

ESTIMATING PASTORAL LAND USE CHANGE FOR THE WAIKATO REGION

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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. The past decade conversion from plantation forest to pastoral land has meant higher stocking rates and more intensive farming practices. With ongoing land use change maintaining the soil resource and water quality is vital to the Waikato region's prosperity. This requires knowledge of the location and changes of land use pressures. A spatial "picture" is fundamental to understanding these trends and developing and prioritising sensible management practices and policy. The New Zealand Land Use Capability classification (LUC) provides a comparative assessment of land use pressure. This paper presents a method for spatial analysis of pastoral land use change relative to land use capability to assess pastoral land related pressures across the Waikato region.

A vector point array based spatial analysis method was undertaken using Manifold® System Release 8. Pastoral land conversion (plantation forest to pasture) was interpreted from land cover data from Land Cover Database 2 (2002 data) and LUCAS (2008 data). Pastoral intensification trend analysis used existing Waikato regional land use indicator stock density classes and Agribase data for 2001 and 2008. Pastoral intensification and destocking were classed as moderate if there was a single class increase and major for an increase of two or more classes. Results are presented regionally and sub-regionally.

Conversion of plantation forest to pastoral land accounted for about one third, intensification on existing pastoral land accounting for two thirds.

Plantation forest conversion to pastoral land use occurred predominantly in the Upper Waikato zone. Pastoral land use change was greatest in the Waihou, Waipa and upper Waikato zones whereas a decline in stock density was observed for the Lake Taupo and West Coast zones. Pastoral land use change occurred predominantly on LUC Class 6, with lesser change on LUC Classes 2, 3 and 4 land. About one third of the land use change on LUC Class 6 land is likely to involve dairy land use and will require good environmental management to minimise the risk of soil degradation and decline in water quality. The drivers of pastoral land use change in the Waikato region from 2002 to 2008 were intensification of existing pastoral land uses > plantation forest conversion to pastoral land uses > conversion between pastoral land uses (e.g. non-dairy conversion to dairy).

Introduction

The Waikato region encompasses most of New Zealand's central North Island with a land area of about 2.5 million hectares (ha). About half (1.3 million ha) is in pastoral land use; slightly more than half of which is dairy land use (Environment Waikato, 2011a). Maintaining the soil resource and water quality is vital to the Waikato region's prosperity.

Safeguarding the soil and water resource requires knowledge of where land use pressures are and may be changing.

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). 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 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, *Escherichia coli*, consistent with increased agriculture intensity above and beyond any improvements made through best management practice (Vant, 2008).

Fundamental to understanding these trends is describing the drivers for change from which likely pressures on land and water can be spatially identified and quantified in a relative sense, if not an absolute sense. Improved clarity about the types of intensification in a spatial construct can improve this understanding by describing the types of intensification and their location within the region and individual catchments.

To date there has been limited spatial description of the types of land change in the Waikato region. Improved and more available regional spatial datasets with increased resolution have facilitated the spatial analysis of land use changes in the Waikato region. 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 the input of accurate input data to provide valid scenarios. Such analysis is often hamstrung by the detail and date of spatial data sets (e.g. CLUES uses 2002 land use data). This report provides a spatial description of the types of land use change and intensification across the Waikato region and an assessment of land use change relative to land use capability to provide an indication of increased pressures and risk to the soil resource and water quality.

Method

Plantation forest conversion to pastoral land and pastoral land use and change in the Waikato region from 2002 to 2008 was estimated using a vector point array based spatial analysis method to examine existing spatial data sets held on Environment Waikato's Geographic Information System (GIS) using Manifold® Professional System Release 8.

It should be noted that the analysis and results are preliminary and the analysis is limited by the scale and currency of the data. Additionally, each of the analyses has been performed independently and using different combinations of data. Therefore, output values presented in the results should not be taken as absolute but as indicative and relative to other values of each analysis.

The extent of land use change and characterisation of change drivers over the last decade were analysed using available land cover and land use data sets for 2001, 2002 and 2008 as well as existing stock unit density classes used by Environment Waikato for State of Environment reporting for land use intensification (Environment Waikato, 2001b). Pastoral land use changes were then compared against land use capability using the New Zealand Land Resource Inventory's Land Use Capability classification (LUC).

Plantation forest conversion to 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 (e.g. intensification in dairy or change from sheep and beef to dairy support).

Sub-regional analysis – management zones

The Waikato region was delineated into predefined management zones (Environment Waikato, 2011c) to provide sub-regional statistics. Environment Waikato provides river and catchment services within eight management zones in the region. These include the Coromandel Peninsula, Waihou/Piako, Lake Taupo, Upper Waikato, Middle Waikato, Lower Waikato, Waipa and West Coast zones (Environment Waikato, 2011c). The information in this analysis is useful for prioritising works in each zone and rating.

Datasets (land cover, land use)

The land cover and land use information was based on a combination of Land Cover Database 2 (LCDB2) for 2002 land cover, the Land Use Carbon Accounting System (LUCAS) Land Use Map Version 3 for the 2008 land cover and AgriBase (AsureQuality Ltd, 2001 and 2008 versions) for stock unit density and land use.

The 2001 AgriBase and LCDB2 datasets are referred to in this report as representing land use and land cover respectively as of 2002. The 2008 AgriBase and LUCAS datasets are used to represent land use and land cover respectively as of 2008.

Spatial analysis framework

Creating a spatial picture of pastoral change requires a method of tracking the land use at any given location between land use snapshots. Preliminary attempts to achieve this, focused on matching whole farm polygons between snapshots. However, this proved unreliable due to the way in which unique farm identifiers had been assigned and farm polygon topological issues including farm amalgamations, conversions and overlaps. To overcome these issues a regularised 100 x 100 metre vector point array consisting of some three million points and comprising the entire Waikato region was used. A point array of this dimension assumes that each point comprises the centroid of its enclosing one hectare square. Additionally, it assumes that a value at each point is uniform across its enclosing square. The vector array method offers a number of benefits from a GIS perspective;

- A vector array avoids the issues associated with tracking whole farm polygons between Agribase snapshots,
- Structured Query Language (SQL) is optimized for large datasets,
- multiple attribute analysis is possible with SQL (single grid, many analyses),
- ease of integration and use with spatial models (e.g. CLUES),
- raster classifications can be dynamically linked directly from the vector array using SQL,
- a small disk footprint.

Pine to pasture conversion

Conversion from planted forest to pasture between the 2002 and 2008 interval was estimated using Land Cover Database 2 (LCDB2) as being indicative of 2002 planted forest extent and the Land Use Carbon Accounting System Land Map Version 3 (LUCAS) dataset to indicate 2008 pastoral extent.

Within the LCDB2 dataset, land under planted forest in 2002 was identified by [LCDB2_NAME] attributes *Afforestation (not imaged)*, *Afforestation (imaged, post LCDB 1)*, *Forest Harvested*, *Pine Forest - Open Canopy*, *Pine Forest - Closed Canopy*, *Other Exotic Forest*. The 2008 pastoral extent was defined by LUCAS dataset [LUC_NAME] attributes *Grassland - High producing*, *Grassland - Low producing*.

The class '*Grassland - With woody biomass*' was excluded from this study as comparison with WRAPS aerial photography taken in 2007 showed much of this class to be scrub and woodland rather than grazing land.

Pastoral stock unit density

Pastoral stock unit density and typical farm system data calculated for each of the 2002 and 2008 snapshots was imposed onto the array within the GIS using spatial overlay techniques. Animal counts for dairy cattle, beef cattle, deer and sheep were converted into their stock unit equivalents from each of the 2001 and 2008 Agribase snapshots. All other pastoral livestock were excluded from consideration. Existing stock unit density classes used for State of Environment reporting (Environment Waikato, 2011b) 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 (Environment Waikato, 2011b).

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

Pastoral land use change

Using the criteria described in Table 1 as a base, pastoral intensity change at each point location were identified and a measure of the magnitude of change in terms of typical farm system breaks made. The magnitude and direction of change was classified as in Table 2.

Table 2. 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 2002 and then classed as “Higher stocked dairy farms” in 2008, would be a “Two or more class increase” and “Major intensification”. Plantation forest converted to pastoral land was interpreted as at least Moderate intensification. Any ambiguity existing between the 2002 and 2008 data was classified as “no data”. As such the analyses are likely to underestimate the magnitude of change.

Results and discussion

Independent analyses of plantation forest conversion to pastoral land use and stock unit density change from 2002 and 2001 respectively to 2008 were combined to estimate pastoral land use change from 2002 to 2008. Independent examination of these two analyses provided detail of the drivers of pastoral land use change across the region. The combination provided the overall “picture” of total pastoral land use change irrespective of the drivers. Comparison with Land Use Capability informs of the relative pressures these changes have on the land resource. The results presented and discussed regionally and sub regionally.

Plantation forest conversion to pastoral land

An estimated 37,298 hectares (ha) was converted from plantation forest to pastoral land use in the region from 2002 to 2008 (Table 3). A map showing the regional distribution of plantation forest conversion to pastoral land and pastoral land to plantation forest for the Waikato region is shown in Appendix 1.

Table 3. Plantation forest conversion to pastoral land from 2002 to 2008 for management zones of the Waikato region.

Management zone	Plantation forest 2002 to pasture 2008 (ha)	Pasture 2002 to plantation forest 2008 (ha)	Net Change (ha)
Central Waikato	229	218	11
Coromandel	268	1086	-818
Lake Taupo	1201	823	378
Lower Waikato	715	1491	-776
Upper Waikato	31,474	2430	29,044
Waihou Piako	967	1316	-349
Waipa	878	1329	-451
West Coast	1566	4772	-3206
Total	37,298	13,465	23,833

This compares with an estimate of 5708 ha for the 1989 to 2002 period using the LUCAS Land Use Map version 3 “pre-1990” data. The greatest area of conversion occurred in the Upper Waikato. Conversion in the other management zones was significantly less ranging between 229 ha and 1566 ha. However, the area of conversion was offset by an estimated 13,465 hectares converted from pasture to plantation forest. The net change from plantation forest to pastoral land from 2002 to 2008 for the Waikato region was 23,833 ha. The greatest net change occurred in the Upper Waikato zone, with an estimated conversion to pasture of 29,044 ha. A net increase in plantation forest relative to pasture was indicated for the Coromandel, Lower Waikato and Waihou-Piako zones. The results indicate that plantation forest conversion to pastoral land is only likely to be the main driver of pastoral land use change in the Upper Waikato zone and not in other zones.

Pastoral land use change

Pastoral stock unit density results comprise the greatest component of the overall pastoral land use change. From 2002 to 2008 there was a net regional intensification of pastoral land use in the Waikato region (Table 4). A map showing the regional distribution of pastoral stock unit density and overall pastoral land change for the Waikato region are shown in Appendices 2 and 3 respectively. About 310,000 ha or 24% of the region's pasture in 2008 had undergone intensification, about one third had not changed and 210,000 ha (16%) had undergone destocking since 2002. There was no reliable farm data for 28% of the area analysed.

Table 4. Pastoral land change in management zones of the Waikato region, 2002 to 2008.

Management zone	Intensification (ha)		No change (ha)	Destocking (ha)		No data (ha)
	major	moderate		major	moderate	
Central Waikato	2321	6253	8793	3101	5066	24,114
Coromandel	1783	4594	12,875	1144	4507	10,742
Lake Taupo	1205	8767	22,787	2083	11,995	21,623
Lower Waikato	9860	26,857	60,397	8636	21,238	82,907
Upper Waikato	13,649	55,924	62,022	10,274	19,197	55,070
Waihou-Piako	22,260	60,695	74,683	13,684	27,278	60,523
Waipa	16,144	46,206	73,752	12,029	26,543	53,231
West Coast	2338	32,753	109,665	5245	38,591	52,686
Total (ha)	69,560	242,049	424,974	56,196	154,415	360,896
(%)	(5%)	(19%)	(32%)	(4%)	(12%)	(28%)

Net intensification (total intensification minus total destocking) was estimated at 100,998 ha; of which 23,833 hectares is the result of net plantation forestry conversion to pastoral land (Table 5).

Table 5. Net change in pastoral land change for management zones of the Waikato region, 2002 to 2008.

Management zone	Total intensification (ha)	Total destocking (ha)	Net change (ha)
Central Waikato	8574	8167	407
Coromandel	6377	5651	726
Lake Taupo	9972	14,078	-4106
Lower Waikato	36,717	29,874	6843
Upper Waikato	69,573	29,471	40,102
Waihou Piako	82,955	40,962	41,993
Waipa	62,350	38,572	23,778
West Coast	35,091	43,836	-8745
Total	311,609	210,611	100,998

The Waihou-Piako, Upper Waikato and Waipa zones showed the greatest net intensification from 2002 to 2008. Plantation forest conversion to pastoral land was the predominant driver of change in the Upper Waikato, whereas intensification of existing pastoral land, either a change of land use (e.g. sheep to dairy) or intensification within a land use (e.g. intensification of dairy) were the main drivers of change in the other zones. Two zones (Lake Taupo and West Coast) indicated a net destocking. 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 zone.

Farm type

Comparison of the estimated net areas for individual farm type changes (Figure 1) indicated as of 2008 most of the plantation forestry conversion had been to lower stocked pastoral land representing “Sheep farms”. This possibly reflects the lower stock carrying capacity of the Upper Waikato zone soils and climate (pumice dominated soils and lower rainfall) but also reflects the fact that a lot of this newly converted and stocked land was not captured in the Agribase 2008 dataset.

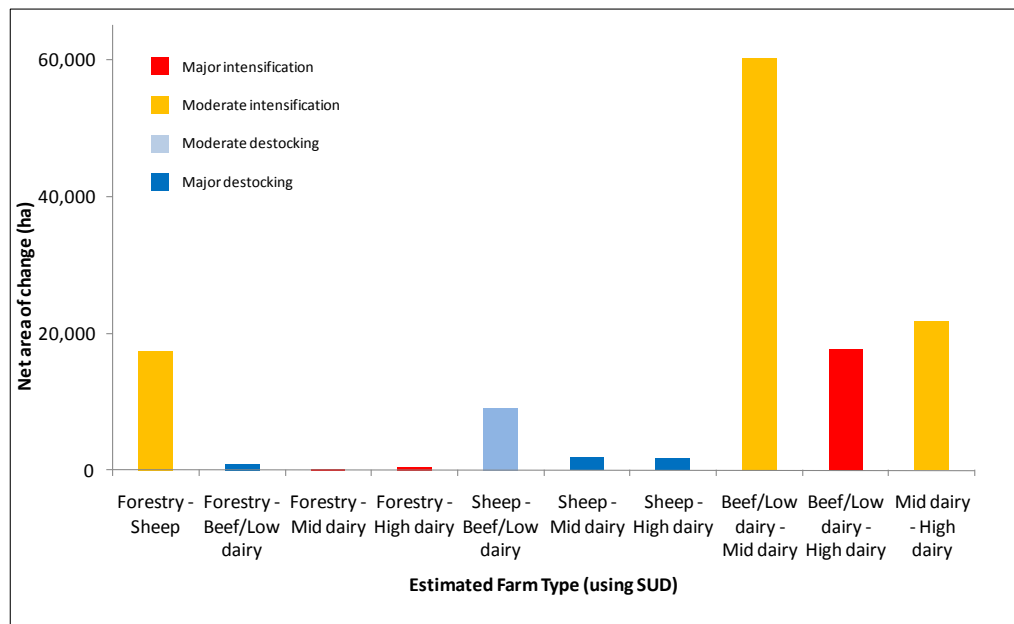


Figure 1. Area of farm type change for the Waikato region (2002 to 2008) as approximated using pastoral stock unit density classes; intensification: moderate = orange, major = red; destocking: moderate = light blue, major = dark blue.

It is evident that intensification of dairy is the primary driver of intensification with Beef/Low stocked dairy and Mid stocked dairy intensifying to Mid and High stocked dairy.

Comparison with Land Use Capability

Comparison of plantation forest converted to pastoral land and LUC Class showed that 54% of the net change occurred on LUC Classes 3 and 4, that is, on land with a high suitability for pastoral land uses (Table 6). The remainder of the net change occurred on land with a low suitability for pastoral land use (LUC Classes 6 and 7).

Table 6. Difference in plantation forest and pastoral land for LUC Classes in the Waikato region, 2002 to 2008.

LUC class	Plantation forest 2002 to pastoral land 2008 (ha)	Pastoral land 2002 to plantation forest 2008 (ha)	Net change in pastoral land (ha)	Contribution to the conversion to pastoral land
1	45	-58	-13	0%
2	283	-397	-114	0%
3	5557	-894	4663	20%
4	9681	-1651	8030	34%
5	20	-38	-18	0%
6	17,134	-8482	8652	36%
7	4265	-1789	2476	10%
8	313	-156	157	1%
Total	37,298	-13,465	23,833	100%

Comparison of pastoral land use change with Land Use Capability was used to indicate 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. Figure 2 shows that although a proportion of intensification occurred on LUC Classes 2, 3 and 4 a high proportion of intensification on land less capable of supporting pastoral land use (LUC Class 6 land). Pastoral intensification on this class of land requires good management practice to minimise the risk of soil degradation.

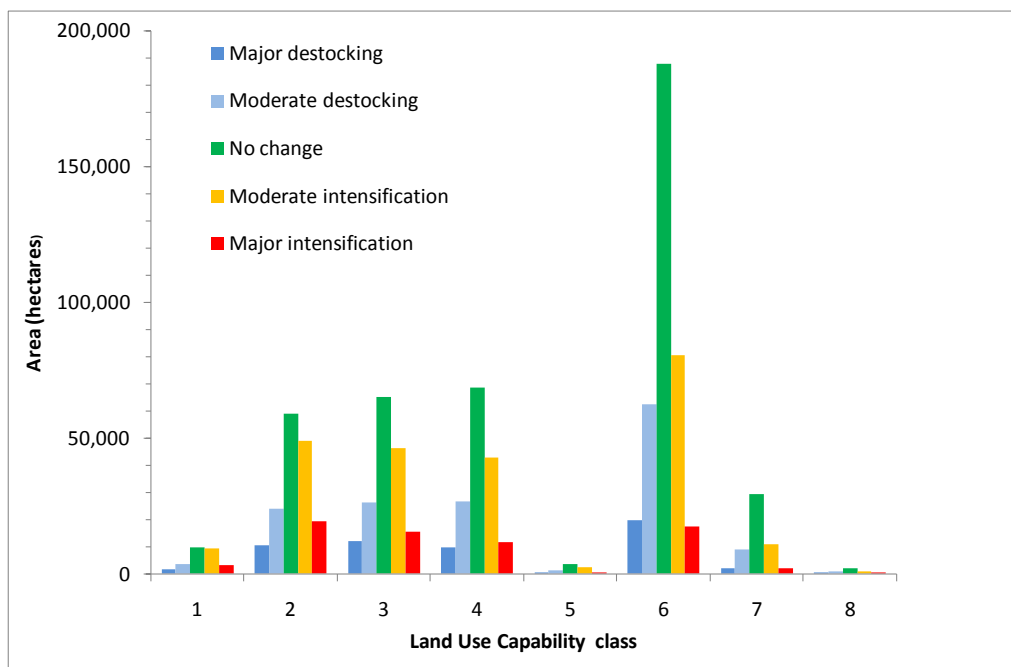


Figure 2. Area of pastoral land use conversion for the Waikato region, by Land Use Capability Class 2002 to 2008.

Pastoral farm types (dairy pasture and non-dairy pasture) were also assessed against Land Use Capability to indicate the general farm types that may be increasing on different classes of land (as classified using LUC). Figure 3 shows that while the majority of new dairy 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 pasture (LUC Class 6).

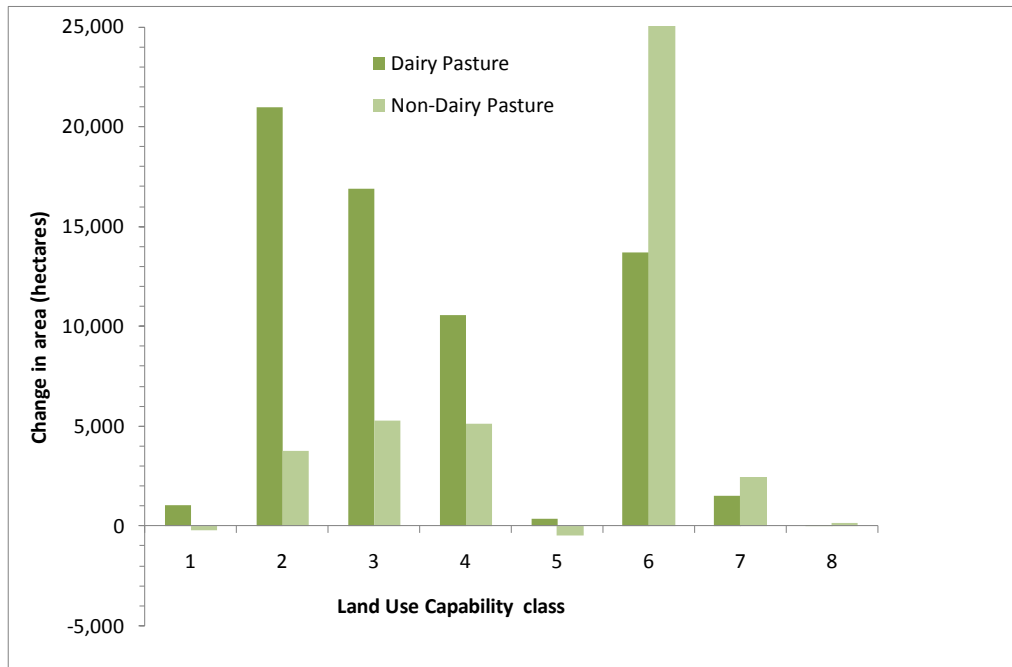


Figure 3. Area of pastoral land use conversion for the Waikato region, by Land Use Capability Class 2002 to 2008.

Limitations of datasets

There was no reliable farm data for 28% of the pastoral land use change analysis (Table 4) due to missing data within the Agribase data set and between Agribase snapshots. Where this was the case, no attempt was made to interpret incomplete data and the data was classes “No data”. Such limitations and inconsistencies within and between data snapshots is an important issue that limits accurate spatial analysis. Also, the land use data (Agribase dataset) does not represent one point in time data, due to the voluntary data collection method.

Future directions

Further refinement of the method and analysis at a sub regional level is required, including detailed analysis of farm type changes in zones. Land use change outputs will be used to refine Environment Waikato’s State of Environment land use indicators. Application of these outputs with spatial land use impact models such as CLUES can be used to spatially model the water quality impacts of land use change.

Conclusions

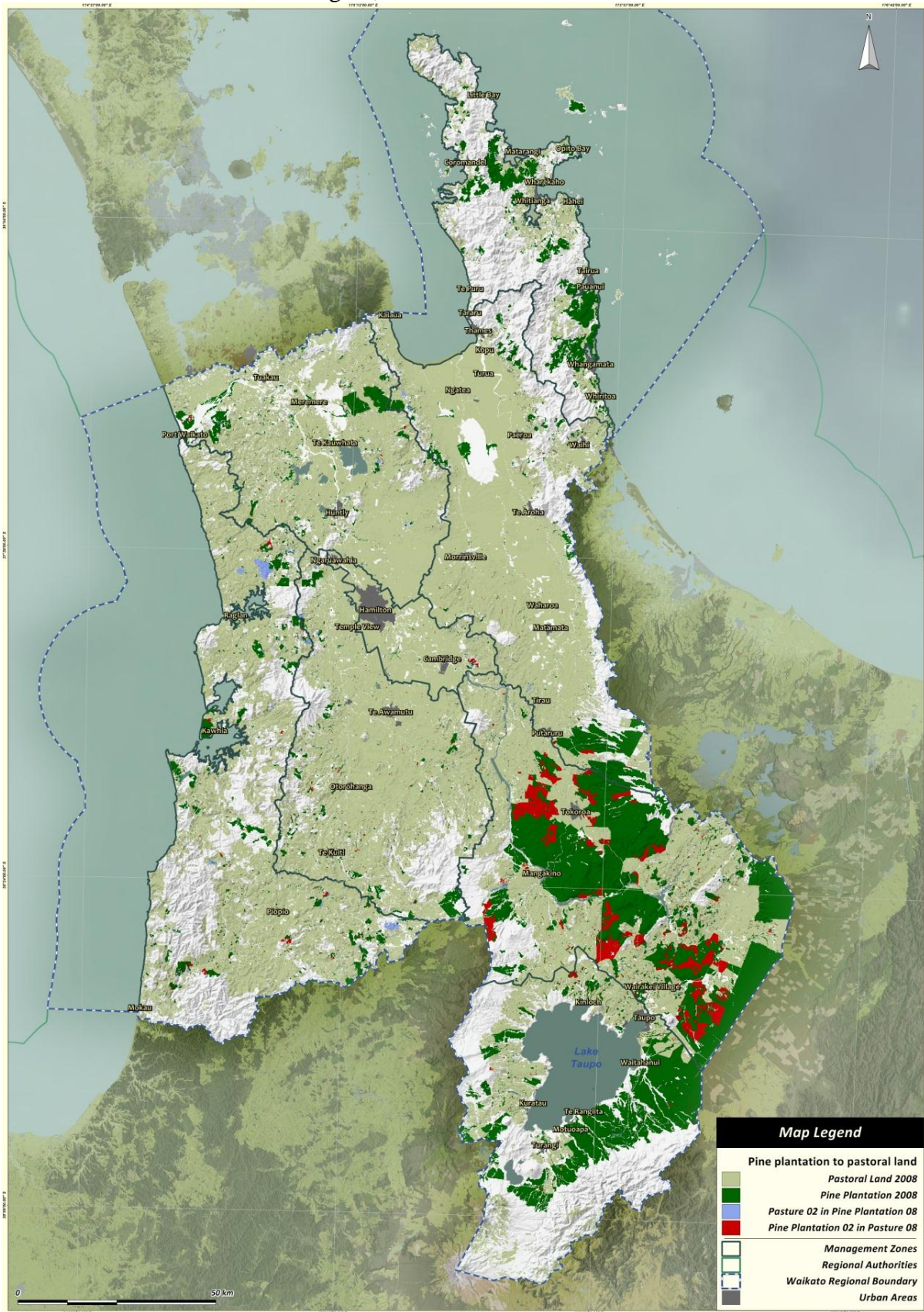
- Plantation forest conversion to pastoral land from 2002 to 2008 was estimated at 37,298 ha. However, conversion of pasture to plantation forest of 13,465 ha during the same period resulted in a net conversion to pasture of 23,833 ha.

- By far the greatest area of net conversion to pasture occurred in the Upper Waikato zone (29,044 ha). In this zone conversion was the predominant driver of pastoral land use change.
- About one third of regional land use change was the result of plantation forest conversion to pastoral land, predominantly in the upper Waikato.
- Regionally, 24% (a little more than 300,000 ha) of pastoral land was subject to intensification. This was offset by about 200,000 ha of land subjected to destocking, leaving a net intensification of about 101,000 ha.
- The greatest pastoral land use change by area occurred in the Waihou-Piako, Upper Waikato and Waipa zones.
- Regionally, intensification of existing pastoral land was the greatest driver of pastoral land use change in the Waikato region from 2002 to 2008, followed by plantation forest conversion to pastoral land and pastoral land use conversion.
- More intensive pastoral land uses are moving onto less “capable” land resulting in the increased risk to soil degradation on LUC Class 6, 7 and 8 land and increased potential for offsite water quality impacts.
- The spatial analysis approach provides a clear regional and sub-regional scale “picture” of pastoral land use change for the Waikato region.
- Improving the availability and quality land use data would greatly improve estimates of land use change at a regional and sub-regional scale.

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Appendix 1: Map of plantation forest conversion to and from pastoral land for the Waikato region, 2002 to 2008.



Appendix 2: Map of pastoral stock unit density change for the Waikato region, 2001 to 2008.

