

Pastoral land cover and intensity changes in the Waikato region 2001-2018

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Abbreviations

CLUES	Catchment Land Use for Environmental Sustainability model
GIS	Geographic Information System
LCDB	Land Cover Database
LCDB5	LCDB v5.0 Version Trace
LRIS	Land Resource Information System
LUC	Land Use Capability
LUCCS	Land Use Capability Classification System
NZLRI	New Zealand Land Resource Inventory
SQL	Structural Query Language
WRC	Waikato Regional Council

Abstract

The Waikato region encompasses most of New Zealand's central North Island with a land area of about 2.5 million ha. Of this area about half (1.3 million ha) is in pastoral land use. Since the 2000s, conversion from planted forest to pastoral land, and conversion of non-dairy pastoral land to dairy has increased the area of pastoral land and its intensity of use. With land use intensification, greater pressure can be placed on existing soil and water resources. Maintaining the quality of these resources is vital to the Waikato region's prosperity. This requires knowledge of the location and changes in land use pressures. This knowledge is fundamental to understanding trends and developing and prioritising sensible management practices and policy.

This report provides the first comprehensive spatial analysis of pastoral land cover change and intensity for the Waikato region. Conversion of planted forest to pastoral land, and changes in the intensity of pastoral land use in the Waikato region between 2001 to 2018 at three timesteps (2002-2008, 2008-2012, and 2012-2018) is presented. A multiple intersect-based spatial analysis method using Manifold® Professional System Release 9 was used to derive two main metrics: (1) conversion of planted forest to pastoral land, and (2) pastoral land intensity change.

Metrics were interrogated sub-regionally by management zone, land use capability class, and farm type to determine where, and on what land, pressures may be increasing or decreasing with respect to pastoral land intensity changes. Two pastoral land intensity indicators identify the changes in pastoral land intensity through time (every five years), for different parts of the region (management zones), and on different types of land (land use capability class).

Executive summary

Introduction

To date there has been limited spatial description of the types of land use change in the Waikato region. Improved and more available regional spatial datasets with increased resolution have facilitated the spatial analysis of planted forest and pastoral land use changes. The results applied in conjunction with other data such as the New Zealand Land Resource Inventory's Land Use Capability classification (LUC) can provide an indication of risk to soil and water resources at regional and sub-regional scales. This report provides a spatial description of the conversion between planted forest and pastoral land, and the changes in pastoral land intensity between 2001 to 2018, and at three timesteps: 2001-2008, 2008-2012, and 2012-2018 across the Waikato region.

Methods

The method builds on the approach developed by Hill and Borman (2011) to assess pine to pastoral land and pastoral land intensity changes in the Waikato region for the 2001-2008 timestep.

Improvements to the previous method include a revision of the spatial analysis techniques, the use of several new geospatial data layers at refined and more recent timesteps, and improved quality assurance procedures.

For this study, datasets from 2001/02, 2008/09, 2012/13 and 2018/19 were used to provide analysis timesteps for 2001-2008, 2008-2012, and 2012-2018. The selection of the data is aligned with the availability of land cover data provided by the Land Cover Database version 5.0 (LCDB v5.0).

Stock unit density data for the Waikato region, derived from Agribase® data provided by AsureQuality, has been collected and stored at six monthly intervals since 2001. Available snapshots of the stock unit density data were selected and processed within the GIS to align with the LCDB v5.0 data (i.e. 2001/02, 2008/09, 2012/13, and 2018/19).

All geospatial modelling and analyses were performed using the Manifold® System Release 9 platform using structured query language (SQL) scripts. The use of SQL allows for rapid query development and tuning, repeatability, and optimisation for working with large spatial database tables. SQL represents an industry standard tool for working with database tables which is optimised for all data sizes. Manifold® System Release 9 can interoperate with almost any other database irrespective of data size.

The following metrics were derived from the analyses:

1. Conversion between planted forest and pastoral land
2. Net change in pastoral land
3. Pastoral land intensity

All three metrics were derived using a combination of land cover data, farm type, and stock unit density data. Conversion between planted forest and pastoral land was estimated using Land Cover Database Version 5.0 Trace (LCDB5)¹ data and further confirmed using Agribase® farm type data. Estimates of pastoral land intensity combined LCDB5 data and Agribase® farm type and stock unit density data. Farm type classes for the Waikato region were then applied to determine pastoral land intensity changes.

¹ <https://iris.scinfo.org.nz/layer/104441-lcdb-v50-version-trace-mainland-new-zealand/>; LCDB v5.0 Version Trace allows users to track changes back to the previous version (v4.1), and to reconcile derived quantities, such as the total area of a class in a region, to those derived from the earlier LCDB version.

The metrics were analysed for 2001-2018, and for individual timesteps (2001-2008, 2008-2012, and 2012-2018). The metrics were further analysed sub-regionally and with land use capability for 2001-2018 and the three timesteps, to determine where and when the main changes were occurring and where pressures on the soil, land, and water are most likely.

Results

- An estimated 57,418 hectares (ha) of planted forest was converted to pastoral land use in the region from 2001 to 2018, while an estimated 15,891 ha of pastoral land was converted to planted forest. The net change in planted forest converted to pastoral land in the region for 2001-2018 was an estimated 41,527 ha.
- Comparing the regional changes between planted forest and pastoral land for each timestep showed a net increase in planted forest conversion to pasture from 2001-2008 to 2008-2012, followed by a net decrease for 2012-2018.
- Between 2001 and 2018, net planted forest conversion to pastoral land in the Waikato region was greatest in the Upper Waikato zone (49,525 ha). Excluding the Upper Waikato zone, the area of conversion for the other zones was lower, ranging from a net increase in pastoral land in the Waihou Piako zone (544 ha), to a net decrease in pastoral land in the Lake Taupo zone (-6120 ha).
- A comparison of conversion between planted forest and pastoral land by LUC class for 2001-2018 showed that the greatest net increase in pasture occurred on LUC 6 (17,060 ha - 41.1%), followed by LUC 4 (11,884 ha - 28.6%), and LUC 3 (9,310 ha - 22.4%). The balance of planted forest conversion to pastoral land (collectively 3281 ha - 7.9%) was spread across the remaining LUC classes.
- Between 2001 and 2018, an estimated 504,335 ha (40%) of pastoral land had undergone some intensification, 491,582 ha (38%) showed no change, and 280,921 ha (22%) had undergone destocking. On an annual basis, this represents an annual net intensification rate of just over 1% per annum for the 17-year period.
- Both intensification and destocking showed decreases from the first timestep (2001-2008) to the most recent timestep (2012-2018), with a corresponding increase in the area showing no change.
- Between 2001 and 2018, moderate intensification and major intensification have been greatest in the Upper Waikato zone, most likely driven by the conversion of planted forest to pastoral land. On average 39% of management zone area showed no change in pastoral land intensity from 2001 to 2018.
- Major destocking was 8% of pastoral land area on average across all management zones, with the lowest percentages in the West Coast and Upper Waikato zones, and the highest percentages in the Central Waikato and Lake Taupo zones.
- Between 2001 and 2018, major intensification across the region was greatest for the arable LUC classes (LUC 1-4). However, moderate intensification is only marginally less for non-arable LUC classes (LUC 5-8) when compared to arable LUC classes (LUC 1-4).
- Moderate destocking was generally consistent across all LUC classes, except for LUC 1 which was slightly less as a proportion of pastoral land area (9%). Major destocking was slightly higher for arable LUC classes compared with non-arable LUC classes.

Conclusions

- The methods and analyses presented in this report provide the first comprehensive spatial analysis of pastoral land cover change and intensity for the Waikato region.
- From 2011 to 2018, pastoral land in the Waikato region increased in area by an estimated 41,527 ha due to the net conversion of planted forest.
- By far the greatest area of net conversion of planted forest to pastoral land occurred in the Upper Waikato zone.
- The Lake Taupo zone had the greatest conversion of pastoral land to planted forest, which may reflect the implementation of Waikato Regional Plan Variation 5 policies and rules to manage land use in the catchment.
- From 2001 to 2018, an estimated 504,335 ha (40%) of pastoral land had undergone some intensification, 491,582 ha (38%) showed no change, and 280,921 ha (22%) had undergone destocking.
- On an annual basis, this represents an annual net intensification rate of just over 1% per annum for the 17-year period.
- Regionally, both intensification and destocking have declined since the first timestep, with a corresponding increase in the area of pastoral land showing no change.
- Regionally, intensification of existing pastoral land was the greatest driver of pastoral land use change in the Waikato region between 2001 and 2018, followed by planted forest conversion to pastoral land.
- The Upper Waikato zone was the only management zone where planted forest conversion to pastoral land was the main driver of pastoral intensity.
- The majority of new dairy land in the Waikato region has occurred in the Upper Waikato zone.
- Two regional indicators are proposed for ongoing monitoring of pastoral land cover change and intensification; *Pastoral land intensity changes for land use capability classes in the Waikato region 2001-2018*, and *Pastoral land intensity changes for management zones in the Waikato region 2001-2018*.
- Improving the availability and quality land use data would greatly improve estimates of land use change at a regional and sub-regional scale.

Recommendations

- Although the Waikato farm types used for analysis in this report provide a reasonable relative delineation of farm type intensity, a more thorough re-evaluation of the farm type classes, using currently available data may be worthwhile.
- Repeating the analysis with the release of subsequent LCDB data would provide ongoing monitoring of pastoral land cover change and intensity trends.
- Incorporating other land use intensification such as cropping could be investigated to provide monitoring beyond pastoral land alone.
- Investigating spatial relationships between pastoral land intensity and other monitoring data such as soil quality and water quality would strengthen the link between land use changes and impacts and could aid in the implementation of land management practices to mitigate the impacts.

1 Introduction

The Waikato region encompasses most of New Zealand's central North Island with a land area of about 2.5 million hectares (ha). As of 2018, an estimated 53% of the Waikato region was in pastoral land use, and 13% in exotic forest (planted forest).

Planted forest conversion to pastoral land, dairy conversions, changes in ownership patterns, higher stocking rates, and more intensive farming practices have occurred in the Waikato region over the past decade (Cameron et.al., 2009; Hill and Borman, 2011). Additionally, many sheep and beef farms have moved into dairy support roles, such as the grazing of dairy heifers or cropping for maize silage. There has been significant conversion from plantation forest to dairying and other pastoral uses in the southern Waikato, although forestry remains significant (Cameron et.al., 2009). Water quality trends for the Waikato River and other rivers and streams are indicating significant increases in total nitrogen, nitrate, total phosphorus, and *Escherichia coli*, consistent with increased agriculture intensity above and beyond any improvements made through best management practice (Vant, 2018).

To date there has been limited spatial description of the types of land use change in the Waikato region. Improved and more available regional spatial datasets with increased resolution have facilitated the spatial analysis of planted forest and pastoral land use changes. The results applied in conjunction with other data such as the New Zealand Land Resource Inventory's Land Use Capability classification (LUC) can provide an indication of risk to soil and water resources at regional and sub-regional scales. Scenario modelling relies on accurate input data to provide valid scenarios. Such analysis is often hamstrung by the detail and date of spatial data. This report provides a spatial description of the conversion between planted forest and pastoral land, and the changes in pastoral land intensity between 2001 and 2018, and three timesteps; 2001-2008, 2008-2012, and 2012-2018 across the Waikato region.

Conversion of land between planted forest and pastoral land, and pastoral stock unit density were used to determine categories of pastoral land use change. Three categories of land use change were identified; (1) land cover change: land cover change from one of low management inputs to high management inputs (e.g., increased fertiliser use) associated with a significant land cover change from either non-productive to productive land use or from low input land use to higher management inputs (e.g., drystock to cropping), (2) land use change: land use change within a given land cover (e.g., change from dry stock farming to dairy farming), and (3) intensification within a land use: land use remains the same but increased stock numbers or other intensity changes (e.g., intensification in dairy or change from sheep and beef to dairy support).

Pastoral land use changes were then compared sub-regionally using management zones and against land use capability using the New Zealand Land Resource Inventory's Land Use Capability classification (LUC).

2 Method

2.1 Datasets

Two main data sets were used to derive land cover, land use, and stock unit density data for the analysis; Land Cover Database v5.0 (LCDB5) and AgriBase (AsureQuality Ltd, 2001/02, 2008/09, 2012/13 and 2018/19) snapshot data for the Waikato region. Additional spatial data included Waikato management zone boundaries, and the New Zealand Land Resource Inventory's Land Use Capability classification (LUC) polygons. These data were used for further interrogating the landcover, land use, and stock unit density data.

2.1.1 Land Cover Database v5.0

The New Zealand Land Cover Database (LCDB) is a multi-temporal, thematic classification of New Zealand's land cover. Land cover features are described by a polygon boundary, a land cover code, and a land cover name at nominal timesteps. The Ministry for the Environment (MfE), with support from other central government agencies, updates the LCDB approximately every five years. The LCDB has data available for summer 1996/97, summer 2001/02, summer 2008/09, summer 2012/13, and summer 2018/19. LCDB v5.0 Version Trace² (LCDB5) was released in January 2020 and includes corrections to all timesteps 1997/97, 2001/02, 2008/09, 2012/13 and 2018/19. For the analyses in this report, the 2001/02, 2008/09, 2012/13, and 2018/19 timestep data have been used. The data are available on Manaaki Whenua – Landcare Research's Land Resource Information System (LRIS) portal (Manaaki Whenua – Landcare Research, 2021).

2.1.2 Agribase

AgriBase provides the most complete and wide-ranging spatial database of farm type and stock unit density for the Waikato region. AsureQuality New Zealand Limited maintains AgriBase records through routine contact with farmers and monthly updates of property changes from Quotable Value New Zealand. Following a one-off purchase of 2001/02 Agribase data for the Waikato region, Waikato Regional Council has purchased six-monthly data updates on an ongoing basis. Agribase data has been selected to align with the LCDB timesteps (2001/02, 2008/09, 2012/13 and 2018/19) for the analysis in this report.

2.1.3 Waikato catchment management zones

Waikato Regional Council delineates the Waikato region into eight management zones to administer its river and catchment services. These include the Coromandel, Waihou Piako, Lake Taupo, Upper Waikato, Central Waikato, Lower Waikato, Waipa, and West Coast zones (Figure 1).

² <https://lris.scinfo.org.nz/layer/104441-lcdb-v50-version-trace-mainland-new-zealand/>; LCDB v5.0 Version Trace allows users to track changes back to the previous version (v4.1), and to reconcile derived quantities, such as the total area of a class in a region, to those derived from the earlier LCDB version.

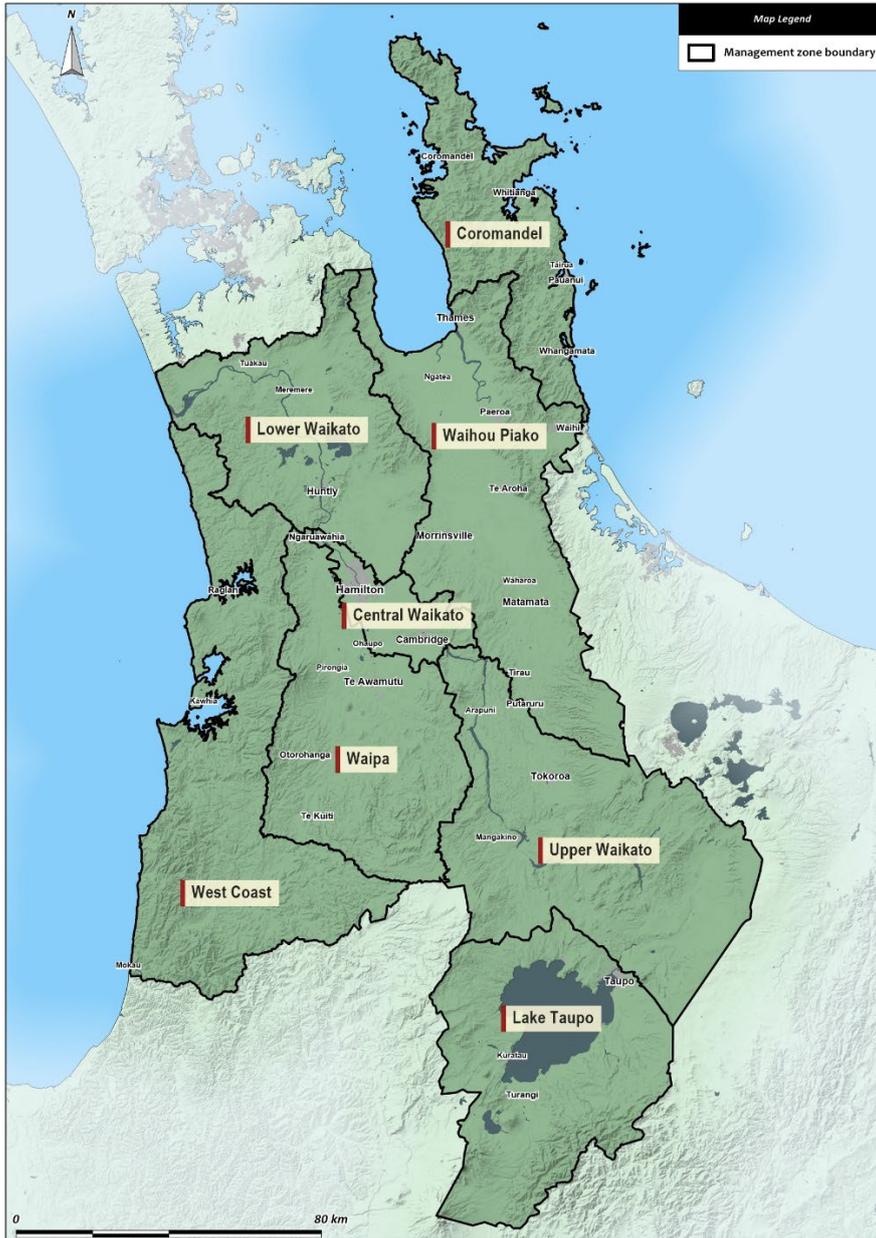


Figure 1. Waikato Regional Council management zones for the Waikato region.

2.1.4 Land use capability

The land use capability (LUC) classification is an assessment of the capacity of the land for long-term sustainable agricultural production. The land use capability classification for New Zealand is part of the New Zealand Land Resource Inventory, sometimes referred to as the Land Use Capability Classification System (LUCCS). Land use capability delineates the land based on its capability to support broad land uses (including arable cropping, pasture, and planted forest), and identifies the land’s limitations to do so.

The land use capability classification for New Zealand is a three-level hierarchical classification system, comprising LUC class, LUC subclass, and LUC unit. The analysis in this report used LUC Class. LUC class classifies the land into eight main classes, based on increasing physical limitations and decreasing versatility for long-term agricultural uses (Figure 2).

Increasing limitations to use	LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability	Decreasing versatility of use
	1	High ↓ Low	High ↓ Low	High ↓ Low	Multiple use land	
	2					
	3					
	4					
	5	Unsuitable	Low ↓ Unsuitable	Low ↓ Unsuitable	Pastoral or forestry land	
	6					
	7					
	8					
			Unsuitable	Unsuitable	Conservation land	

Figure 2. Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8 (after Lynn et al., 2009).

The LUC data for the analysis was sourced from Manaaki Whenua’s Land Resource Information System (LRIS) database.

2.2 Spatial analysis

The method builds upon the approach developed by Hill and Borman (2011) to assess pine to pastoral land and pastoral land intensity changes in the Waikato region for the 2001-2008 period.

Improvements to the previous method included a revision of the spatial analysis techniques, the use of several new geospatial data layers at refined and more recent timesteps, and improved quality assurance procedures.

For this study, datasets from 2001/02, 2008/09, 2012/13, and 2018/19 were used to provide analysis timesteps for 2001-2008, 2008-2012, and 2012-2018. The selection of the data aligned with the availability of land cover data provided by LCDB5.

Stock unit density data for the Waikato region, derived from Agribase® data provided byASUREQuality, has been collected and stored at six monthly intervals since 2001. Available snapshots of the stock unit density data were selected and processed within the GIS to align with the LCDB5 data (i.e. 2001/02, 2008/09, 2012/13, and 2018/19).

All geospatial modelling and analyses were performed using the Manifold® System Release 9 platform using structured query language (SQL) scripts. The use of SQL allows for rapid query development and tuning, repeatability, and optimisation for working with large spatial database tables. SQL represents an industry standard tool for working with database tables which is optimised for all data sizes. Manifold® System Release 9 is a massively parallel single file database which can interoperate with almost any other database irrespective of data size. The use of a universally understood and standardized language such as SQL inherently provides its own process nature as it explicitly describes the analysis steps to the GIS practitioner.

To prepare the data for analysis, AgriBase® data closely aligned to each of the LCDB v5.0 intervals was initially compiled. These were subsequently run through a custom ‘flattening’ process which seeks to ‘flatten’ spatially overlapping farm records within the raw Agribase® dataset while correctly accounting for the contained stocking information. Without this pre-processing step,

many traditional GIS methods would result in double counting and the overestimation of animal counts.

The various source data layers are initially brought together into a single base layer via a series of union topology overlay operations. Union retains all data from both input layers and 'cookie cuts' spatially coincident farm polygons. The result of these series of operations is a single base table and spatial layer containing all attribution from the source layers, totalling some 2.5 million objects.

Before use, this layer requires a final clean-up to remove tiny sliver polygons which are created during the union intersections and result from coordinate rounding in the source data.

Coordinate normalisation was achieved by setting a nominal coordinate precision or epsilon value for the dataset and rebuilding the topology. The value used for the work is 0.001 m (or 1 mm). Using this value, any coordinates closer than 1 mm from each other will be snapped together. In the case of a very thin sliver polygon, if all the coordinates are within 1 mm of each other, the sliver polygon will be snapped out of existence and hence 'cleaned' from the dataset.

With the base dataset prepared, SQL was used to add live computed columns to the base table. This technique is similar to adding a new attribute and updating it permanently but is more flexible as it allows the computed column definition to be updated or changed and the results propagated throughout the dataset immediately.

Computed columns were used to classify the base AgriBase® data into data such as intensification classes which can subsequently be used by queries to calculate intensification change across the dataset. As classifications commonly required a degree of modification to ensure that they were capturing all groups, the computed columns made for a very efficient tool to adjust classification code and instantly view the results.

Once all the required information is available in a single base table, the indicator change statistics and graphs were created by coding a series of targeted SQL queries to extract and summarise the required information in tabular format, for graphing or for report mapping.

Where changes to data outputs or new data are required, SQL query(s) can be refactored, or additional SQL queries developed and stored with the source data in a single file MAP project. This provides a very streamlined process which can be opened instantly when the indicator next requires updating. All metadata and instructions are stored within the project file helping the user understand the process after any interval of elapsed time.

2.3 Metrics and analyses

Applying the methodology allows for the determination of changes in the area of pastoral land and the intensity of pastoral land. The following metrics are derived for the analyses:

1. Conversion between planted forest and pastoral land
2. Net change in pastoral land
3. Pastoral land intensity

All three metrics were derived using a combination of land cover data, farm type, and stock unit density data. The metrics were analysed for 2001-2018, and for three individual timesteps (2001-2008, 2008-2012, and 2012-2018). The metrics were further analysed sub-regionally and with land use capability for 2001-2018 and the three timesteps to determine where and when the main changes were occurring and where pressures on the soil, land, and water are most likely.

2.3.1 Planted forest conversion to pastoral land

Conversion between planted forest and pastoral land for the 2002-2008, 2008-2012, and 2012-2018 timesteps was estimated using Land Cover Database v5.0 (LCDB5) data and further confirmed using Agribase farm type data.

Within the LCDB5 dataset, land under planted forest was identified by [LCDB_NAME] attributes Exotic Forest and Forest - Harvested.

The pastoral extent was defined by LCDB5 dataset [LCDB_NAME] attributes Grassland - High producing, Grassland - Low producing, and Grassland - Depleted.

The data for each of the beginning years of the timestep were then spatially compared to determine the change in area from planted forest to pastoral land or pastoral land to planted forest. To provide a relative indication of conversion across the three timesteps, data were presented as the average annual change for each timestep. This is required because each timestep includes a different number of years; 2001-2008 (seven years), 2008-2012 (four years), and 2012-2018 (6 years).

2.3.2 Pastoral stock unit density

To calculate stock unit density from AgriBase data, Waikato Regional Council uses the AsureQuality stock unit conversion factors. These factors are used to work out feed budgets in the agricultural industry. Pastoral stock unit density and typical farm system data calculated for each of the timesteps was spatially compared within the GIS using spatial intersection techniques. Animal counts for dairy cattle, beef cattle, deer and sheep were converted into their stock unit equivalents from each of the Agribase data snapshots. All other pastoral livestock were excluded from consideration. Existing stock unit density classes for State of Environment reporting (Brown et al., 2002; Hill and Borman, 2011) were used to assign typical farm system classes for given density ranges (Table 1). An additional category for plantation forest was added and stock unit density was assumed to be zero.

Table 1. Stock unit density classes used for State of Environment reporting (Hill and Borman, 2011).

Pastoral stock unit density class (stock units/ha)	Farm type where stock unit density class typically observed	Cows per hectare equivalent
0	Plantation forest	0
Greater than 0 to 10.5	Sheep farms	Greater than 0 to 1.5
10.5 to 17.5	Beef farms and lower stocked dairy farms	Greater than 1.5 to 2.5
17.5 to 24.5	Mid-range of dairy farms	Greater than 2.5 to 3.5
Greater than 24.5	Higher stocked dairy farms	Greater than 3.5

It is important to note that these estimated farm types are only meant to provide a relative picture of intensity and changes. The farm types used were derived more than ten years ago, and it is likely that the stock unit ranges used may have changed for some farm types.

To check if the farm types were still relevant, current statistics for farm types were compared. Beef & Lamb provides stock unit ranges for North Island hill country and finishing farms (Table 2).

Table 2. Beef and Lamb farm class data for North Island farms (Beef and Lamb, 2021).

Farm type	Stock units per hectare	Cows per hectare equivalent
North Island hard hill country	6 - 10	0.9 – 1.4
North Island hill country	7 - 13	1.0 – 1.9
North Island finishing farms	8 - 15	1.1 – 2.1

In general, the range of stock units from the Beef & Lamb data fits within the Sheep farms and Beef farms and lower stocked dairy farm types used. For dairy farms, based on *Quickstats about dairy - Waikato region* data (DairyNZ, 2021) the average cows per ha for Waikato dairy farms is estimated at 2.92 cows per ha. This equates to 20.44 stock units and aligns with the mid-point value for the Mid-range dairy farm type used.

2.3.3 Pastoral land intensity

Pastoral land intensity is calculated by combining the data for conversion between planted forest and pastoral land, and stock unit density data. Using the criteria described in Table 1 as a base, the pastoral land intensity for each farm and point in time were identified, and a measure of the magnitude of change in terms of typical farm system breaks was made. The magnitude and direction of change was classified as described in Table 3.

Table 3. Classes of pastoral stock unit density change.

Pastoral stock unit density class change	Pastoral land use change class
Two or more class increase	Major intensification
One class increase	Moderate intensification
No class change	No change
One class decrease	Moderate destocking
Two or more class decrease	Major destocking
No reliable stock data	No data

For example, a given pastoral point classed as a “Beef farms and lower stocked dairy farms” in 2012 and then classed as “Higher stocked dairy farms” in 2018, would be a “Two or more class increase” corresponding to “Major intensification”. Planted forest converted to pastoral land was interpreted as at least Moderate intensification. If the LCDB data identified a change from planted forest to pastoral land but there was no Agribase data, this was interpreted as a Moderate intensification³. The approach also recognises decreases in pastoral intensification (i.e., “destocking”). Table 4 provides the pastoral land intensity change between farm type (and SUD) classes.

³ Based on the assumption that there can be a lag in the collection of Agribase data, but a LCDB change to pasture indicates that livestock are likely to be present at some SUD – the lowest SUD class is conservatively assumed.

Table 4. Change in pastoral land intensity between farm type (and SUD) classes.

Original Farm type:	Change to:				
	Planted forest (0 stock units/ha)	Sheep farms (<10.5 stock units/ha)	Beef farms and lower stocked dairy farms (10.5 to 17.5 stock units/ha)	Mid-range of dairy farms (17.5 to 24.5 stock units/ha)	Higher stocked dairy farms (>24.5 stock units/ha)
Planted forest (0 stock units/ha)	No change	Moderate intensification	Major intensification	Major intensification	Major intensification
Sheep farms (<10.5 stock units/ha)	Moderate destocking	No change	Moderate intensification	Major intensification	Major intensification
Beef farms and lower stocked dairy farms (10.5 to 17.5 stock units/ha)	Major destocking	Moderate destocking	No change	Moderate intensification	Major intensification
Mid-range of dairy farms (17.5 to 24.5 stock units/ha)	Major destocking	Major destocking	Moderate destocking	No change	Moderate intensification
Higher stocked dairy farms (>24.5 stock units/ha)	Major destocking	Major destocking	Major destocking	Moderate destocking	No change

2.3.4 Sub-regional analysis (management zones)

Independent examination of conversion between planted forest and pastoral land, and pastoral land intensity by management zone provided detail of where the greatest changes were occurring in the region and potential pressures associated with these changes.

Within the Waikato region there are areas that are more sensitive to the impacts of land cover changes and pastoral land intensity changes. For example, conversion of planted forest to pastoral land in the Coromandel zone or in the Upper Waikato zone can increase the potential for soil and land impacts such as erosion, and water quality impacts such as increased nutrients and microbes.

2.3.5 Land use capability analysis

Independent examination of conversion between planted forest and pastoral land, and pastoral land intensity by land use capability provided detail of where the greatest changes were occurring in the region and potential pressures associated with these changes.

For arable LUC classes (LUC 1-4), a change from planted forest to pastoral land can increase the potential for soil quality and water quality related impacts associated increased nutrient use and loss. A change from planted forest to pastoral land also means the land and soil are subjected to the impacts of stock, which can increase surface erosion, reduce soil infiltration (Taylor et. al., 2010), increase nutrient and microbial runoff, and increase the potential for soil quality issues such as soil compaction. This potential increases with an increase in pastoral land intensity (Waikato Regional Council (Environment Waikato), 2008).

For non-arable LUC classes (LUC 5-8), a change from planted forest to pastoral land can increase the potential for erosion because land cover protection provided by pasture is less than that provided by woody vegetation (planted forest). A change to pastoral land also means the land and soil are subjected to the impacts of stock, which can increase surface erosion, nutrient and microbial runoff, and increase the potential for soil quality issues such as soil compaction. These potential impacts generally increase with increasing pastoral intensity.

3 Results and discussion

3.1 Conversion between planted forest and pastoral land

3.1.1 Regional changes

The changes between pastoral land and planted forest for the Waikato region from 2001 to 2018 are shown in Table 5.

Table 5. Regional changes in planted forest and pastoral land, 2001-2018.

Timestep	Planted forest to pastoral land (ha)	Pastoral land to planted forest (ha)	Net change to pastoral land (ha)
2001-2008	21494	4258	17235
2008-2012	22521	3369	19153
2012-2018	13403	8264	5138
Total (2001-2018)	57418	15891	41527

An estimated 57,418 hectares (ha) of planted forest was converted to pastoral land use in the region between 2001 and 2018, while an estimated 15,891 ha of pastoral land was converted to planted forest. The net change in planted forest converted to pastoral land in the region for 2001-2018 was an estimated 41,527 ha.

Comparing the area of conversion from planted forest to pastoral land for each timestep, there was an increase in planted forest to pastoral land from 2001-2008 to 2008-2012, followed by a decrease from 2008-2012 to 2012-2018. For conversion from pastoral land to planted forest for each timestep, there was an initial decrease in the area converted from pastoral land to planted forest to pastoral land from 2001-2008 to 2008-2012, followed by an increase from 2008-2012 to 2012-2018.

The net decrease in the change to pastoral land for 2012-2018 (compared with previous timesteps (2001-2008 and 2008-2012), was due both to a decrease in the area converted from planted forest to pastoral land (13,403 ha), as well as an increase in the area of pastoral land converted to planted forest (8264 ha).

A map showing the regional distribution of planted forest conversion to pastoral land and pastoral land to planted forest in the Waikato region for 2001-2018 is shown in Figure 3.

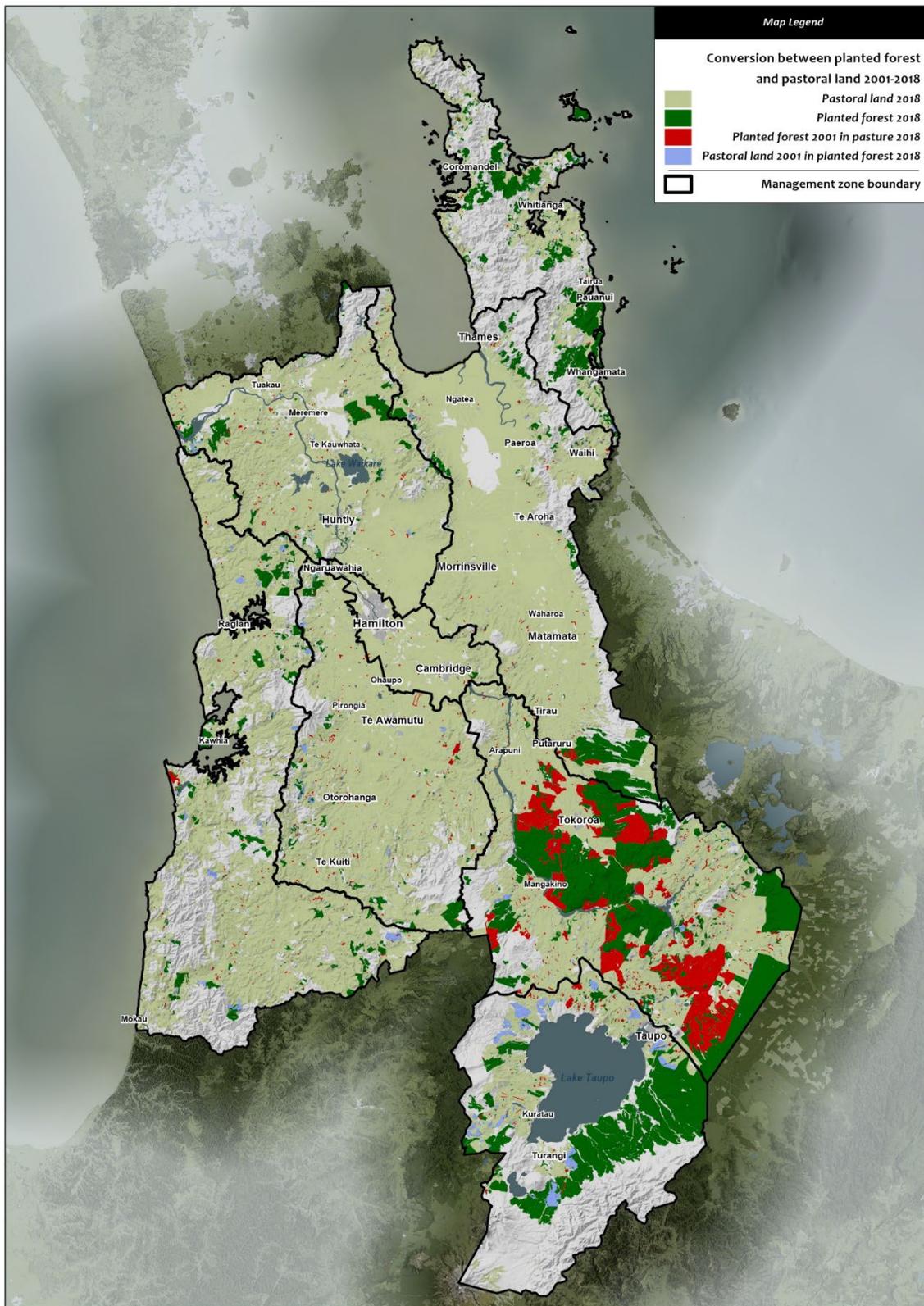


Figure 3. Map of conversion between planted forest and pastoral land for the Waikato region, 2001 to 2018.

3.1.2 Management zone changes

Table 6 shows the areas of conversion between planted forest and pastoral land by management zones in the Waikato region for 2001-2018. The results indicated that most of the planted forest conversion to pastoral land in the Waikato region occurred in the Upper Waikato zone.

Table 6. Areas of conversion between planted forest and pastoral land, and the net change to pastoral land by management zone in the Waikato region, 2001-2018.

Management zone	Planted forest to pastoral land (ha)	Pastoral land to planted forest (ha)	Net change to pastoral land (ha)
Central Waikato	72	71	1
Coromandel	251	603	-352
Lake Taupo	1219	7339	-6120
Lower Waikato	715	760	-45
Upper Waikato	52185	2661	49525
Waihou Piako	1100	555	544
Waipa	1052	1185	-133
West Coast	824	2718	-1893
Total	57418	15891	41527

Excluding the Upper Waikato zone, the area of conversion for the other zones was lower, ranging from a net increase in pastoral land in the Waihou Piako zone (544 ha), to a net decrease in the Lake Taupo zone (-6120 ha).

3.1.2.1 Planted forest conversion to pastoral land by management zone

Figure 4 shows the area converted from planted forest to pastoral land by management zone for the 2001-2008, 2008-2012, and 2012-2018 timesteps. The areas are presented as average area change per year to provide relativity across the timesteps.

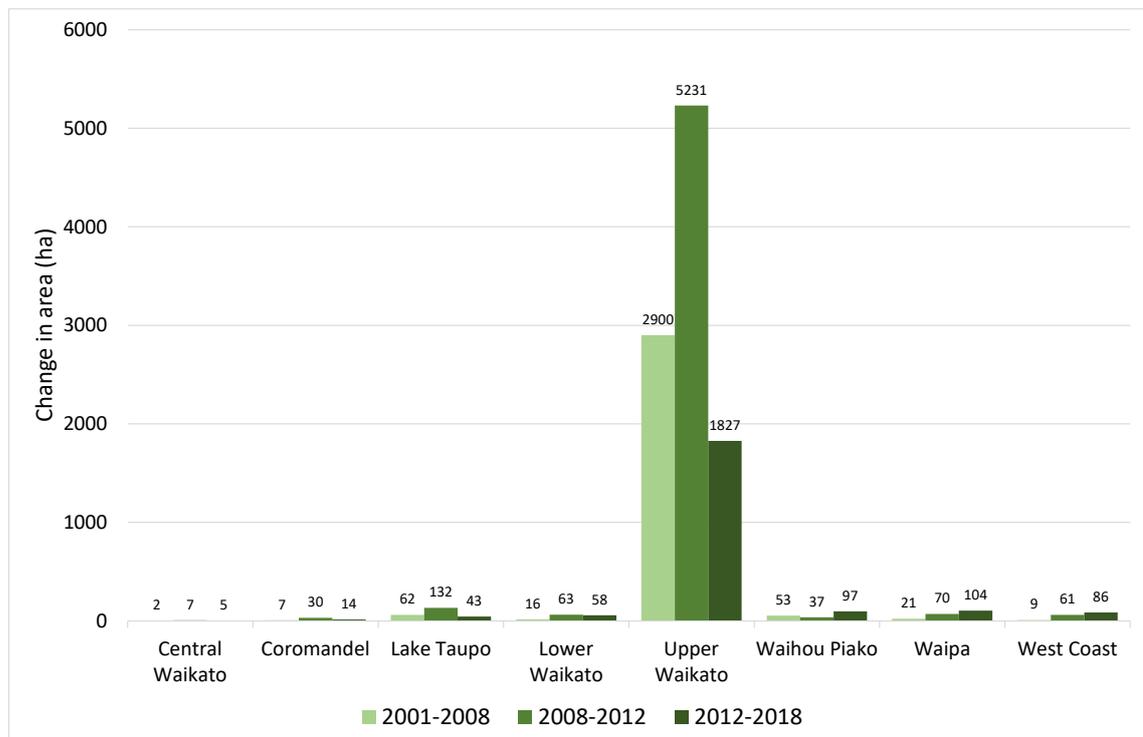


Figure 4. Conversion from planted forest to pastoral land by management zone (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

By far the greatest conversion occurred in the upper Waikato zone. The rate of conversion in the Upper Waikato zone peaked between 2008-2012 at an average conversion rate of 5231 ha/year, dropping to 1827 ha/year for 2012-2018.

3.1.2.2 Pastoral land conversion to planted forest by management zone

Figure 5 shows the area converted from pastoral land to planted forest by management zone for the 2001-2008, 2008-2012, and 2012-2018 timesteps. The areas are presented as average area change per year to provide relativity across the timesteps.

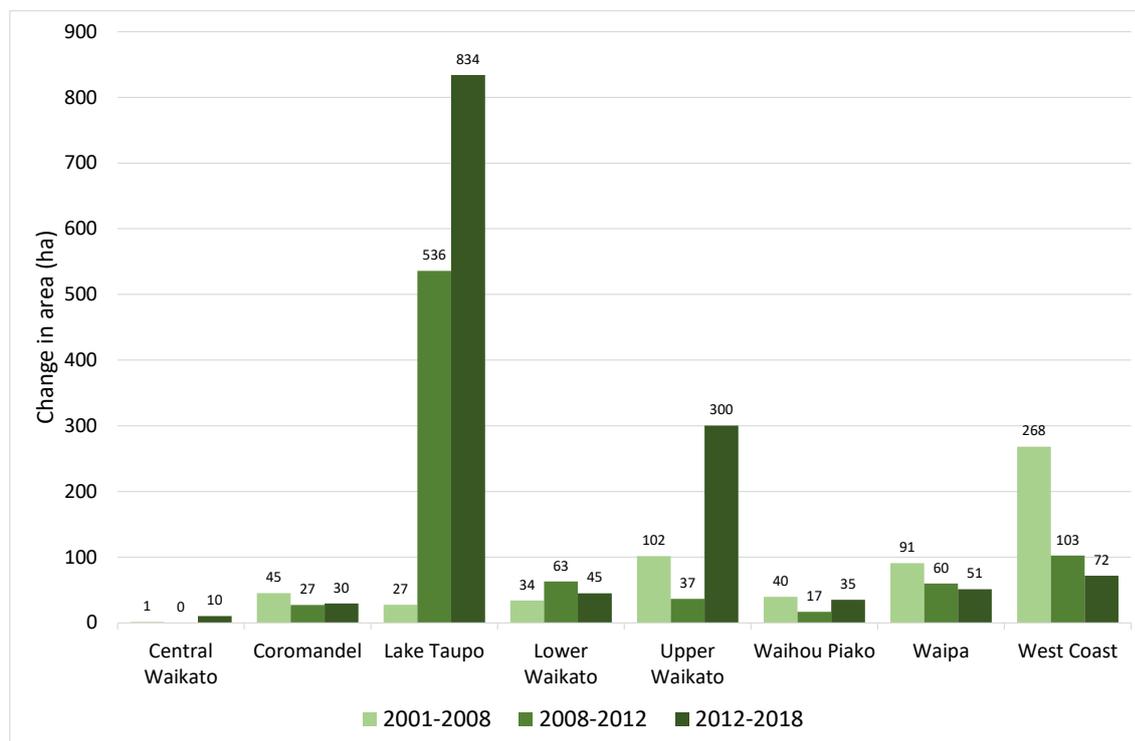


Figure 5. Conversion from pastoral land to planted forest by management zone (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

Pasture conversion to planted forest has increased in Lake Taupo zone and to a lesser extent in the Upper Waikato zone. In contrast, pasture conversion to planted forest in the West Coast zone was the highest by area of all management zones for 2001-2008 but has subsequently decreased. This trend is similar for Waipa, Waihou Piako, and Coromandel zones. For the Lower Waikato zone, pasture conversion to planted forest has remained relatively constant across the time steps.

3.1.2.3 Net change in pastoral land by management zone

The average annual net area change in pastoral land by management zone for each timestep is shown in Figure 6. A positive value represents a net increase in pastoral land relative to planted forest. A negative value represents a net increase in planted forest relative to pastoral land.

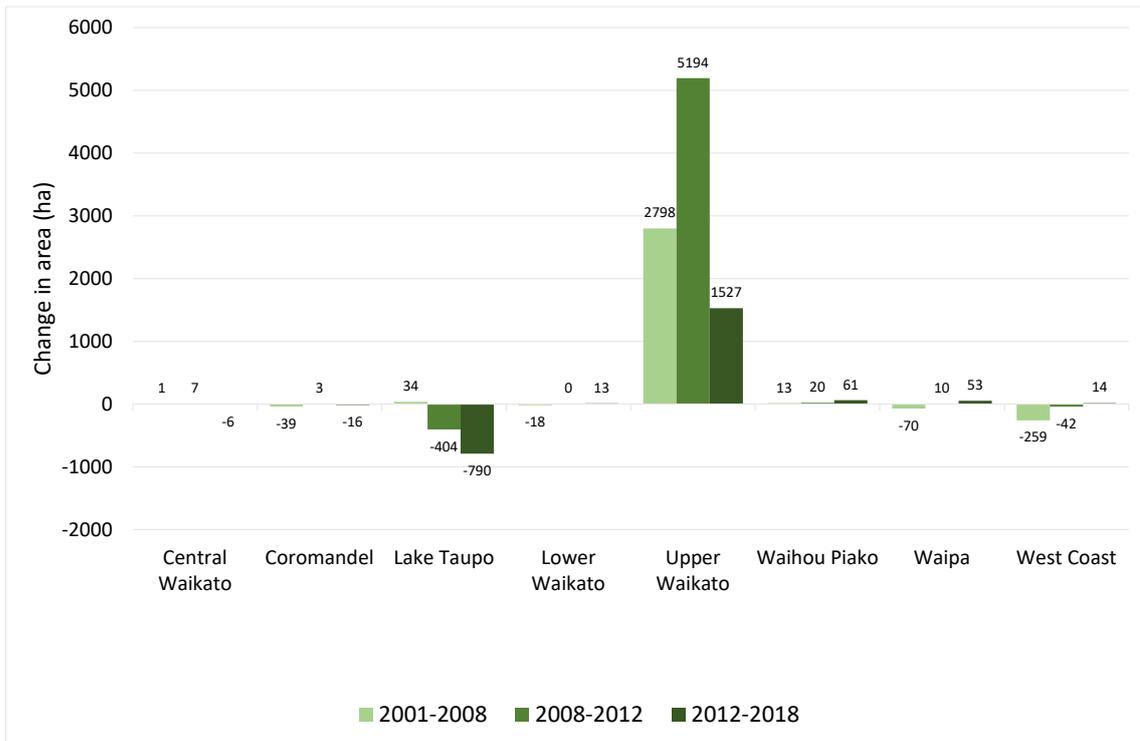


Figure 6. Net change in pastoral land relative to planted forest by management zone (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

By far the greatest net increase in pastoral land was in the Upper Waikato zone, with the greatest increase occurring for the 2008-2012 timestep. Also evident is the net decrease in pastoral land for the Lake Taupo zone, and lesser decreases for the West Coast, Waipa, and Coromandel zones, respectively. For the Lake Taupo zone, the average annual area of planted forest has continued to increase relative to pastoral land since 2008. The reasons for this are difficult to link to on ground actions. However, implementation of land use policy (Variation 5) in the Lake Taupo Catchment is likely to be a driver for pastoral land use change in that zone. The planting of forest for carbon benefits and soil conservation are possible drivers in the West Coast and other zones.

3.1.3 LUC changes

Examination of pastoral land use change in relation to land use capability indicates where increased risk of soil degradation may occur due to a change to pastoral land use. In general, where land use is more intensive than the LUC indicates the land is capable of supporting, the greater the risk of degradation. Table 7 shows the areas of conversion between planted forest and pastoral land by LUC classes in the Waikato region for 2001-2018.

Table 7. Conversion between planted forest and pastoral land for LUC classes in the Waikato region, 2001 to 2018.

LUC class	Plantation forest 2001 to pastoral land 2018 (ha)	Pastoral land 2001 to plantation forest 2018 (ha)	Net pastoral land increase (ha)	Contribution to net pasture increase (%)
LUC 1	53	10	43	0.1%
LUC 2	256	147	109	0.3%
LUC 3	9949	639	9310	22.4%
LUC 4	14168	2284	11884	28.6%
LUC 5	22	6	16	0.0%
LUC 6	27132	10072	17060	41.1%
LUC 7	5292	2530	2763	6.7%
LUC 8	545	203	342	0.8%
Total	57418	15891	41527	100.0%

A comparison of conversion between planted forest and pastoral land by LUC class for 2001-2018 showed that the greatest net increase in pasture occurred on LUC 6 (17,060 ha - 41.1%), followed by LUC 4 (11,884 ha - 28.6%), and LUC 3 (9,310 ha - 22.4%). The balance of planted forest conversion to pastoral land (collectively 3281 ha - 7.9%) was spread across the remaining LUC classes. Of most concern was the large area of planted forest conversion to pastoral land on LUC 6, which is classed as land with a low suitability for pastoral land use.

3.1.3.1 Planted forest conversion to pastoral land by LUC class

The change in area of planted forest converted to pastoral land by LUC class for each of the timesteps is shown in Figure 7. The areas are presented as average area change per year to provide relativity across the timesteps.

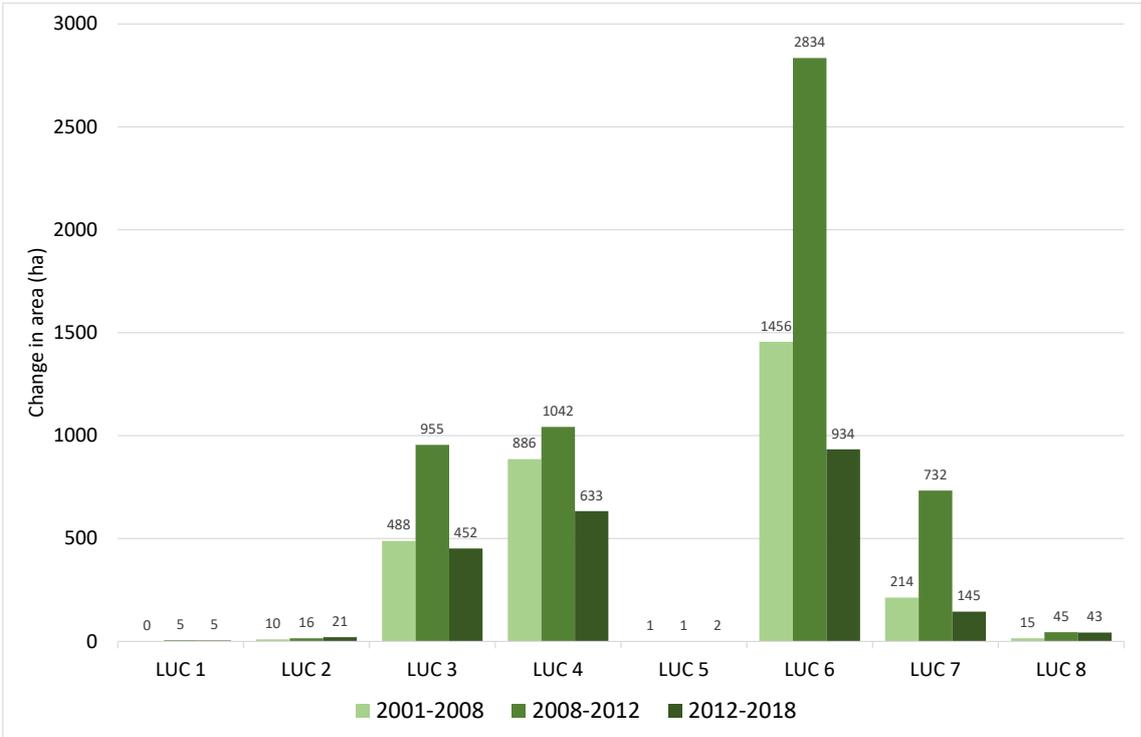


Figure 7. Conversion from planted forest to pastoral land by LUC class (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

The greatest average annual change in area for planted forest conversion to pastoral land occurred in LUC 6 for the 2001-2008, 2008-2012, and 2012-2018 timesteps. Conversion peaked during the 2008-2012 timestep for LUC 6, LUC 4, LUC 3, LUC 7, and LUC 8. Conversion from planted forest to pastoral land on the non-arable LUC classes (LUC5-8) increases the potential for soil erosion due to the reduction in woody vegetation cover provided by planted forest.

3.1.3.2 Pastoral land conversion to planted forest by LUC class

The change in area for pastoral land converted to planted forest by LUC class for each timestep is shown in Figure 8. The areas are presented as average area change per year to provide relativity across the timesteps.

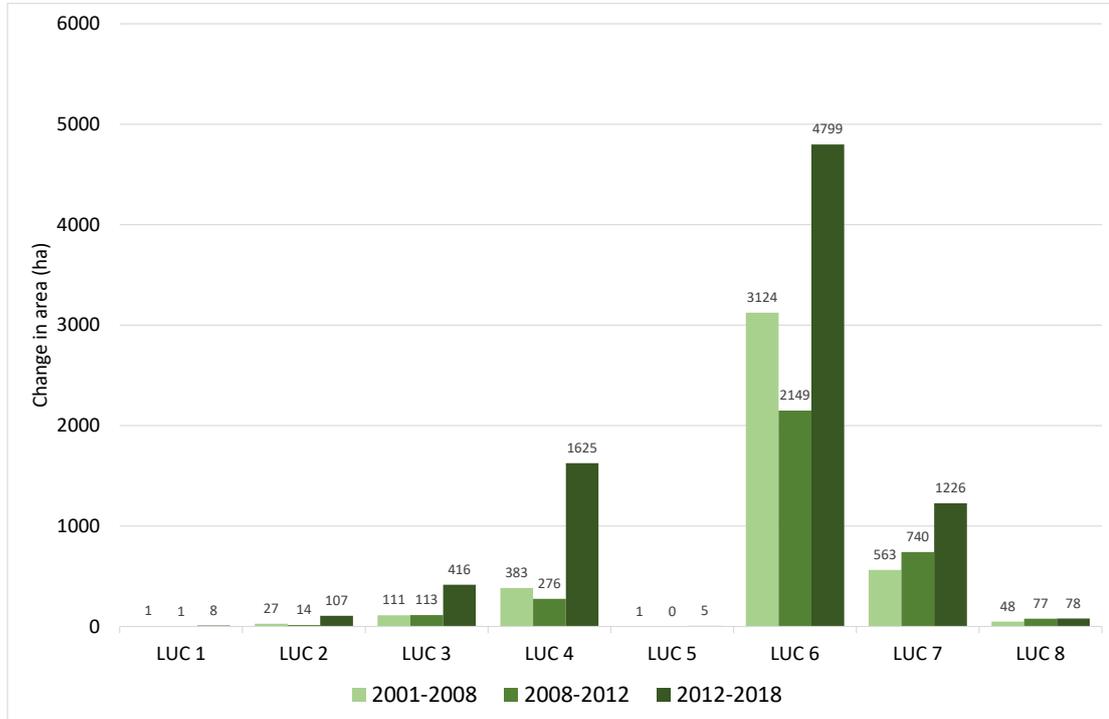


Figure 8. Conversion from pastoral land to planted forest by LUC class (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

The greatest average annual change in area for pastoral land conversion to planted forest occurred in LUC 6 for the 2001-2008, 2008-2012, and 2012-2018 timesteps. Conversion also peaked during the 2012-2018 timestep for all other LUC classes. Conversion from pastoral land to planted forest on the non-arable LUC classes (LUC 5-8) decreases the potential for soil erosion due to the increase in woody vegetation cover provided by planted forest.

3.1.3.3 Net change in pastoral land by LUC class

Figure 9 shows the average annual net area change in pastoral land by LUC class, for each timestep. A positive value represents a net increase in pastoral land relative to planted forest. A negative value represents a net increase in planted forest relative to pastoral land.

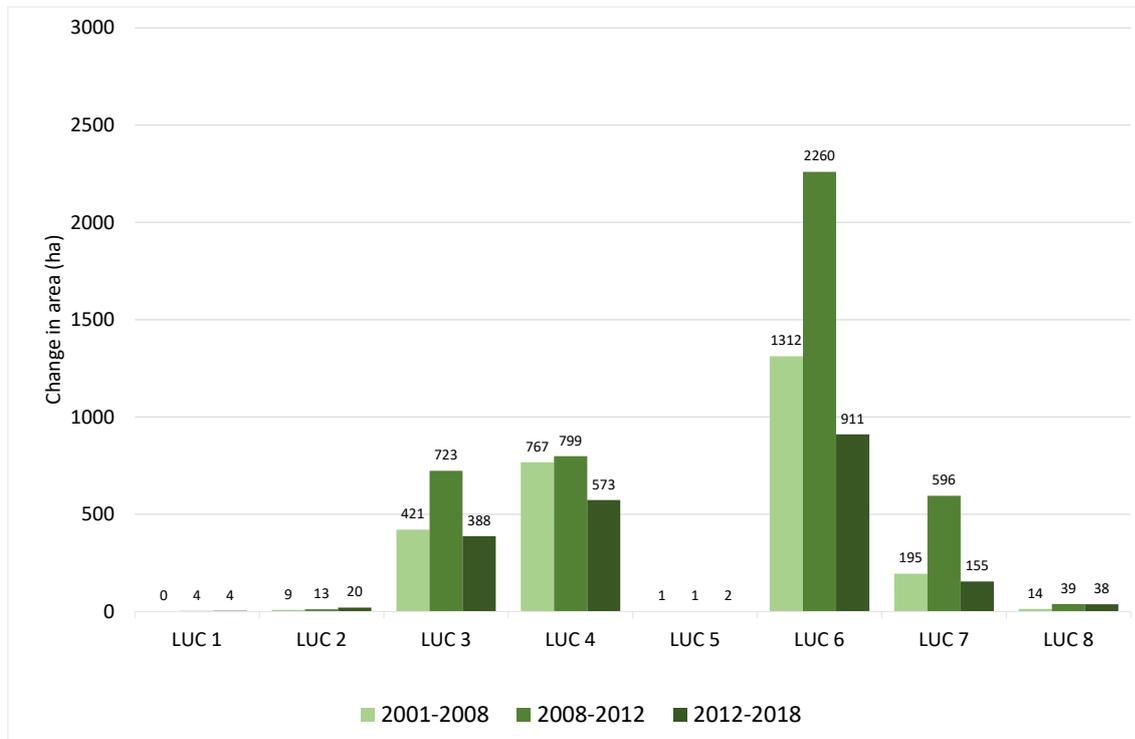


Figure 9. Net change in pastoral land by LUC class (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

Most evident is the net increase in pastoral land for LUC 6, followed by lesser increases for LUC 4, LUC 3, and LUC 7, respectively. For all four of these LUC classes, the greatest increases were for the 2008-2012 timestep. For the non-arable LUC classes (particularly LUC 6 and LUC 7), the presence of pastoral land (rather than woody vegetation cover such as planted forest) increases the potential for erosion due to decreased vegetation protection.

3.2 Pastoral land intensity

3.2.1 Regional changes

Table 8 shows the regional pastoral land intensity changes in area and as a percentage of total area for 2001-2018, in addition to the individual timesteps (2001-2008, 2008-2012, and 2012-2018).

Table 8. Regional area changes in pastoral land intensity, 2001 to 2018.

Time step	Major intensification		Moderate intensification		No change		Moderate destocking		Major destocking	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
2001-2008	134,441	11	269,662	22	626,121	51	144,821	12	63,535	5
2008-2012	37,307	3	158,310	13	878,141	70	140,345	11	40,283	3
2012-2018	48,569	4	128,165	10	954,121	75	100,428	8	36,363	3
2001-2018	188,741	15	315,594	25	491,582	38	192,439	15	88,483	7

Between 2001 and 2018, an estimated 504,335 ha (40%) of pastoral land had undergone some intensification, 491,582 ha (38%) showed no change, and 280,921 ha (22%) had undergone destocking. On an annual basis, this represents a net intensification rate of just over 1% per annum for the 17-year period. Both intensification and destocking showed decreases from the first timestep (2001-2008) to the most recent timestep (2012-2018), with a corresponding increase in the area showing no change.

A map showing the regional distribution of pastoral land intensity changes for the Waikato region (2001-2018) is shown in Figure 10.

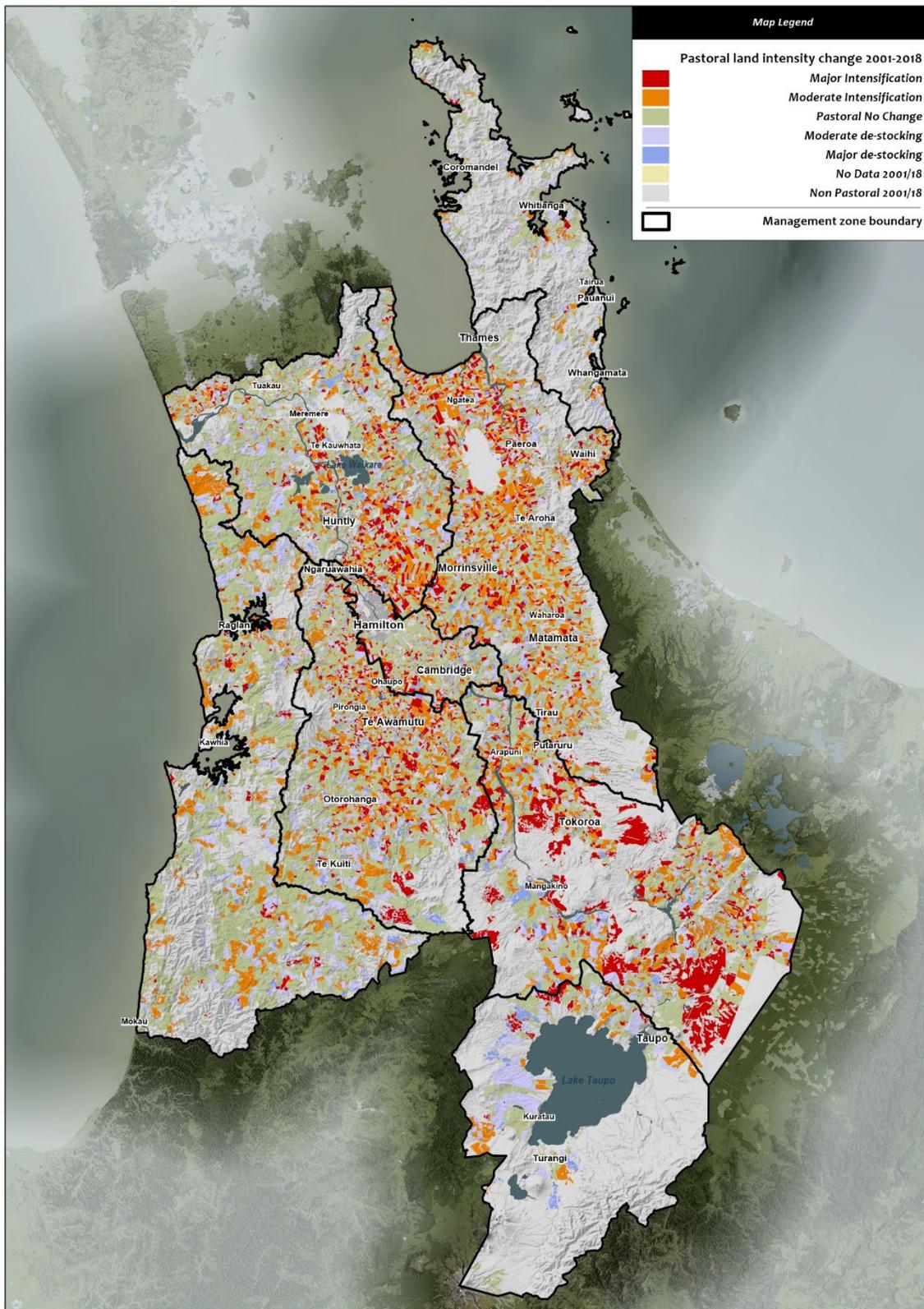


Figure 10. Map of pastoral land intensity change for the Waikato region, 2001 to 2018.

Comparing the pastoral land intensity for each timestep indicated that the highest net intensification occurred for 2001-2008, decreased during 2008-2012, and has since stabilised (Figure 11).

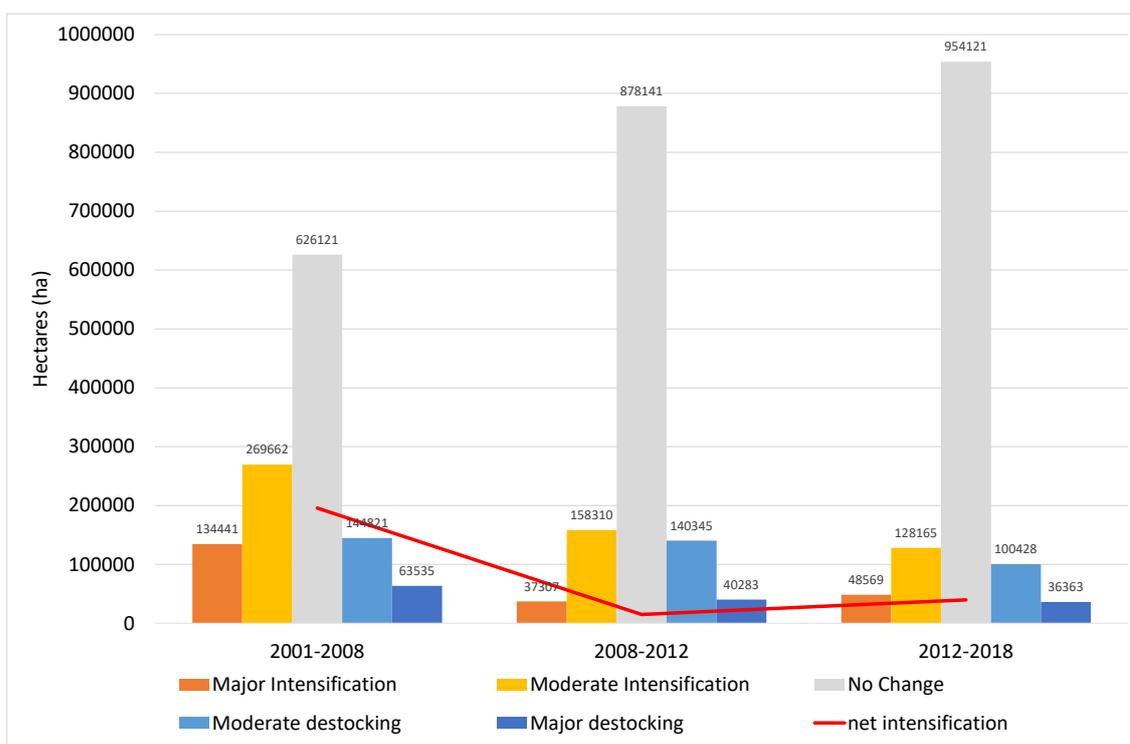


Figure 11. Changes in pastoral land intensity (2001-2008, 2008-2012, and 2012-2018).

From 2001-2008 to 2012-2018, the area of pastoral land that showed no change in intensity increased from 626,121 ha for the 2001-2008 timestep to 954,121 ha for the 2012-2018 timestep, representing a 54% increase in the area of pastoral land with no change in intensity.

3.2.2 Management zone changes

The area changes in pastoral land intensity for all management zones are presented in Table 9.

Table 9. Changes in pastoral land intensity by management zone in the Waikato region, 2001 to 2018.

Management zone	Major intensification		Moderate intensification		No change		Moderate destocking		Major destocking	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Central Waikato	8664	19	8067	18	16604	36	6721	15	5537	12
Coromandel	2383	7	6420	18	17337	48	7802	21	2524	7
Lake Taupo	4890	9	10690	19	18485	32	17469	30	5933	10
Lower Waikato	30698	16	39538	20	81028	41	30992	16	14909	8
Upper Waikato	48187	21	75656	33	67154	29	26596	11	14219	6
Waihou Piako	46308	18	72493	29	82800	33	32664	13	18767	7
Waipa	39343	18	51690	23	83419	38	29253	13	17694	8
West Coast	8268	4	51039	22	124757	53	40941	18	8899	4
Mean	23593	14	39449	23	61448	39	24055	17	11060	8

For 2001-2018, moderate and major intensification have been greatest in the Upper Waikato zone (a combined change of 123,843 ha), most likely driven by the conversion of planted forest to pastoral land. This change equates to an average annual change of about 7,285 ha. On average, 39% of management zone pastoral land area showed no change in intensity between 2001 and 2018. Major destocking was 8% of pastoral land area on average across all

management zones, with the lowest percentages in the West Coast and Upper Waikato zones, and the highest percentages in the Central Waikato and Lake Taupo zones.

Changes in pastoral land intensity by management zone for each of the timesteps (2001-2008, 2008-2012, and 2012-2018) are shown in Figure 12. The data are presented as average area change per year for each timestep.

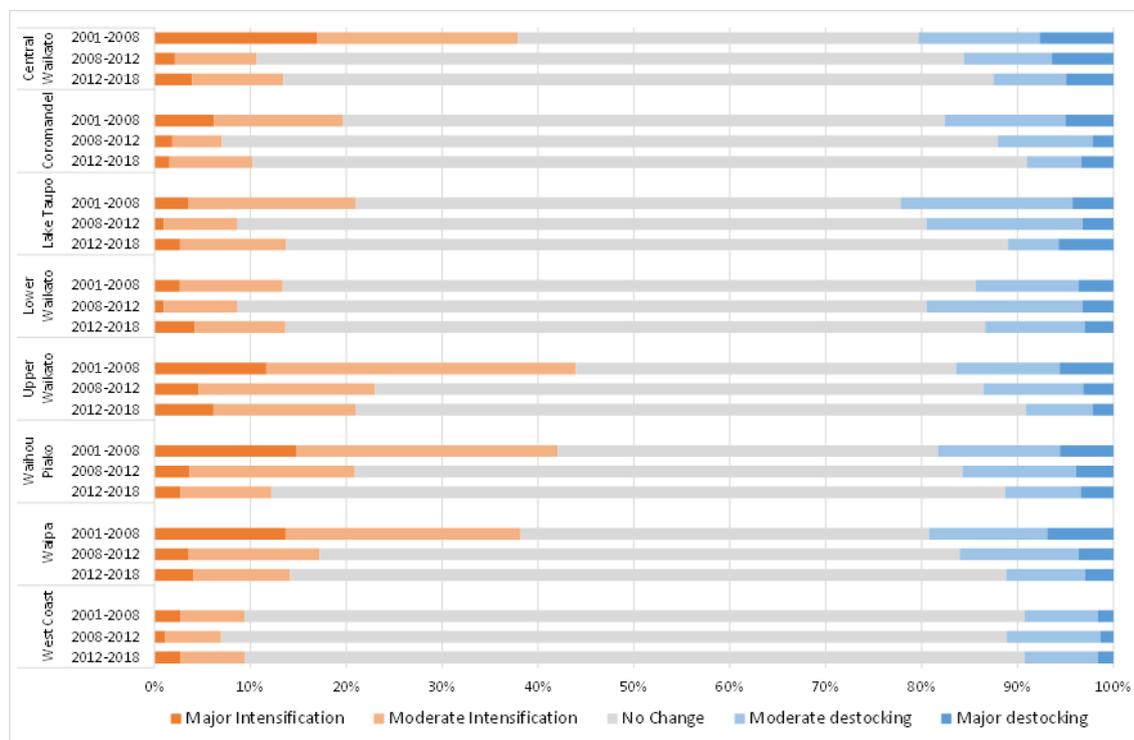


Figure 12. Changes in pastoral land intensity by management zone for each timestep (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

3.2.2.1 Net change by management zone

Changes in net pastoral land intensity by management zone for each of the timesteps (represented by the average area change per year for each timestep) are shown in Figure 13. For intensification and destocking, major and moderate values have been combined to provide the net intensity change. A positive value represents a net increase in pastoral land intensity and a negative value represents a net decrease in pastoral land intensity for the given management zone.

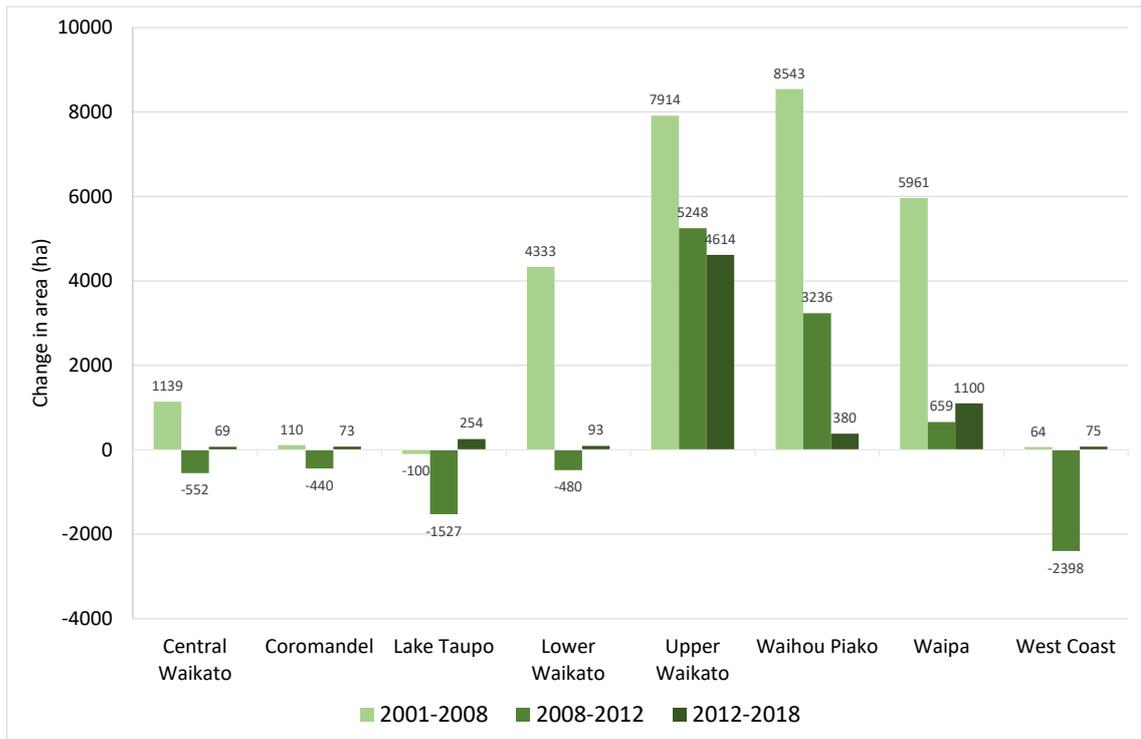


Figure 13. Net pastoral land intensity changes by management zone (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

Net increases in pastoral land intensity were greatest in the Upper Waikato zone for the 2008-2012 and 2012-2018 timesteps. The Waihou Piako zone had the greatest net increase in pastoral intensity for the 2001-2008 timestep. In general, pastoral land intensity has declined in the Upper Waikato, Waihou Piako, Waipa, and Lower Waikato zones since 2008. The West Coast and Lake Taupo zones both had net destocking in 2008-2012 but showed some net intensification in 2012-2018.

3.2.3 LUC class changes

Comparison of pastoral land use intensity with land use capability indicates where increased risk of soil degradation may occur due to the intensification of pastoral land use. In general, where land use is more intensive than the LUC indicates the land is capable of supporting, the greater the risk of degradation. The changes in pastoral land intensity for LUC class are presented in Table 10.

Table 10. Changes in pastoral land intensity by LUC class in the Waikato region, 2001 to 2018.

LUC class	Major intensification		Moderate intensification		No change		Moderate destocking		Major destocking	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
LUC 1	6882	18	10610	27	13924	36	3628	9	3613	9
LUC 2	50829	23	58877	26	68773	31	27413	12	17205	8
LUC 3	41900	18	60893	27	75910	33	32254	14	16850	7
LUC 4	33638	16	52286	24	79744	37	34461	16	15670	7
LUC 5	115	1	1647	21	4671	59	1327	17	155	2
LUC 6	49495	10	112087	23	213153	44	80787	17	30755	6
LUC 7	5355	8	17620	25	31900	46	11345	16	3791	5
LUC 8	527	7	1573	22	3508	48	1223	17	443	6

For 2001-2018, major intensification across the region has been greatest in the arable LUC classes (LUC 1-4). However, moderate intensification was only marginally less for non-arable LUC classes (LUC 5-8) when compared to arable LUC classes (LUC 1-4). Moderate destocking was generally consistent across all LUC classes, except for LUC 1 which was slightly less as a proportion of pastoral land area (9%). Major destocking was slightly higher for arable LUC classes compared with non-arable LUC classes.

3.2.3.1 Pastoral land intensity changes by LUC class for individual timesteps

The change in pastoral intensity by LUC class for each of the timesteps is shown in Figure 14. The data are presented as average area change per year for each timestep.

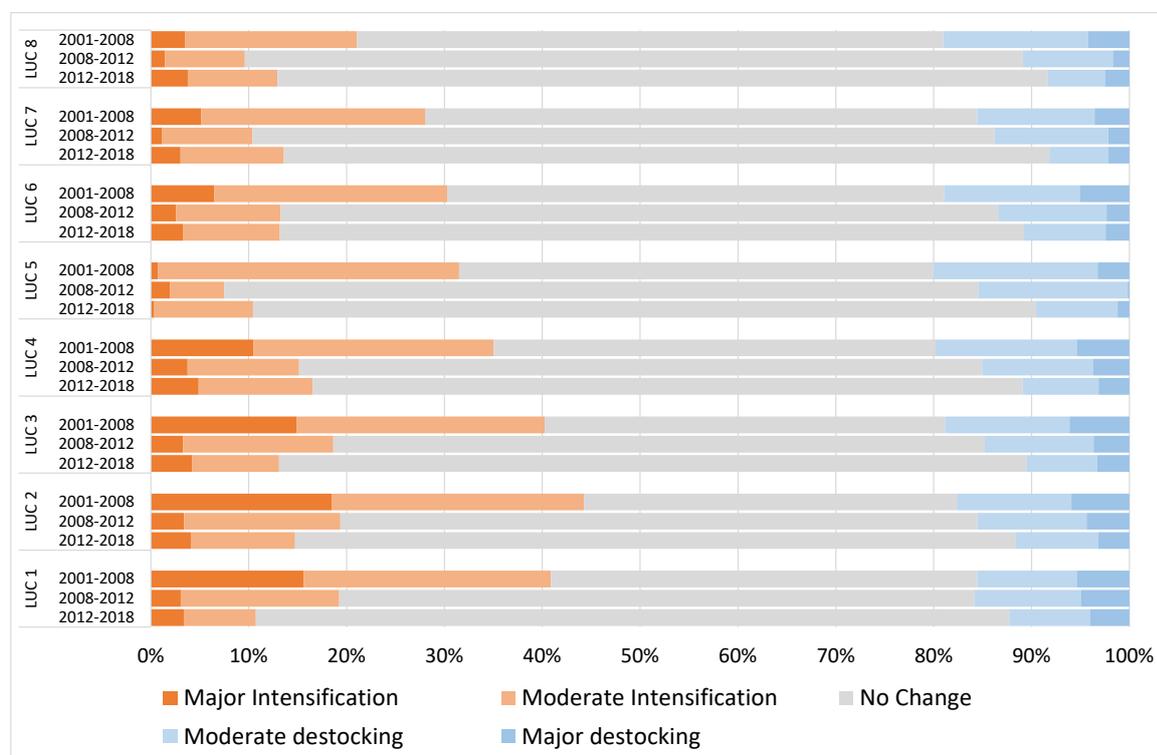


Figure 14. Changes in pastoral land intensity by LUC class for each of the timesteps (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

For all LUC classes, intensification was greatest for 2001-2008. For destocking, the same is evident except for LUC 1 which showed a slight increase in destocking from 2001-2008 to 2008-2012. For LUC 1, LUC 2, and LUC 6, intensification declined from 2001-2008 through to 2012-

2018, whereas LUC 4, LUC 7, and LUC 8 show an initial decline from 2001-2008 to 2008-2012, followed by an increase to 2012-2018.

3.2.3.2 Net pastoral land intensity change by LUC class

The net pastoral land intensity changes for LUC class (represented by the average area change per year for each timestep) are shown in Figure 15. For intensification and destocking, major and moderate values have been combined to provide the net intensity change. A positive value represents a net increase in pastoral land intensity and a negative value represents a net decrease in pastoral land intensity for the given LUC class.

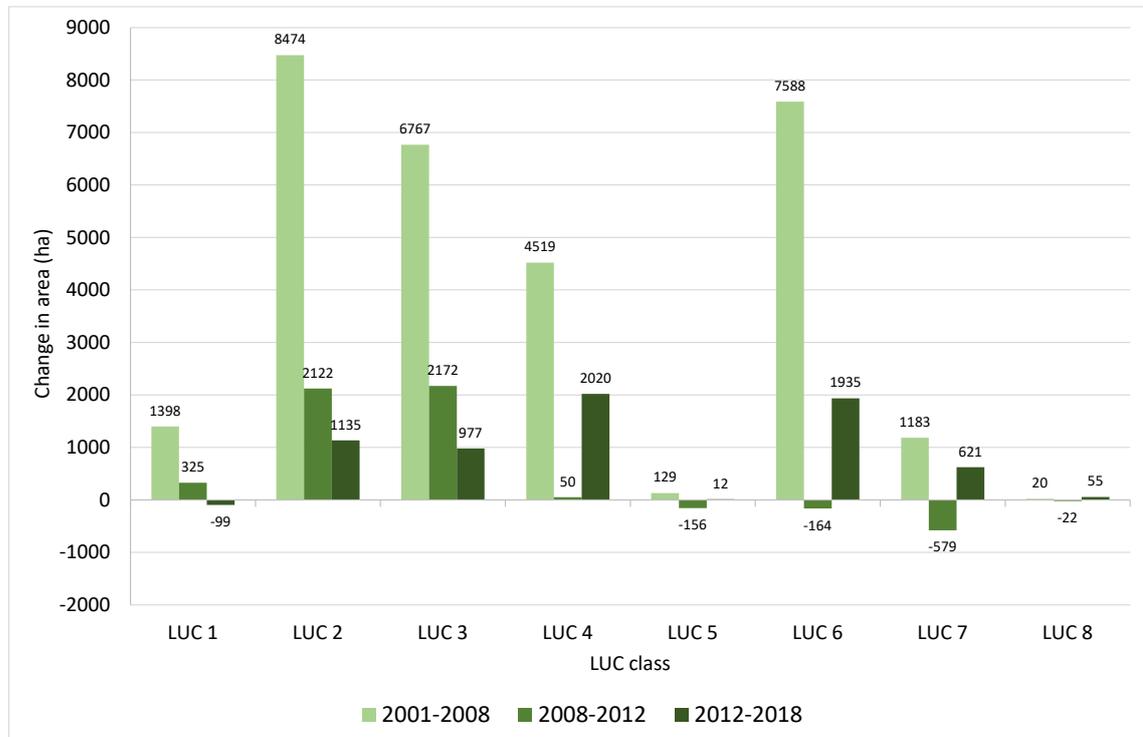


Figure 15. Net pastoral land intensity changes by LUC class (represented by the average area change per year for each timestep), 2001-2008, 2008-2012, and 2012-2018.

Net increases in pastoral land intensity were greatest in all LUC classes (excepting LUC 8) for 2001-2008. Net pastoral land intensity shows a decline from 2001-2008 to 2012-2018 for LUC 1-3 from 2001 to 2018 whereas LUC 4-8 all show initial decline from 2001-2008 to 2008-2012 (some showing net destocking during 2008-2012), followed by a net increase from 2008-2012 to 2012-2018.

3.3 Dairy and non-dairy pastoral land

3.3.1 Regional changes

The estimated areas of dairy and non-dairy pastoral land in the Waikato region for 2001, 2008, 2012, and 2018 are shown in Table 11.

Table 11. Estimated areas of dairy and non-dairy pastoral land in the Waikato region.

Farm type	2001		2008		2012		2018		Change 2001 to 2018	
	ha	%	ha	%	ha	%	ha	%	ha	%
Dairy pastoral land	422,667	43	487,798	44	500,707	45	574,217	50	151,550	36
Non-dairy pastoral land	569,049	57	612,513	56	622,671	55	565,741	50	-3,308	-1
Total pastoral land	991,716	100	1,100,311	100	1,123,378	100	1,139,959	100	148,243	15

From 2001 to 2018, pastoral land in the Waikato region has increased by an estimated 148,243 ha, from 991,716 ha in 2001 to 1,139,959 ha in 2018. During this period, the area of dairy pastoral land increased from 422,667 ha in 2001 to 574,217 ha in 2018, and non-dairy pastoral land decreased slightly from 569,049 ha in 2001 to 565,741 ha in 2018. The changes in the proportions of dairy and non-dairy pastoral land across the years from 2001 to 2018 are shown in Figure 16.

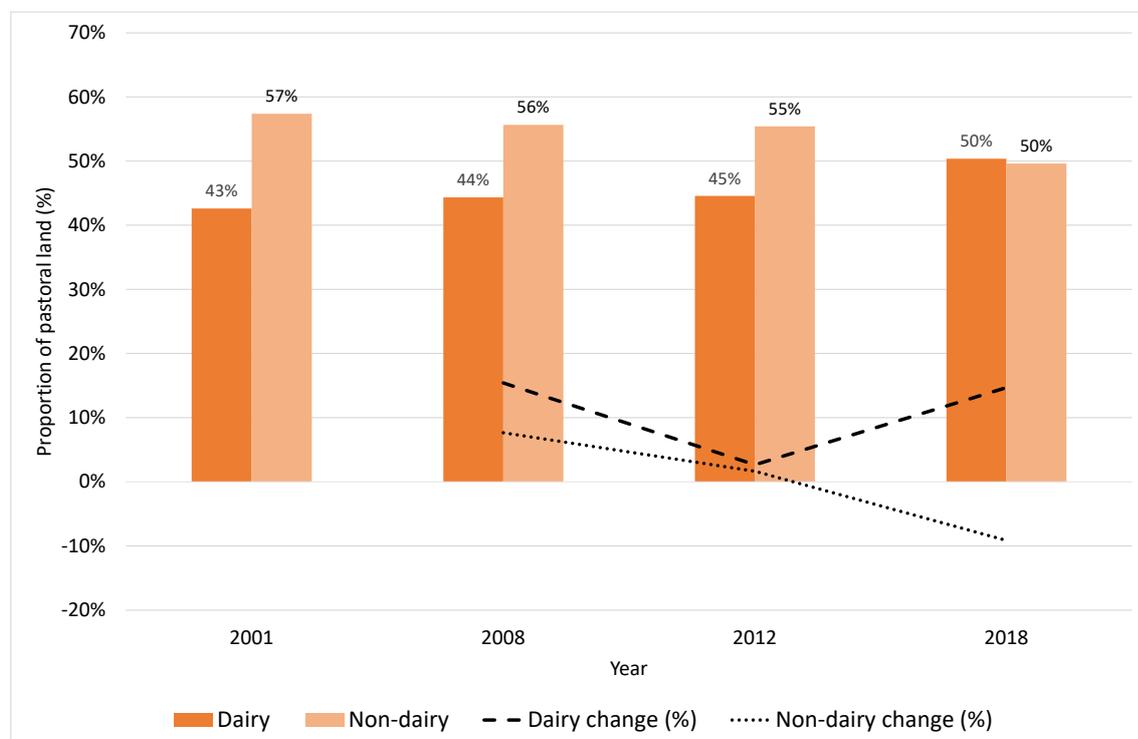


Figure 16. Area of dairy and non-dairy pastoral land in the Waikato region, 2001 to 2018.

The greatest change was from 2001 to 2008, decreasing through 2008-2012 and increasing again through 2012-2018. Over the same period, the area of dairy pastoral land increased by 151,550 ha, representing a 36% increase, and an average annual increase of 2% for the 2001-2018 period.

In contrast, the area of non-dairy pastoral land has decreased by 3308 ha, representing a 1% decrease for the 2001-2018 period. The greatest change from non-dairy to dairy pastoral land occurred from 2012 to 2018.

3.3.2 Management zone changes

Pastoral farm types (dairy and non-dairy pastoral land) were assessed against management zones to indicate the change in farm type area across the Waikato region (Figure 17).

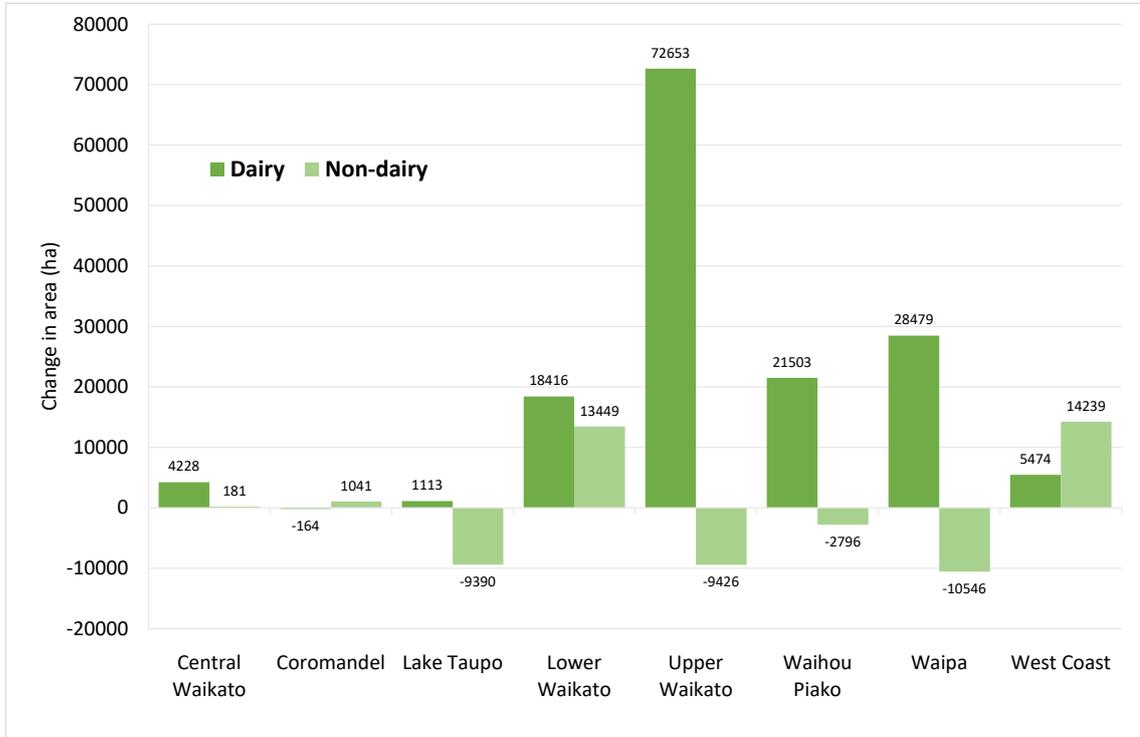


Figure 17. Changes in dairy and non-dairy pastoral land area by management zone for the Waikato region, 2001 to 2018.

Figure 17 shows that the majority of new dairy land in the Waikato region occurred in the Upper Waikato zone. The Waipa, Waihou Piako and Lower Waikato zones were similar, but with lesser increases in dairy land. The Lower Waikato, West Coast, and Central Waikato zones showed increases in both dairy and non-dairy land. The Lake Taupo zone showed a small increase in dairy land and a decrease in non-dairy land. The Lake Taupo zone was the only zone to show a net decrease in pastoral land.

3.3.3 LUC class changes

Pastoral farm types (dairy and non-dairy pastoral land) were assessed against land use capability class to indicate the change in in farm type area across the Waikato region (Figure 18).

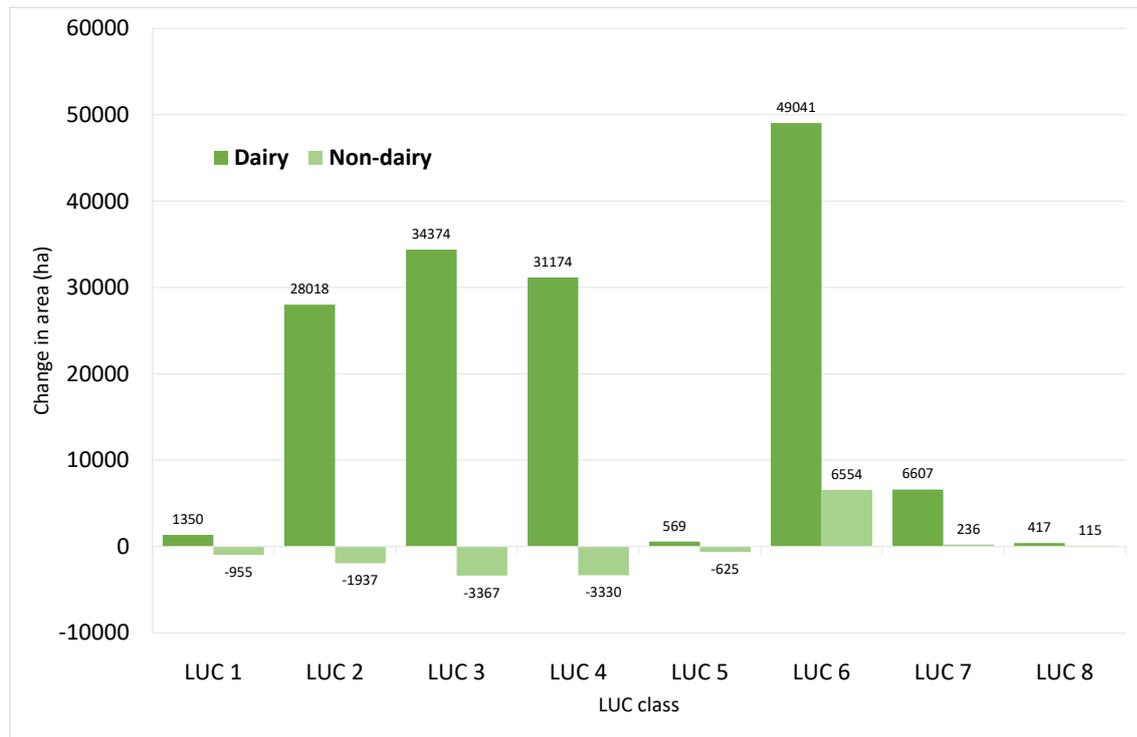


Figure 18. Changes in dairy and non-dairy pastoral land area by LUC class for the Waikato region, 2001 to 2018.

Figure 18 shows that the majority of new dairy land is occurring on LUC classes 1 to 4 (land with a high suitability for dairy pasture), about one third of the new dairy is on land with a low suitability for dairy (LUC classes 6 to 8).

3.4 Pastoral land intensity pressure indicators

Two pressure indicators have been developed to identify the changes in pastoral land intensity through time (every five years) in different parts of the region (management zones), and on different types of land (land use capability class).

These pressure indicators follow a similar format to those currently presented on the Waikato Regional Council website⁴. However, these revised indicators use mean changes per year for a given timestep. This provides an improved relative representation of the changes where timesteps are of differing length. For example, the 2001-2008 timestep encompasses seven years, whereas the 2008-2012 timestep covers only four years. These differences relate to the provision of the LCDB data, on which the revision of the pastoral land intensity indicator is dependant.

The two indicators have been developed to show where in the region changes in pastoral land are occurring (by management zone), and on what type of land these changes are occurring (by LUC class). The indicators simplify the data for intensification and destocking, grouping minor and major data for each, to provide changes in the percentage of intensification, destocking, and no change. Additionally, the indicators use the average area change per year, rather than the absolute areas for each timestep. This provides improved relativity where timesteps comprise a different number of years. The 2001-2018 pastoral land intensity indicators for management zones and LUC class in the Waikato region are shown in Figures 19 and 20 respectively.

⁴ <https://www.waikatoregion.govt.nz/environment/land-and-soil/land-and-soil-monitoring/pastoral-intensification/#e8239>

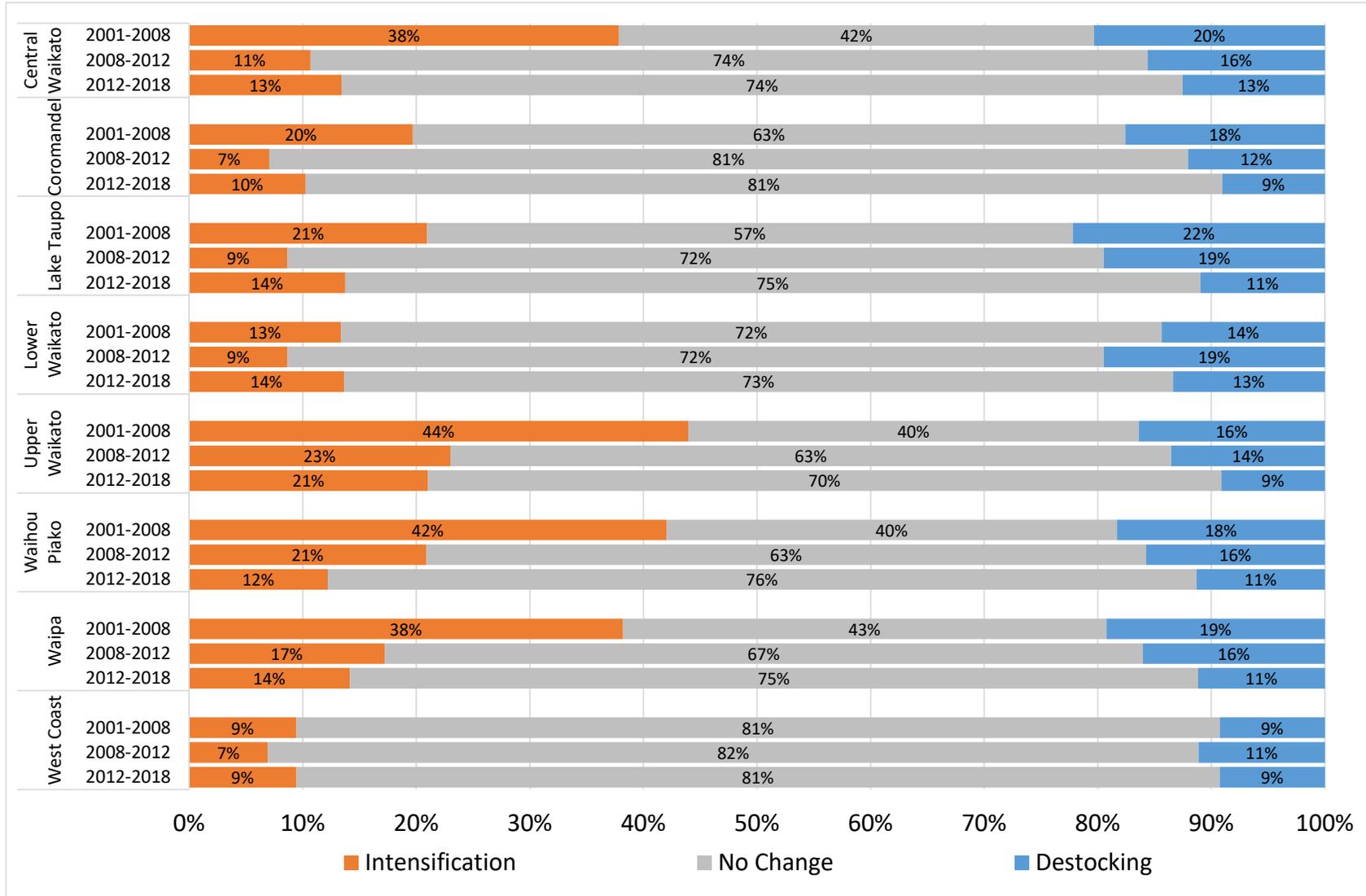


Figure 19. Pastoral land intensity changes for management zones in the Waikato region, 2001-2018.

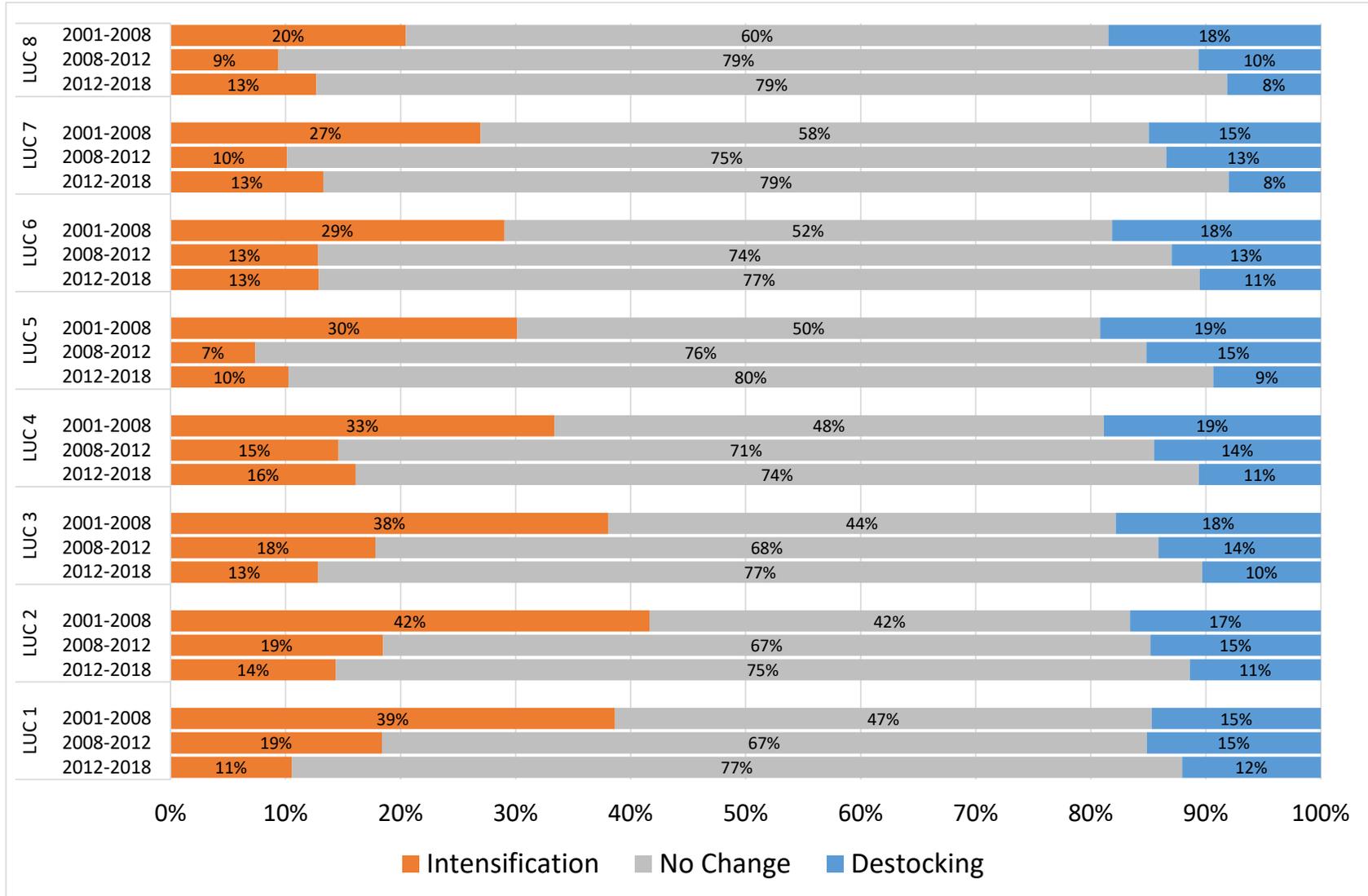


Figure 20. Pastoral land intensity changes for land use capability classes in the Waikato region, 2001-2018.

4 Limitations of datasets

The Agribase data remains the most complete farm type and stock unit data for regional analysis of land use change and intensity. However, missing or unreliable farm data within the Agribase data and between Agribase data timesteps resulted in areas of pastoral land with no data. The area of no data for each management zone and timestep is shown in Table 12. The area of no data ranged from 143.2 ha for 2001-2008 to 21.4 ha for 2012-2018, representing 0.01% or less of the pastoral land area used in the analysis.

Table 12. Area of 'No data' for each management zone and time step.

Management zone	2001-2008		2008-2012		2012-2018	
	No data (ha)	No data (% of pastoral land)	No data (ha)	No data (% of pastoral land)	No data (ha)	No data (% of pastoral land)
Central Waikato	0.0	0.00%	0.0	0.00%	0.0	0.00%
Coromandel	58.2	0.16%	27.8	0.08%	13.4	0.04%
Lake Taupo	0.0	0.00%	0.0	0.00%	0.0	0.00%
Lower Waikato	0.3	0.00%	0.2	0.00%	0.0	0.00%
Upper Waikato	0.0	0.00%	0.0	0.00%	0.0	0.00%
Waihou Piako	0.6	0.00%	0.6	0.00%	0.1	0.00%
Waipa	0.0	0.00%	0.0	0.00%	0.0	0.00%
West Coast	84.1	0.04%	16.4	0.01%	7.8	0.00%
Total	143.2	0.01%	45.0	0.00%	21.4	0.00%

Where there was no data, no attempt was made to interpret incomplete data and the data was classed 'No data' due to the small areas concerned.

Another limitation of the land use data (Agribase dataset) is that it does not represent data for one point in time, mainly due to the voluntary data collection method. As a result, data are progressively collected as requested, as resources allow, or as properties change ownership, meaning there are some likely lags in the data which will be carried through the analysis. These lags may also vary spatially within the region. Overall, these limitations are not considered to have a major impact on the analysis over time.

5 Conclusions

- The methods and analyses presented in this report provide the first comprehensive spatial analysis of pastoral land cover change and intensity for the Waikato region.
- From 2001 to 2018, pastoral land in the Waikato region increased in area by an estimated 41,527 ha due to the net conversion of planted forest.
- By far the greatest area of net conversion of planted forest to pastoral land occurred in the Upper Waikato zone.
- The Lake Taupo zone had the greatest conversion of pastoral land to planted forest, which may reflect the implementation of Waikato Regional Plan Variation 5 policy and rules to manage land use and nutrient discharges in the catchment.
- From 2001 to 2018, an estimated 504,335 ha (40%) of pastoral land underwent some intensification, 491,582 ha (38%) showed no change, and 280,921 ha (22%) underwent destocking.
- On an annual basis, this represents an annual net intensification rate of just over 1% per annum for the 17-year period (2001 to 2018).
- Regionally, both intensification and destocking have declined since the first timestep, with a corresponding increase in the area of pastoral land showing no change.
- From 2001 to 2018, intensification of existing pastoral land was the greatest driver of pastoral land use change in the Waikato region, followed by planted forest conversion to pastoral land.
- The Upper Waikato zone was the only management zone where planted forest conversion to pastoral land was the main driver of pastoral intensity.
- The majority of new dairy land in the Waikato region has occurred in the Upper Waikato zone.
- Two regional indicators are proposed for ongoing monitoring of pastoral land cover change and intensification: *Pastoral land intensity changes for land use capability classes in the Waikato region 2001-2018*, and *Pastoral land intensity changes for management zones in the Waikato region 2001-2018*.
- Improving the availability and quality land use data would greatly improve estimates of land use change at a regional and sub-regional scale.

6 Recommendations

- Although the Waikato farm types used for analysis in this report provide a reasonable relative delineation of farm type intensity, a more thorough re-evaluation of the farm type classes, using current available data may be worthwhile.
- Repeating the analysis with the release of subsequent LCDB data would provide ongoing monitoring of pastoral land cover change and intensity trends.
- Incorporating other land use intensification such as cropping could be investigated to provide monitoring beyond pastoral land alone.
- Investigating pastoral land intensity spatial relationships with other monitoring data such as soil quality and water quality would strengthen the link between land use changes and impacts and could aid in the implementation of land management practices to mitigate the impacts.

References

- Beef and Lamb NZ 2021. [Farm classes | Beef + Lamb New Zealand \(beeflambnz.com\)](#). [accessed June 2021].
- Brown L, Hill RB, Singleton PL 2002 Modelling surface water nitrogen. Proceedings of the New Zealand Soil Science Society Conference, Wellington December 2002.
- Cameron M, Barrett P, Cochrane B and K McNeill, K 2009. Implications of agricultural change in the Waikato region: Current trends and future scenarios. Environment Waikato Technical Report 2009/28. Hamilton, Environment Waikato (Waikato Regional Council).
- DairyNZ 2021. QuickStats about dairying – Waikato Region. <https://www.dairynz.co.nz/media/5793948/quickstats-waikato-2020.pdf>. [accessed June 2021]
- Hill RB, Borman DW 2011. Estimating pastoral land use change for the Waikato region. In: Currie LD, Christensen CL eds. Adding to the knowledge base for the nutrient manager. Occasional Report No. 24. Palmerston North NZ, Fertilizer and Lime Research Centre, Massey University.
- Lynn IH, Manderson AK, Page MJ, Harmsworth GR, Eyles GO, Douglas GB, Mackay AD, Newsome PJF 2009. Land use capability survey handbook – a New Zealand handbook for the classification of land. 3rd ed. Hamilton AgResearch; Lincoln, Landcare Research; Lower Hutt, GNS Science.
- Manaaki Whenua – Landcare Research 2021. LRIS portal. <https://iris.scinfo.org.nz/>. [accessed June 2021].
- Vant B 2018. Trends in river water quality in the Waikato region, 1993-2017. Waikato Regional Council Technical Report 2018/30. Hamilton, Waikato Regional Council.
- Waikato Regional Council (Environment Waikato) 2008. The condition of rural water and soil in the Waikato region – risks and opportunities. July 2008. Hamilton, Environment Waikato (Waikato Regional Council).