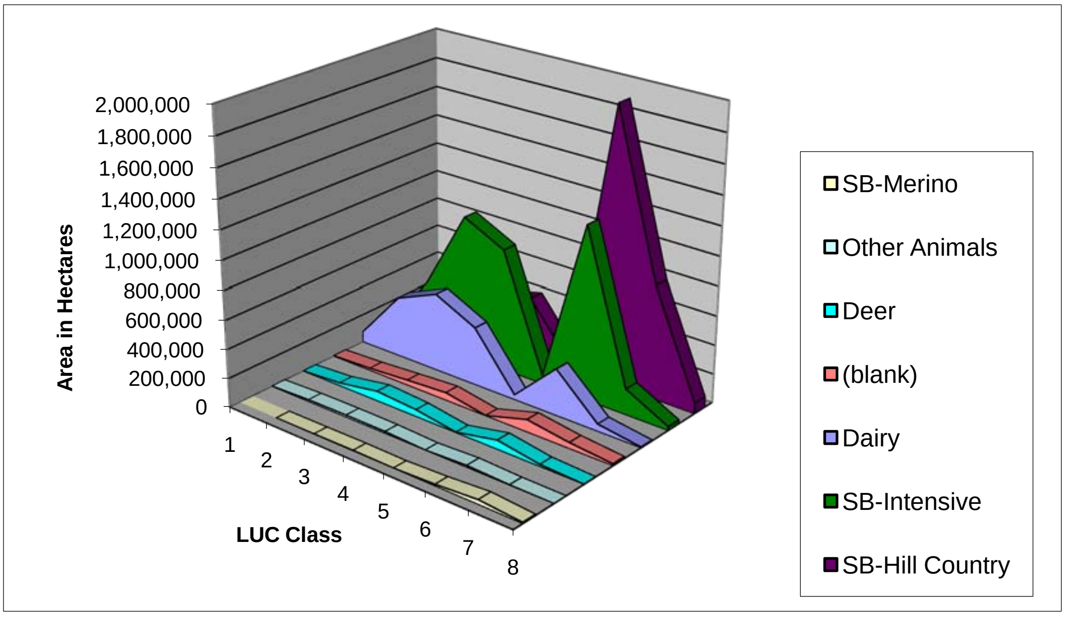
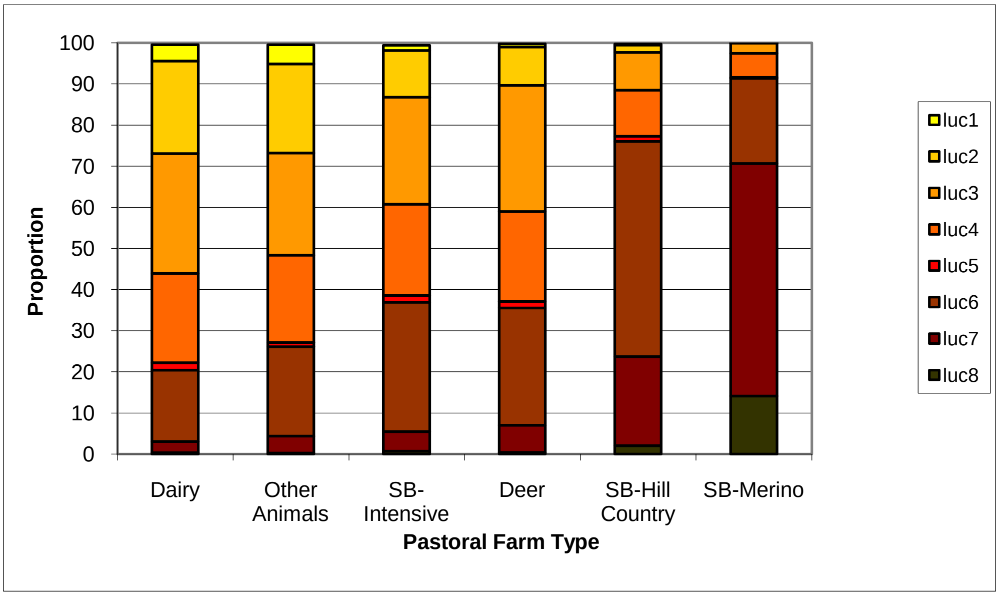


Figure 7. Another visualisation of private pastureland by farm type and LUC class in 2002



Reversing the above image, we can examine the distribution of LUC class within farm type. In Figure 8, dairy is shown at the far left because we expect to find dairy farming on the highest quality pastureland. Intensive sheep and beef farming requires fairly high quality land and hill country sheep and beef farming can take place on lower average quality land. We do not have clear priors on where deer farming and other animals fit into this picture, however these farm types comprise only about 3 percent of pastoral use by area. Sheep farming for merino wool takes place on high elevations on very low quality land. About 70 percent of this farm type occurs on land in LUC classes VII and VIII.

Figure 8. Proportions of LUC class by 2002 pastoral farm type



The histograms in Figure 9, 10 and 11 illustrate the distribution of mean slope for three different pastoral farm types. These figures illustrate frequency of means within polygons weighted by the area of the polygons, as in the slope histograms shown above for land cover. There are some clear relationships between slope and pastoral farm type. Dairy farms are clearly on flat land with more than 85 percent of total dairy area located within sub-farms that have a slope near zero. Intensive sheep and beef farming and hill country sheep and beef farming take place on progressively steeper land than dairy, as expected.

Figure 9. Dairy farms: Histogram of average slope weighted by polygon area

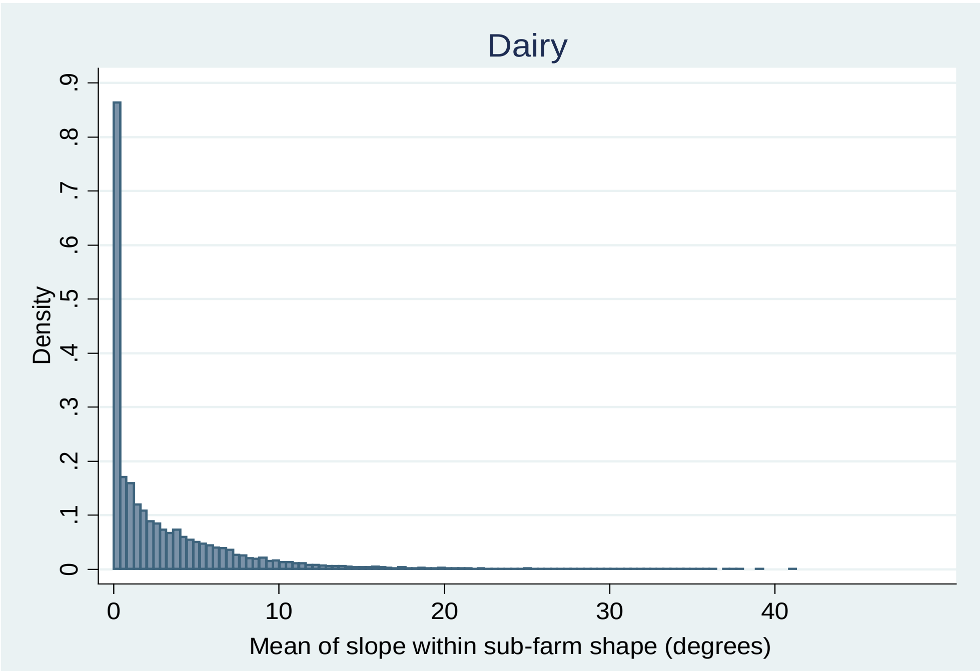


Figure 10. Sheep/Beef intensive: Histogram of average slope weighted by polygon area

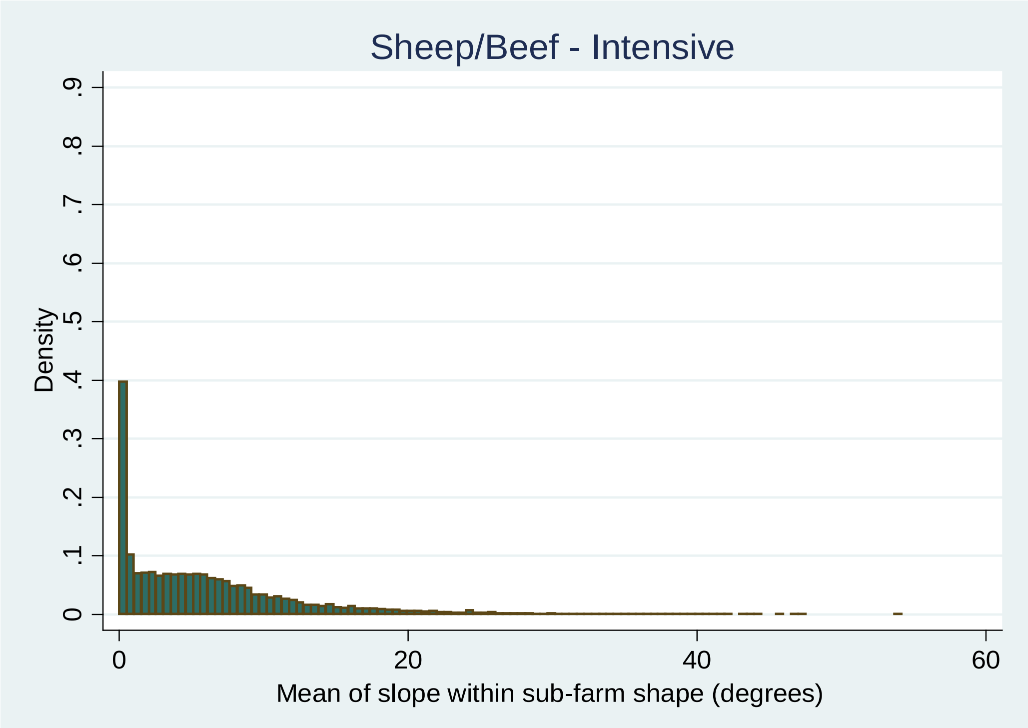
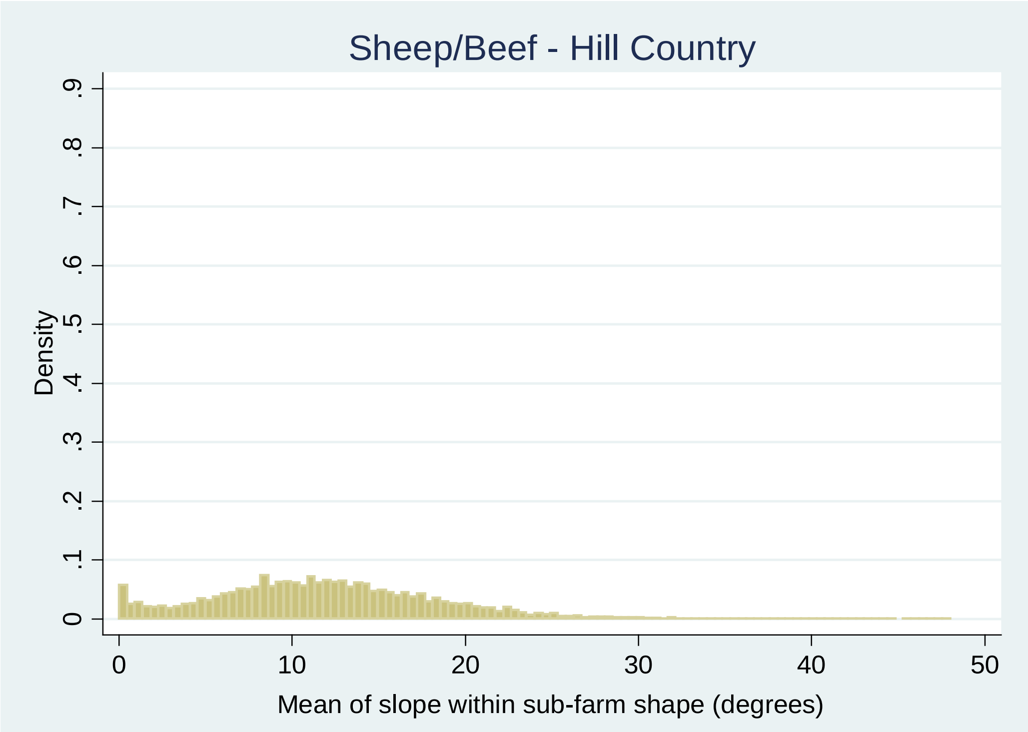


Figure 11. Sheep/Beef Hill Country: Histogram of average slope weighted by polygon area



Together, scrub and native forests comprise the second most common land cover type in New Zealand, covering 2.5 million hectares of private land. As shown in Figure 12, most of this land is in indigenous forest, manuka and kanuka and broadleaved indigenous hardwoods. Figure 14 shows the distribution of scrubland by LUC class. Much of the scrub and native forest on the South Island is located on public land and is not included here. There is very little scrub on the higher quality land in classes I through V.

Figure 12. Area of private land in scrub and native cover categories by Island

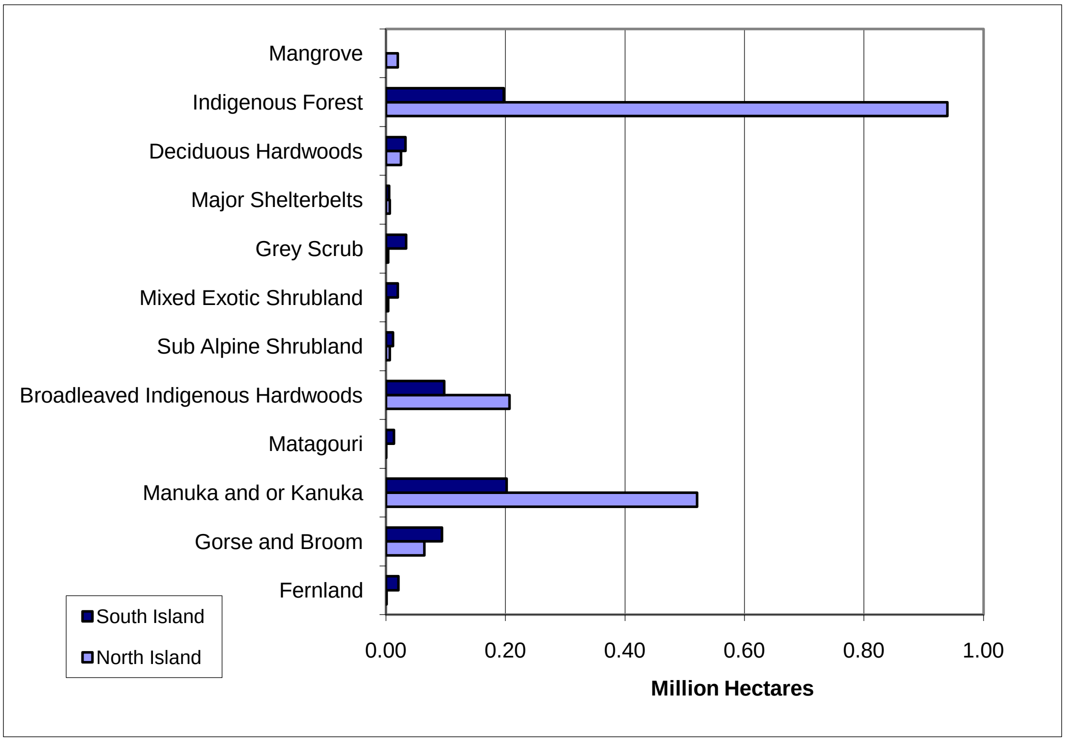


Figure 13. Area of private land in scrub and native cover categories by LCDB2 class

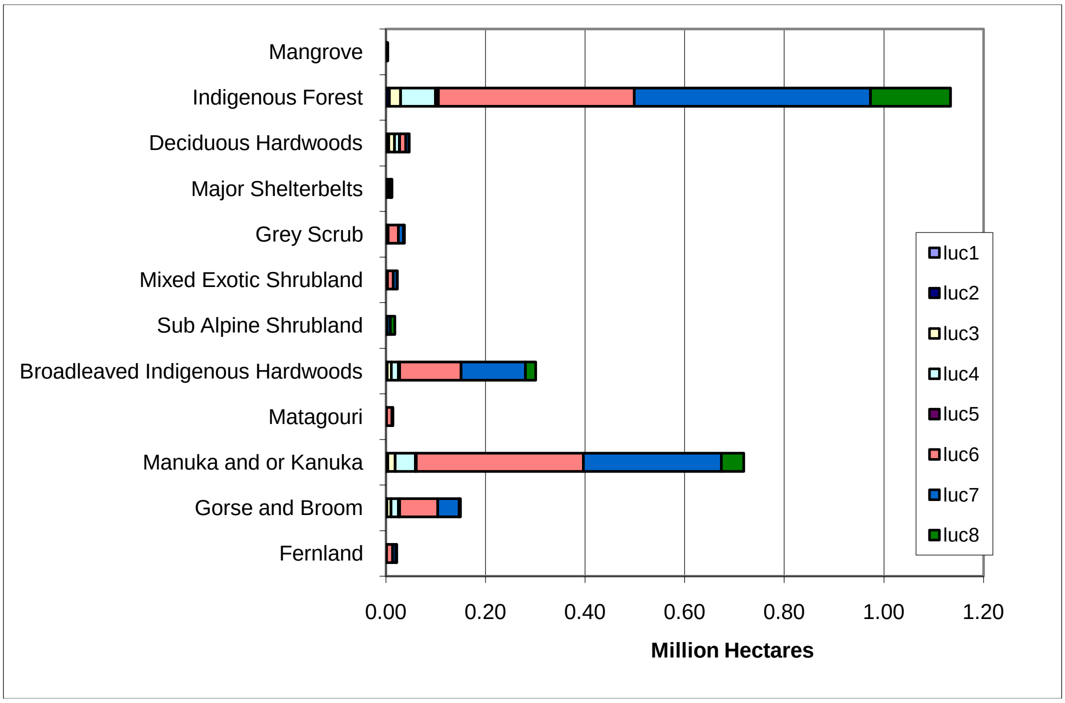
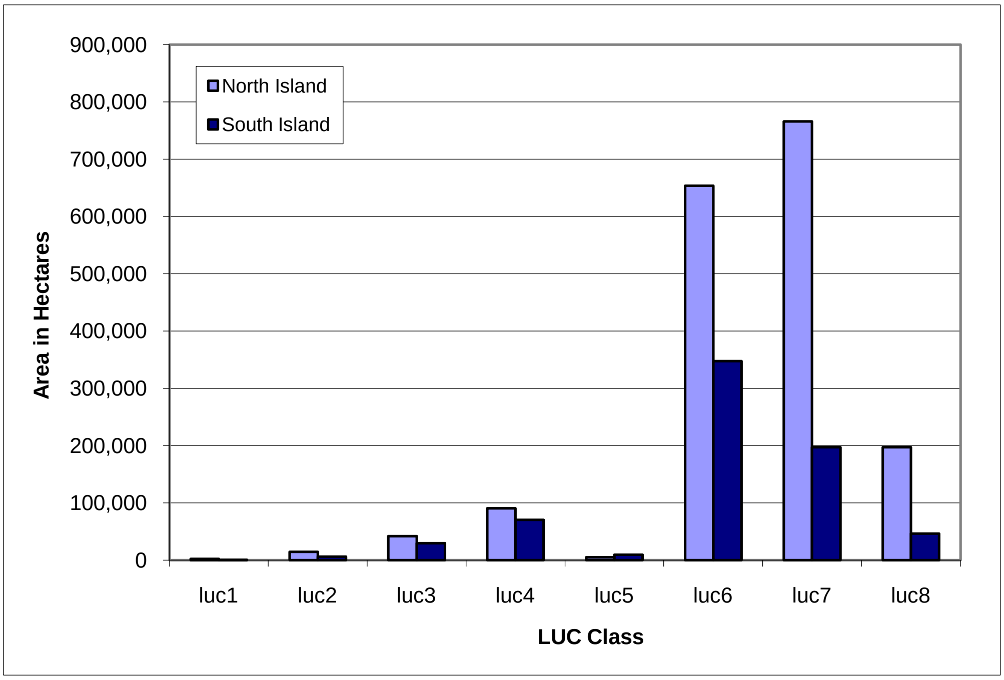


Figure 14. Distribution of private land in scrub and native cover by LUC class



4.2 Change from 1996 to 2002

Table 10 in the Appendix provides a complete set of transitions from the land cover categories in 1996 to the land cover and land use categories in 2002 with some grouping of minor categories. In this section we consider the key transitions, the extent to which the directions of transition meet our prior expectations and the extent to which the land that is involved in each transition is homogeneous in LUC class and slope and accords with our prior expectations.

Before we look at these spatially, it is worth comparing the results using LUNZ/LCDB data with Statistics New Zealand survey data on the same variables.

Table 3. Comparison between LCDB and Statistics New Zealand Land cover data

Measured in hectares

	Total pasture	Forest	Scrub
Statistics NZ 1996	9,888,429	1,429,278	1,248,813
Statistics NZ 2002	8,805,642	1,551,875	1,407,950
Statistics NZ Change	-1,082,787	122,597	159,137
LCDB change(private, non-Maori land)	-121,000	129,000	-18,000
LCDB change (total)	-130,000	140,000	-20,000

Some differences between the two datasets are pertinent. The Statistics New Zealand data has been calibrated to match 2002 LCDB data in each category. It is collected for all GST registered farms. Thus it excludes very small rural properties (and non-commercial ones) but includes Maori land and some public land that is used commercially. In contrast our LCDB dataset excludes current Maori and public land but includes all pasture on private land.

Estimated plantation forest changes in the two datasets are similar. There is very little forest on public land but there is quite a lot on Maori land. The data suggests an increase of 9,000 ha of forest on Maori or public land from 1996–2000. This suggests that they have reasonably accurately identified newly planted forests in both LCDB years even though they are not visible by satellite (or that there are offsetting errors).

In contrast, the scrub estimates are very different. LCDB estimates a loss of scrub on private land, while Statistics NZ finds a considerable increase. This could relate to difficulties identifying abandoned land that a farmer may consider scrub while the satellite will still identify it as pasture. One possibility to reconcile this is to assume that all pasture land that has no farm type specified in LUNZ (256,600 ha in 2002) has been abandoned between 1996 and 2000. If this land was all reported as ‘scrub’ by farmers, this would more than explain the difference between Statistics NZ and LCDB. Another difference between the datasets is the classification of publicly owned land that is used for commercial farming (e.g. pastoral leases in the South Island); this land is included in Statistics data but excluded from LCDB. If scrub was increasing on that land and decreasing on other private land this could explain the difference; however, the data do not support that – the area of scrub falls on public land also (by 2000ha).

The pasture numbers have the greatest difference of all – more than 950,000ha. One possible explanation is that the land has been abandoned and that farmers are reporting it as scrub (could be as much as the difference in the scrub changes – 180,000ha). The other explanation is that some farms have been broken into small holdings for ‘life-style’ properties and that these are too small to register for GST and hence are not captured in the Statistics NZ data. The following quote from (Sanson et al, 2004) suggests that this could explain around another 225,000ha if the spread of lifestyle blocks has been relatively consistent over time and more, if the period 1996–2002 involved a more rapid spread and if, as is likely, only some lifestyle blocks are registered as such in the Valuation Roll. The land use classification in the Valuation Roll is notoriously inaccurate especially around the time of land use change and in cases where there are no rating implications from the classification.

There were 139,868 lifestyle block assessments in the Valuation Roll, totalling over 753,020 ha. The mean block size was 5.53 ha (median = 2.7, range 0.0006 - 955.7 ha).

There were 22,687 farms with a lifestyle farm type (LIF) in AgriBase. The mean size was 4.97 ha (median = 3.8, range 0.01 – 603.1 ha). In all, AgriBase had some 60,213 properties, either categorised as LIF or ≤ 35 ha, involving 539,506 ha of land.

Approximately 6,800 new lifestyle blocks are registered in the Valuation Roll annually. This equates to just over 37,600 ha per year converted to lifestyle blocks (Sanson et al, 2004).

4.2.1 Pasture Transitions

On net, according to LCDB, pasture area on private, non-Maori land declined by more than 120,000 hectares from 1996 to 2002. As shown in Table 4, the largest transitions out of pasture can be attributed to conversions into plantation forestry. More than 115,000 hectares of pasture were converted to plantation forestry and about 3,800 were converted to horticulture. However, new areas of pasture were created over the same period. From 1996 to 2002, 4,400 hectares of new pasture were created on private land and most of this came from conversions of scrubland.

Table 4. Pastureland transitions on private land from 1996 to 2002
Land area changes in hectares

	Out of pasture	Into pasture	Net Change
Arable	88	0	-88
Forest	115,300	333	-114,967
Horticulture	3,847	0	-3,847
Native	0	60	60
Artificial	4,645	58	-4,588
Bare Ground	42	70	28
Scrub	429	3,735	3,306
Water	645	0	-645
Wetland	0	142	142
Total	124,996	4,397	-120,599

Looking in more detail at the characteristics of the land moving into pasture, Figure 15 shows the farm type and LUC class of new pastureland. A blank animal type indicates that there is no information about the pasture in Agribase. Most of the newly created pasture is on land in LUC classes VI and VII and went into sheep and beef farming. Some land converted directly to dairy farming in LUC classes III, IV and VI.

Figure 15. Area of new pastureland by LUC class and animal type

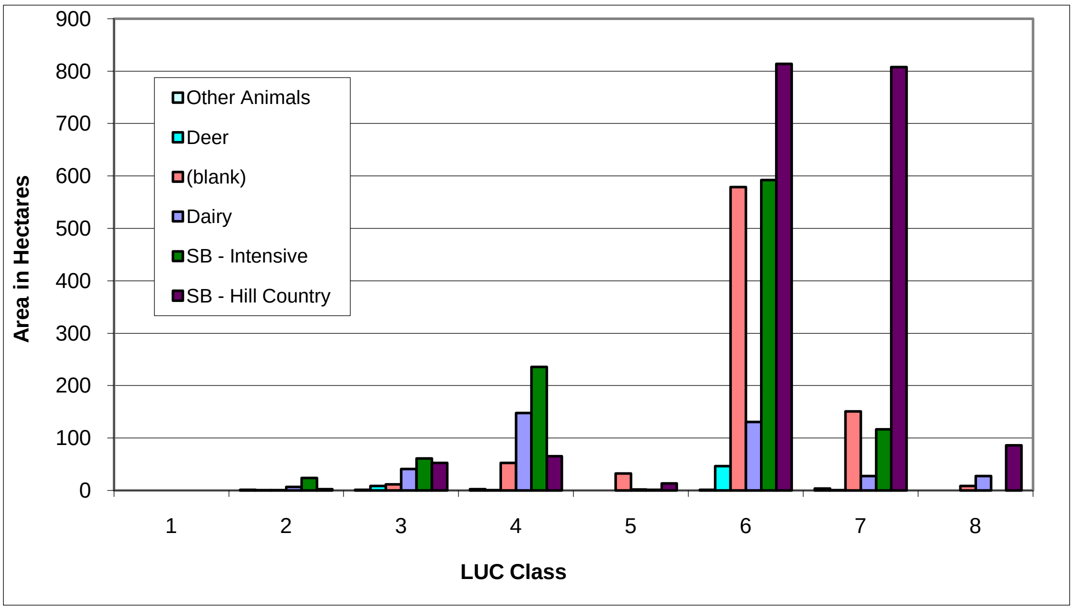


Table 5 shows the transitions that led to the creation of 4,400 new hectares of pasture and where it came from. About 70 percent of the new pasture went into sheep and beef farming, mostly from scrubland. Less than 7 percent of the converted scrubland went into dairy farming, whereas about one third of the converted forestland went directly into dairy (246ha). Table 5 indicates that about 3,000 hectares were converted to pasture for sheep and beef farming and only about 400 hectares were converted to dairy. However, looking at land cover transitions does not pick up the changes occurring between different pastoral uses. We usually observe new dairy land being created from existing sheep and beef pasture, not scrubland. This observation is backed up by Statistics New Zealand data on pastoral land use (Table 6).

Table 5. Private, non-Maori land moving into pasture by previous land cover and new farm type
Land area measured in hectares

	New Farm Type			
Previous Land Cover	Dairy	S/B Intensive	S/B Hill Country	Total
Arable	0	0	0	0
Forest	107	26	123	333
Horticulture	0	0	0	0
Native	11	13	3	60
Artificial	2	52	4	58
Bare Ground	27	31	11	70
Scrub	246	976	1,700	3,735
Water	0	0	0	0
Wetland	0	142	0	142
Total	393	1,239	1,841	4,397

Data from Statistics NZ (Table 6) indicate that area in dairy production increased by about 237,000 hectares, from 1.64 million hectares in 1996/1997 to 1.87 million hectares in 2001/2002. From the perspective of land cover change, we are seeing less than 0.2 percent of this increase in dairy area because most of it is taking place on existing pasture.

Table 6. Pasture statistics from Statistics New Zealand
Areas in thousands of hectares

Statistics NZ Grazing Land Allocation			
	1996/1997	2001/2002	Change
Sheep	7,690	6,674	-1,016
Beef	3,528	3,086	-442
Dairy	1,635	1,872	237
Deer	387	535	148
Goats	25	16	-9
Total	13,265	12,183	-1,082

Next we examine the land that is moving out of pasture and where it is going. Figure 16 shows the proportional allocation of each transition type across LUC classes, so each colour sums to 100 percent across LUC. As expected, most of the pastureland that transitioned into arable or horticulture was on high quality land in LUC classes I, II and III. The pastureland that converted to forest or scrub was lower quality on average, mostly in LUC classes VI and VII.

Figure 16. Proportional distribution of land moving out of pasture across LUC class

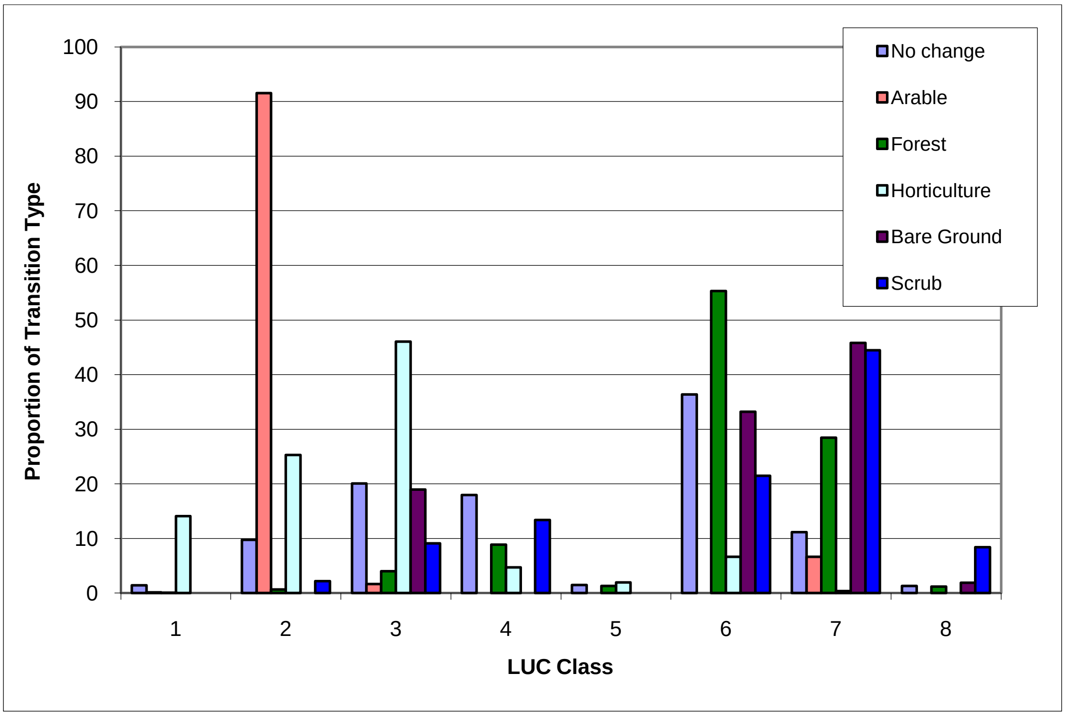


Table 7 presents slope statistics for transitions between rural uses involving pastureland. As expected, the land that moves from pasture use to arable or horticultural use is on very flat land with an average slope of 1 degree and low variability in slope. The pastureland that converted into forest or scrub is on steeper land than the average slope for land that remained in pasture.

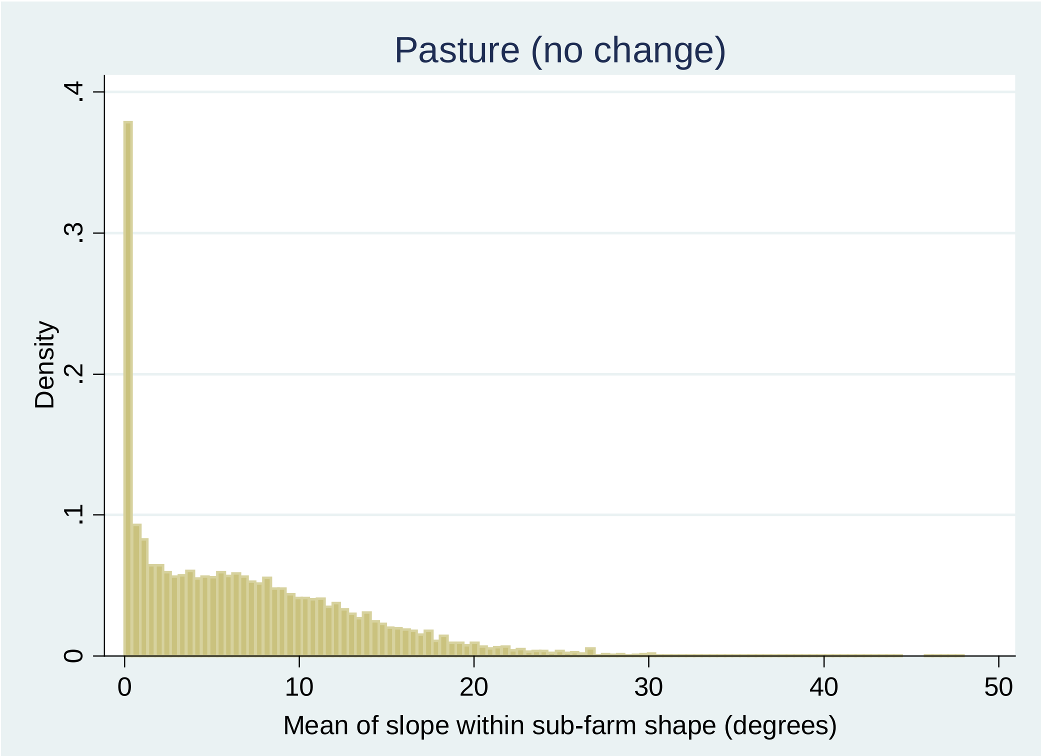
In Figure 17, we compare the average slope within polygons of pastureland that remained in pasture and pasture that converted to forest, since these transition categories represent the largest areas in Table 7. The histograms in the figure focus on the average in each sub-farm shape and only capture variability in the form of differences between sub-farm means. The figure reinforces that pasture that converted into forest is on steeper land on average than pasture that remained in pastoral use.

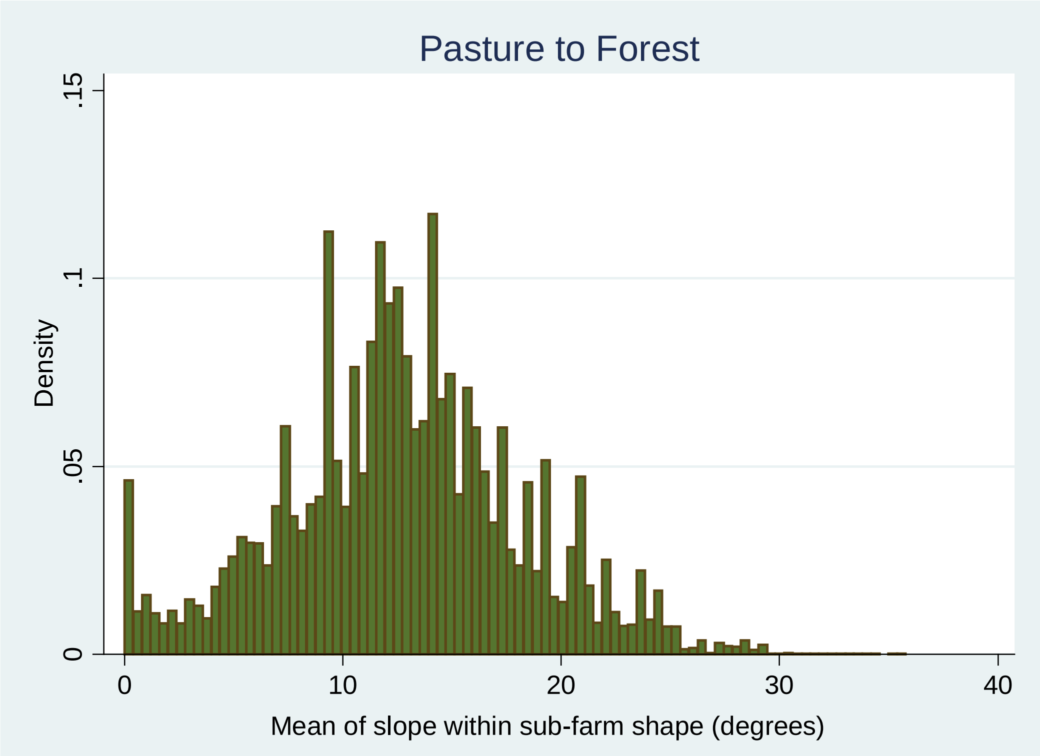
Table 7. Slope statistics for transitions of more than 50 hectares between rural uses involving pasture on private, non-Maori land

Land cover change	Total area (hectares)	Minimum	Minus one standard dev	Average	Plus one standard dev	Maximum
Pasture to Arable	88	0	0	1	1	4
Pasture to Forest	115,300	0	9	13	17	44
Pasture to Horticulture	3,847	0	0	1	2	24
Pasture to Scrub	429	0	9	12	16	42
Pasture (no change)	9,852,000	0	4	7	10	61
Forest to Pasture	333	0	4	7	9	32
Native to Pasture	60	0	6	8	9	22
Bare Ground to Pasture	70	1	18	21	24	52
Scrub to Pasture	3,735	0	7	10	13	37
Wetland to Pasture	142	0	1	2	3	10

Table 2 (see Section 4 on Descriptive Statistics) showed the average slope for each of the source categories.

Figure 17. Histograms comparing average slope of pasture that did not change with pastureland that converted to forest, weighted by polygon area





4.2.2 Scrub Transitions

About 18,700 hectares of scrub and native forest on private land were converted to another land cover type from 1996 to 2002. Less than 1,000 hectares of scrub and native forest regenerated on other land cover types over the same period, so there was a net loss of almost 18,000 hectares of scrubland. Figure 18 shows the area and quality of land that converted out of scrub and native cover. About 8,000 hectares went to plantation forestry, most of this on land in LUC classes VI and VII. About 1,000 hectares of scrub were cleared for pasture, and half of this was in LUC class VI.

Figure 18. Area of land moving out of scrub and native forest by new land cover type

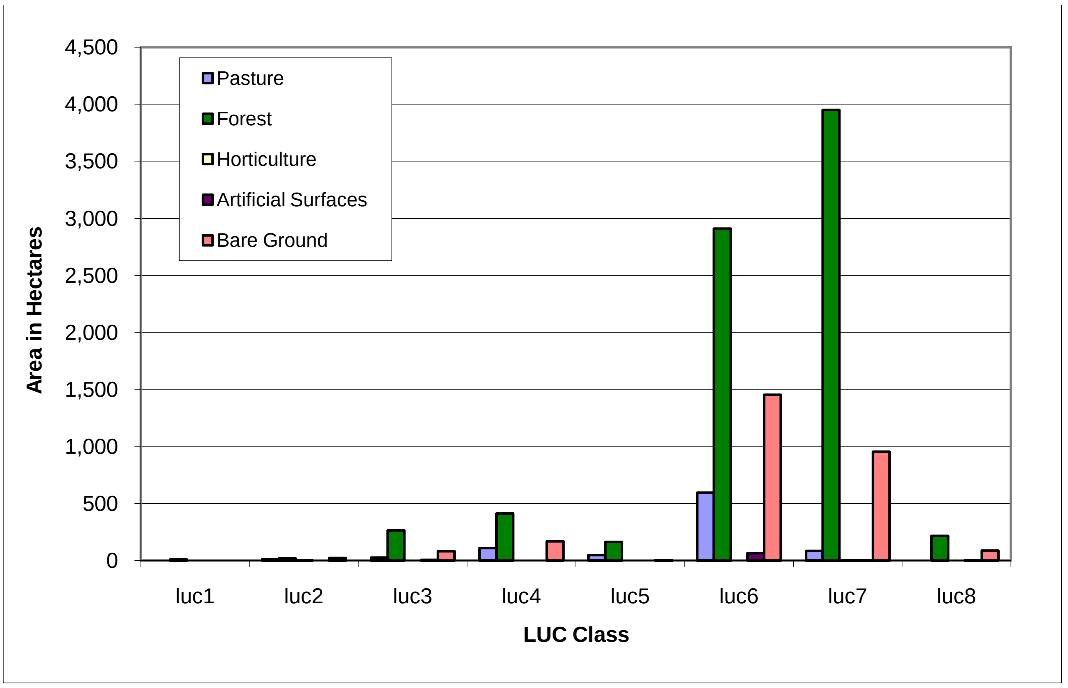
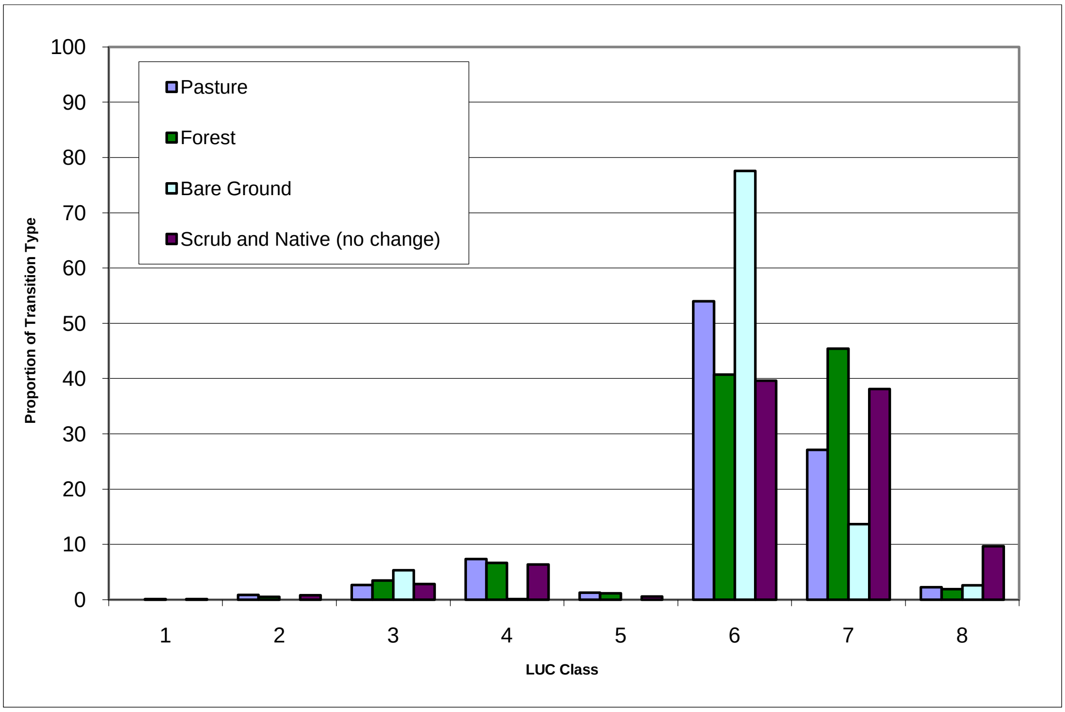


Figure 19 compares the land quality of the 1.7 million hectares of land that remained in scrub with the quality of the land that transitioned out of scrub and native cover. The figure shows the proportional allocation of each transition type across LUC classes, so each colour sums to 100 percent. Horticulture has been excluded here because only 2 hectares of scrub and native forest converted to horticulture. About 86 percent of the land that moved from scrub to plantation forestry was in LUC class VI and VII. The average quality of land that converted to pasture from scrub is slightly higher than the quality of land that converted to plantation forestry, with about 73 percent of new pastureland occurring in LUC classes IV, V and VI. Most of the land that stayed in scrub and native cover is located on land in LUC classes VI, VII and VIII.

Figure 19. Proportional distribution of scrub and native forest transitions across LUC class



Areas of transition into bare ground from other land cover types are shown in Table 8. The new bare ground that appeared from 1996 to 2002 can largely be attributed to landslides and erosion on pasture and scrubland. Looking at land moving out of bare ground, a small area shows up as converting from coastal sand and gravel to afforestation. However this area is small, about 22 hectares out of 114 hectares of bare ground that transitioned into another land cover over the observed time period (or a total of 132,500 hectares of bare ground on private land in 2002.) So it is possible that some land in bare ground is actually transitioning into plantation forestry but these areas are likely to be small if they exist.

Table 8. Transitions into bare ground from other land cover types by LCDB2 categories

1996 Land Cover	2002 Land Cover	Hectares
High Producing Exotic Grassland	River and Lakeshore Gravel and Rock	2
High Producing Exotic Grassland	Landslide	32
High Producing Exotic Grassland	Alpine Gravel and Rock	6
Low Producing Grassland	Coastal Sand and Gravel	2
Gorse and Broom	Coastal Sand and Gravel	4
Manuka and or Kanuka	Landslide	17
Manuka and or Kanuka	Alpine Gravel and Rock	40
Broadleaved Indigenous Hardwoods	Alpine Gravel and Rock	14
Deciduous Hardwoods	River and Lakeshore Gravel and Rock	2
Indigenous Forest	Landslide	6

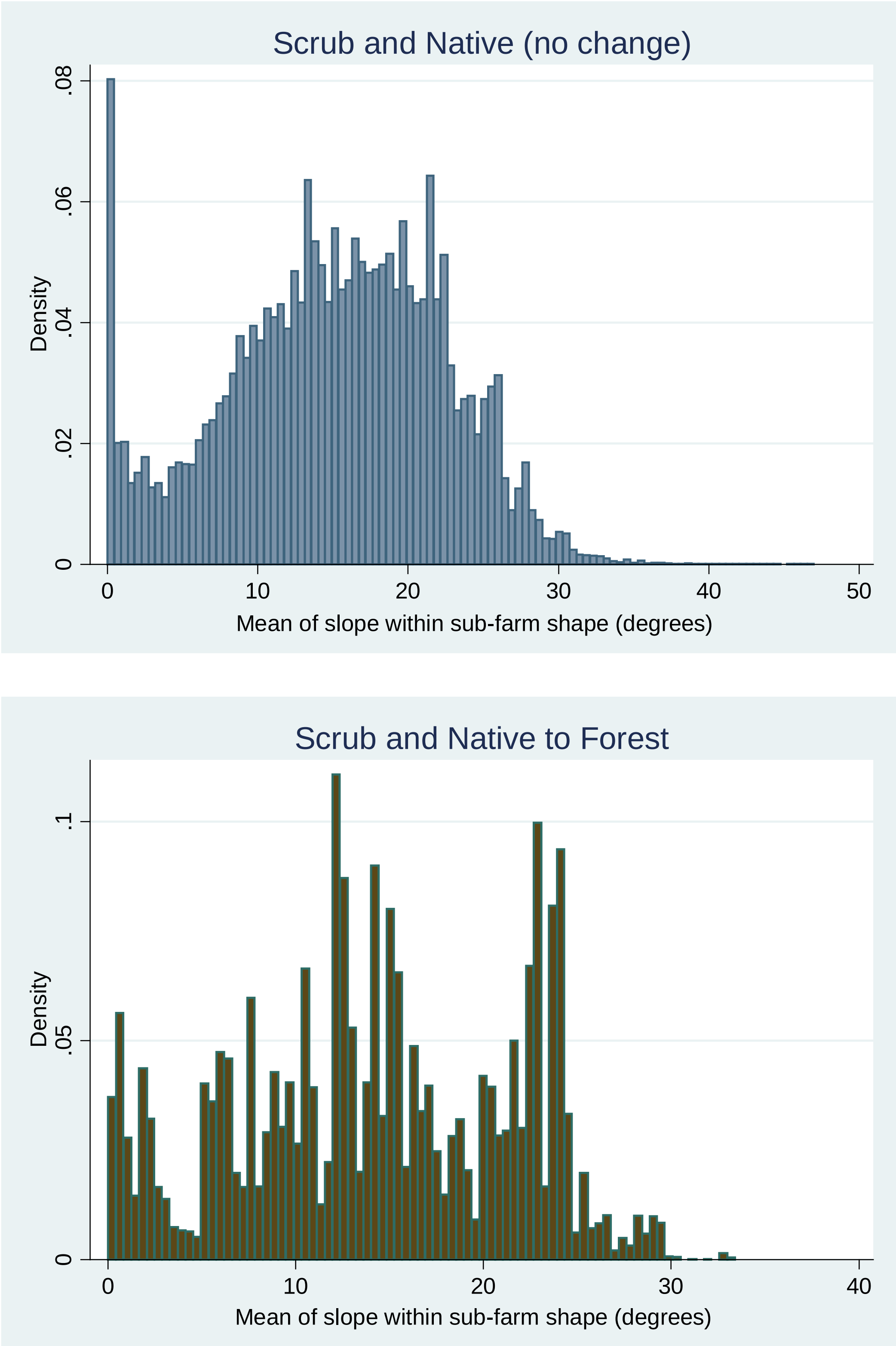
Table 9 presents slope statistics for transitions between rural uses involving scrub and native forest. As expected, the scrubland and native forest that move into pasture have lower average slope than the scrub and native forest that remain in their original land cover types. The slope profile on scrubland that converted to forest is about the same as the slope profile for land that remained in scrub except for the maximum slope. No land moved into native cover over the period 1996 to 2002 and only a small amount of land moved into scrub cover from pasture and forest. The area that converted from forest to scrub is on surprisingly flat land on average.

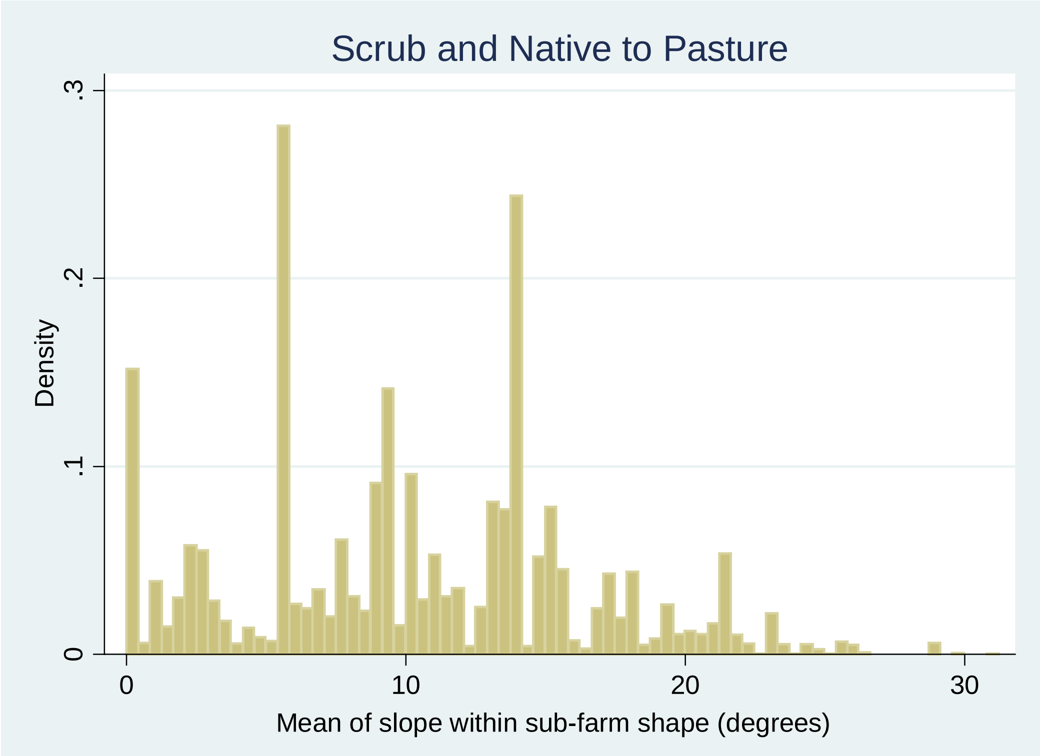
Table 9. Slope statistics for transitions of more than 50 hectares between rural uses involving scrub and native forest on private, non-Maori land

Land cover change	Total area (hectares)	Minimum	Minus one standard dev	Average	Plus one standard dev	Maximum
Scrub to Pasture	3,735	0	7	10	13	37
Scrub to Forest	13,490	0	11	15	19	44
Scrub to Bare Ground	75	0	7	10	13	27
Native to Pasture	60	0	6	8	9	22
Native to Forest	1,358	0	5	8	10	27
Native (no change)	1,214,000	0	11	15	20	61
Scrub (no change)	1,311,000	0	11	15	19	58
Pasture to Scrub	429	0	9	12	16	42
Forest to Scrub	444	0	3	5	7	28

The histograms in Figure 20 compare the average polygon slopes across three different categories of scrub and native forest: that which did not change, converted to plantation forestry or converted to pasture. There is clearly a lot of variability in the slope of land that converted out of scrub and native cover to forest or pasture.

Figure 20. Histograms comparing average slope of scrub and native forest that did not change with scrub and native forest that converted to plantation forestry or pasture, weighted by polygon area





5 Summary

The summary statistics presented here reinforce the land use rules developed for the LURNZ model. The assumptions we make about land use/cover and land quality (Figure 1) are strongly supported by the relationships we see between the land use/cover data in LCDB2 and Agribase and the LUC and slope data. If we measure land quality by the geophysical characteristics captured in LUC and slope, dairy farming occurs on the highest quality land, with sheep and beef farming, plantation forestry and scrub on progressively lower quality land.

However, these results also indicate that deterministic rules and a strict ordering of highest value use to lowest on a particular piece of land are difficult to define. There is significant overlap over the range of LUC classes and slopes between different land covers and land uses. In particular, it is difficult to separate plantation forestry and sheep and beef farming by LUC. Potentially, looking at a composite of LUC, slope and other physical characteristics would provide clearer divisions between land uses.

The results on the type of transitions observed and the characteristics of land that makes transitions so far broadly support the ordering of land suggested in Figure 1. Starting on the worst land, all observed scrub transitions are going out of scrub. Most scrub is converted, as anticipated, to plantation forest. Some native forest also converts to plantations. Some scrub goes into pasture – mostly into sheep/beef on hill country or deer, goats and other animals. The scrub that goes to forest is almost indistinguishable by LUC from that converting to pasture but the forest tends to be established on steeper land.

Almost no forest converts to other uses. Most new forest comes from pasture. The pasture that converts to forest tends to be on relatively steep and low quality land.

Very little pasture is observably lost – a small amount goes to plantation forest. However this masks a reduction of more than one million hectares of commercial pasture land reported in the Agricultural statistics data. Most of the lost land is attributed to sheep farms. Some of this land has converted to lifestyle properties or small holdings which are not GST-registered. Another part is likely to be abandoned land that is converting to scrub – up to 180,000 ha – but that is not observable yet by satellite. Some may be young plantation forest blocks that are similarly unobservable.

We know from Statistics New Zealand data that dairy has expanded considerably. These conversions are nearly all occurring on existing pasture. Dairy pasture tends to be on the lower LUC class (i.e. higher quality) lands but there is considerable overlap with other pastoral uses. In contrast, 85% of dairy pasture has zero slope while only 40% of intensive sheep/beef land. Slope may be the most appropriate variable to predict dairy transitions.

The LCDB/Agribase dataset with 1996/1997 land cover and 2002 land use will allow modelling on a scale that is closer to the scale at which landowners make decisions about how to use their properties. Even if the sub-farm polygons are obscured by converting to raster datasets, retaining the farm ID would provide enough information to differentiate between individual landowners.

6 Directions for future research

This paper reflects a first effort to explore this new database and a first step towards formal econometric estimation of the drivers of small scale land transitions. Some ideas for next steps are outlined below.

It would be useful to present Figure 1 in terms of real data, possibly using carrying capacity (based on LUC but converted into a continuous variable which represented the ability of the land to sustainably support a number of stock units). This would provide a useful check on data on profitability and also indicate the precision with which we might allocate land based on predicted profitability in each use.

It would also be useful to repeat some of the analysis, including the transition table, using carrying capacity instead of the discrete LUC classes. This might provide a more parsimonious relationship and would avoid the arbitrary boundaries between classes and the classes with very small areas of land. Another alternative to LUC is Troy Baisden's productivity index (Baisden, dataset, 2003; and Baisden, 2006).

If some land use decisions, such as dairy conversions, are made at a property rather than a parcel level, which seems likely, it would be good to create property level variables.

Other variables we have considered as predictors of land use and land use change are area characteristics – e.g. current land use in territorial authority for dairy/sheep/beef or small radius for land cover; proximity to urban area or processing plant; potential profitability; property size – to distinguish life-style properties from commercial agriculture. We also need to reintroduce the Maori land and explore that separately.

Appendix A:

Table 10. Transitions between land cover (1996) and land cover/use (2002) on private land
The top number in each cell is land area in hectares, the bottom term shows percentage of 1996 cover

	2002 land cover/use									
1996 land cover	Artificial	Horticulture and arable	Pasture: Dairy	Pasture: Sheep/beef intensive	Pasture: sheep/beef hill country incl merino	Pasture: Deer and other animals (including blank)	Forest	Scrub	Native forest	Natural (bare ground, water, wetlands)
Artificial	183,900	0	2	52	4	0	25	7	0	38
	99.93%	0.00%	0.00%	0.03%	0.00%	0.00%	0.01%	0.00%	0.00%	0.02%
Horticulture and arable	23	401,799	0	0	0	0	22	0	0	0
	0.01%	99.99%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
Pasture	4,645	3,935	1,857,807	3,781,761	3,672,429	540,097	115,330	429	0	687
	0.05%	0.04%	18.62%	37.90%	36.81%	5.41%	1.16%	0.00%	0.00%	0.01%
Forest	531	12	107	26	123	77	1,252,300	444	0	0
	0.04%	0.00%	0.01%	0.00%	0.01%	0.01%	99.89%	0.04%	0.00%	0.00%
Scrub	3.793643	3	246	976	1,700	813	13,489	1,311,200	0	75
	0.00%	0.00%	0.02%	0.07%	0.13%	0.06%	1.02%	98.70%	0.00%	0.01%
Native forest	7	2	11	13	3	33	1,358	0	1,216,100	8
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%	99.88%	0.00%
Natural (bare ground, water, wetlands)	2	3	27	173	11	0	43	15	0	436,470
	0.00%	0.00%	0.01%	0.04%	0.00%	0.00%	0.01%	0.00%	0.00%	99.94%

Appendix B: Dataset References

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