Sustainable land-use monitoring in the eastern Taranaki hill country and coastal sand country — 2007 re-survey

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Definitions of terms and expressions

The terms and expressions highlighted below have specific meanings for the purposes of the present study and report:

Accelerated erosion: movement of regolith and/or soil at rates more rapid than natural erosion rates, and due to human influence. The most important human activity promoting accelerated erosion in the eastern hill and sand country of Taranaki is vegetation clearance. Accelerated erosion is comprehensively reviewed for Taranaki by Hicks (1998).

Area of interest (coastal sand country sites): the area of sand dunes and sand flats within the chosen sand country monitoring sites, and as defined by visual interpretation of the extent of the sand dune and sand flat land.

Coastal sand country: land adjacent to the coast, influenced by wind-blown sand, forming sand dunes and sand flats.

Eastern Taranaki hill country: hill country (most slopes between 16 and 25 degrees) and steep land (most slopes >25 degrees) east of the predominantly flat terraces and Taranaki ring plain, excluding Department of Conservation land. The eastern Taranaki hill country, as represented in each of the 25 monitoring sites, may contain flat to undulating river valley terraces and rolling land, but these land types cover just 15% of the total monitoring area.

Eastern Taranaki hill country monitoring site: a quasi-rectangular area of approximately 900 ha, bounded by sides approximately 3 km x 3 km, originally centred on a regular grid at intersections on the New Zealand Map Grid (NZMG) eastings and northings, drawn at 10-km intervals. From this report onwards, following the shift from NZMG to the newer New Zealand Transverse Mercator (NZTM) projection, the boundary of each site is defined by the NZTM coordinates of its four corner points. See Appendix 1.

Pasture with trees: as in Jessen et al. (2000), this expression refers to 'close-planted woodlots of pine or other commercial timber species, interspersed with pasture for animal grazing, or rows of commercial timber species with pasture for animal grazing between the rows' (both are forms of agro forestry). This expression was broadened in 2000 (and is used in the present study) to include areas planted with soil conservation trees (including presently non-commercial trees such as poplar). Trees should be a well-integrated and deliberate part of the farming system for the 'pasture with trees' sustainable land-use class. The 'meat and wool farming with trees' land-use class equates conceptually with the 'pasture with trees' (PT) sustainable land-use class.

Physically sustainable land-use classes: land uses defined and described for Taranaki in Blaschke et al. (1992a). They are made up of land uses linked to specified land-use capability units from the Taranaki/Manawatu Regional New Zealand Land Resource Inventory (NZLRI) classification (Fletcher 1987), and the linkages are listed in Appendix 1 of Blaschke et al. (1992a), and in Appendix 4 of O'Leary et al. (1996). The classes represent the most intensive land use that may be sustainably applied (Table 5) on that land. Because the classes are linked to the spatial database of the NZLRI, they can be represented in map form.

The land-use classes were mapped for each of the 25 eastern Taranaki hill country monitoring sites for 1994 by O'Leary et al. (1996) and for 2000 by Jessen et al. (2000). The present study compares the year 2007 land uses against these.

Physically sustainable or unsustainable land use:

- physically sustainable land use means ‘this land use on the specified area carries a moderate or lower risk of accelerated erosion in the long-term’. Physically unsustainable land use means ‘this land use on the specified area of land carries a severe or higher risk of accelerated erosion in the long-term’. This interpretation brings the concept of sustainability back to the issue of accelerated erosion that the Council is in part addressing with its monitoring programme. The sustainability of land use is detected and measured (its area) by comparing the sustainable land-use class with the actual land use – for example, if the land use ‘meat and wool farming’ is located on the ‘forestry FO’ sustainable land-use class, the land use is assessed as physically unsustainable

- where the words ‘sustainable’ or ‘unsustainable’ are used in the present report, they should be interpreted as being preceded by the word ‘potentially’. Clearly, land management that reduces a significant risk of accelerated erosion would improve the physical sustainability of that land use – the reverse might also be true. An assumption of good average land management is made for the sustainability assessments (this is the same standard assumption made when assessing land-use capability in New Zealand). ‘Good average’ is considered the better side of average for the region, but not extraordinary

Sampling error: (or random error) is the possible error associated with sampling a proportion of the population (in this case, the land-use sustainability changes over 25 eastern hill country sites, or bare ground over 4000 dot grid points in the sand country) and not the whole population. An estimate is written as X±Y, where X is the estimated value and Y is the sampling error. The true or population value of X lies between X-Y and X+Y.

It is important to specify the sampling error when using the results of this monitoring study to make defensible statements for the entire area of the eastern hill country or sand dune land.

Summary

Project and client

Landcare Research (NZ) Ltd was contracted by Taranaki Regional Council to carry out a survey of land-use sustainability on 25 ~900-hectare hill country sites in eastern Taranaki, and monitor bare sand areas on four coastal sand country sites, for 2007. This is a repeat of the monitoring work carried out for Taranaki Regional Council by Landcare for 2000, which was reported in "Sustainable land-use monitoring in the eastern Taranaki hill country and coastal sand country" by Jessen et al. in Landcare Research (NZ) Ltd Contract Report LC9900/125.

As with the 2000 report, this project addresses the monitoring requirements associated with management of the accelerated erosion issue in the two following areas of concern as identified in the Regional Soil Plan for Taranaki, which became operational in 2001:

- accelerated erosion as a result of vegetation clearance in the eastern hill country
- accelerated erosion by wind on the coastal terraces as a result of vegetation disturbance.

Objectives

The objectives were to:

- undertake repeat monitoring of 25 eastern Taranaki hill country sites according to the approach adopted in the 1996 survey and as modified in the 2000 survey
- undertake repeat monitoring of four coastal sand country sites according to the approach adopted in the 2000 survey
- document the methods used and results obtained in this report and retain all records in ARC/INFO GIS files and ERDAS IMAGINE remote sensing files for retrieval and use in future monitoring episodes.

Results

Eastern hill country

Vegetation and land use

- From 1994 to 2000, changes in vegetation over the 25 monitoring sites were mainly small. The most notable changes were a reduction in the area of pasture from 49.0% to 47.6%, while the area of plantation forestry increased from 2.4% to 4.0%, mostly as a result of plantings on former pasture. From 2000 to 2007 the area under pasture declined further to 46.3%, plantation forestry increased further to 4.7%, and other vegetation changes remained small. Overall, the period 1994–2007 saw the total area of pasture reduce from 49.0% to 46.3%, while forestry increased from 2.4% to 4.7%.

- Land-use changes between 1994 and 2000 were dominated by a reduction in the area of meat and wool farming from 53.9% to 51.1%. At the same time, plantation forestry increased from 2.5% to 4.0%, and revegetated meat and wool farming land increased from 24.1% to 25.5%. From 2000 to 2007, a more substantial move away from meat and wool farming occurred: The total area of meat and wool farming fell to 45.1%, most of which went to revegetated meat and wool farming (which increased to 30.8%) and more plantation forestry (which increased to 4.7%).

Physical sustainability of land use

- From 1994 to 2000, overall land-use sustainability improved over the 25 monitoring sites: in 1994, 83.9% of the monitoring area was used sustainably, and 16.1% used unsustainably. By 2000, this had improved to 85.0% and 15.0% respectively, an improvement in sustainability of 1.1 ± 0.7%. Most of this improvement resulted from a reduction in the area of meat and wool farming and an increase in the area of plantation forestry. From 2000 to 2007, an accelerated trend towards sustainability was recorded: by 2007, 87.4% of the monitoring area was used sustainably, and 12.6% was used unsustainably (an improvement in sustainability of 2.4 ± 1.5%. This was the result of a stronger move away from meat and wool farming after 2000 and a consequent increase in the area of revegetated meat and wool farming land. Increases in the area under plantation forestry also contributed to improved land-use sustainability. Overall, from 1994 to 2007, monitoring of the 25 hill country sites showed an improvement in land-use sustainability of 3.5 ± 1.6%.

- Meat and wool farming was the greatest contributor to the area of physically unsustainable land use. In 1994, meat and wool farming made up 53.9% of the monitoring area, with 29.3% of that area being regarded as physically unsustainable. By 2000, meat and wool farming occupied 51.1% of the monitoring area, and 28.7% of that area was regarded as physically unsustainable. From 2000 to 2007, meat and wool farming fell further to 45.1% and, of that, 26.8% was physically unsustainable. By 2007, the total area of unsustainable meat and wool farming recorded in 1994 had fallen by 816 ha, or nearly one-quarter.

- Around one quarter of the area of physically sustainable meat and wool farming occurs on the 'Pasture with trees' (PT) sustainable land-use class. This comprises mostly land-use capability Class 6 land, which carries a moderate risk of accelerated erosion. Tree planting would further improve land management on these areas. The meat and wool farming land that is considered physically unsustainable occurs on sustainable land-use classes 'Forestry' (FO) and 'Protection' (PR), which has a severe to very severe risk of accelerated erosion. Rapid sustainability gains could be made on this land by the use of forestry plantings, or allowing it to revert to scrub and, ultimately, indigenous forest cover. It is noted that the 'meat and wool farming with trees' land-use class was barely recorded on any of the imagery for 1994, 2000 and 2007, indicating that most of the sustainability gains made between 1994 and 2007 have come from the reversion of meat and wool farming land to scrub, or its conversion to plantation forestry.

- The longer term trend, from the early 1950s to 1994, showed a decrease in land-use sustainability from 90.0% to 87.3% (-2.7 ± 0.8%), based on long-term monitoring by O'Leary et al. (1996) of the 17 monitoring sites that had available historical data. Most of this decrease happened before the early 1980s, and the last decade of the pre-1994 period showed little change in sustainability. By 2000, land-use sustainability on these 17 sites had improved to 88.5% (+1.2 ± 1.1%), though this is barely significant based on the higher sampling error when using 17 sites. By 2007, a further improvement by 1.5 ± 1.7% was noted, though this was not significant in the context of the sampling error involved. The overall trend for 1994 to 2007, however, was a significant improvement of 2.7 ± 2.0%, to 90.0%.

Overall, the Council have made good progress, particularly since 2000, in their efforts to manage the issue of accelerated erosion in the eastern Taranaki hill country. Further improvements in land use sustainability are required, however, to meet the Council's 2001 Regional Soil Plan target of 89% sustainable land use in the eastern hill country by 2011 – a further increase of 1.6% by 2011 is implied. Given the relatively small total area of plantation forestry in the hill country, the Council may consider the promotion of additional afforestation, particularly on the presently-farmed land

classes that are most vulnerable to accelerated erosion, as an effective way of further improving the overall sustainability of hill country land use.

Coastal sand country

From 1994 to 2000, the area of bare sand had:

- increased at Site A (Egmont) by 1.5 ± 1.0% (3.0 ha)
- increased at Site B (Hawera) by 1.2 ± 1.0% (7.3 ha)
- not changed at Site C (Patea)
- decreased at Site D (Wanganui) by 1.9 ± 1.5% (25.8 ha).

No significant changes were recorded at any of the sites from 2000 to 2007, and any changes that were noted appeared to relate mainly to natural causes rather than management effects.

Overall, from 1994 to 2007, the area of bare sand had:

- increased at Site A (Egmont) by 2.3 ± 1.0% (3.0 ha)
- increased at Site B (Hawera) by 1.1 ± 1.0% (7.3 ha)
- not changed at Site C (Patea)
- decreased at Site D (Wanganui) by 1.7 ± 1.5% (25.8 ha).

1. Introduction

Section 35 of the Resource Management Act imposes a duty on local authorities to gather information, to monitor and to keep records. The approach of the Taranaki Regional Council ('the Council') to monitoring is to undertake monitoring programmes that reflect significant regional issues. Issue 1 in Section 4 of the Regional Soil Plan for Taranaki addresses accelerated erosion as a result of inappropriate land management practices and focuses on the eastern hill country and coastal terraces. The methods the Council currently uses to address Issue 1 includes giving general advice and promoting its importance, providing sustainable land management planning services, enforcement if necessary, and research and monitoring. This project addresses the monitoring requirement associated with the management of this issue.

The Council established baseline information about vegetation cover, land use and physical sustainability in the region's eastern hill country in 1994 (O'Leary et al. 1996). A repeat monitoring episode was carried out for the Council in 2000 (Jessen et al. 2000) as part of the Council's assessment of their management of Issue 1. At the same time the monitoring programme was expanded to include the other area of interest – the coastal sand country. The 2000 monitoring project made use of two pre-existing methods: 1) as used previously by O'Leary et al. (1996) in the eastern hill country; and 2) as developed and recommended by Stephens and Dymond (1999) in the coastal sand country.

The present study was requested by the Council to measure and report on changes from 2000 to 2007 in vegetation cover and land-use on the hill country sites, and changes in bare sand cover on the coastal sand country sites. For the coastal sites, the same methodology used by Jessen et al. (2000) was repeated. For the 25 hill country sites, changes in technology and improvements in image quality and precision forced a review of the previous monitoring data and also a revision of the 25 monitoring site boundaries. As a result, the data presented in Jessen et al. (2000) have been revised in this report to provide for robust comparisons with the 2007 data. Because the same transformation process was applied to both the 1994 and 2000 data together, the percentage changes in vegetation cover and land use, and the reported percentage changes in land-use sustainability, as reported in Jessen et al. (2000), are essentially unchanged. However, as the actual areas involved have changed slightly, the 1994 and 2000 data are revised in this report for consistency.

2. Objectives

The objectives of the present study were to:

- carry out repeat monitoring of 25 eastern Taranaki hill country sites according to the approach adopted by O'Leary et al. (1996) and O'Leary and Stephens (1996), and as revised in Jessen et al. (2000). Further improvements to the methodology are detailed below. The present study takes the 1994 and 2000 information reported in Jessen et al. (2000) and determines changes to vegetation cover, land use, and physical land-use sustainability from 1994 and 2000 to the present

- undertake monitoring of four coastal sand country sites according to the approach in Stephens & Dymond (1999), and as modified by Jessen et al. (2000). The present study determines changes to the area of bare sand from 1994 and 2000 to the present

- document all results in this report and fully document and archive records in both ARC/INFO GIS software files and ERDAS IMAGINE remote sensing files, ready for retrieval and use for a future monitoring episode.

3. Methods

3.1 Aerial imagery

In contrast to the 1994 and 2000 monitoring episodes where Landcare Research was responsible for the acquisition of new aerial photography, the 2007 imagery used in this study was supplied by the Council as high-resolution digital scans. Details of the imagery used in 1994, 2000 and the present study are summarised in Table 1.

Table 1 Details of imagery used in 1994, 2000 and the present study

Date of imagery	Source of imagery	Images supplied as	Scanned image resolution (m/pixel)	Orthorectified?	Map projection
1994	Aerial Surveys Ltd, Nelson (contracted by Landcare Research)	Contact prints	3.00	No	New Zealand Map Grid
2000	Aerial Surveys Ltd, Nelson (contracted by Landcare Research)	Contact prints	1.00	No	New Zealand Map Grid
2007 (present)	Taranaki Regional Council	High-resolution digital scans	0.75	Yes	New Zealand Transverse Mercator

3.2 Monitoring sites and sampling errors

Eastern hill country

The locations of the 25 eastern hill country monitoring sites are illustrated in Appendix 1. The area of each hill country site was reported in Jessen et al. (2000) as being 900 ha (each site being a 3 km x 3 km square).

The 1994 and 2000 studies used non-orthorectified photographs (O'Leary et al. 1996, Jessen et al. 2000). The change to orthorectified imagery in the present study revealed that the hill country site boundaries on the earlier imagery did not correspond to regular 3 km x 3 km (900 ha) squares on the ground. This is because while orthorectified imagery is processed to remove distortions due to relief displacement and camera/lens geometry, these distortions were not removed from the earlier imagery because of time and cost constraints. (It is only in recent years that the use of orthorectified imagery has become a standard practice, owing to substantial improvements in computing power, software capability and image quality, all of which have reduced the cost of orthorectification to acceptable levels for most mapping applications).

In addition, the imagery supplied by the Council was projected onto the New Zealand Transverse Mercator (NZTM) grid whereas all previous work was projected on the now-superseded New Zealand Map Grid (NZMG). This required a further processing step to convert all earlier ARC/INFO coverages of vegetation and land use to NZTM before the datasets could be directly compared for assessments of change from 1994 and 2000 to the present.

The processing required to bring the 1994 and 2000 mapping into line with the new 2007 mapping is described fully below, and details of the hill country sites with their revised areas are given in Table 2. The actual area of each site has been recalculated from the NZTM coordinates of each

site's corner points that were visually located on the 2007 imagery. The nominal area (900 hectares) is the area for each site as reported for 1994 and 2000.

This sampling strategy (also used by Jessen et al. 2000) contributes to low (between ±0.7% and ±1.6%) random (sampling) errors for the sustainability change data when assessed over 25 sites for the eastern Taranaki hill country. Detailed information about the calculation of errors according to this sampling strategy can be found in Dymond et al. (2001).

Coastal sand country

The four coastal sand country monitoring sites were chosen by the Council to be representative of the range of sand country environments in coastal Taranaki. The sites are quite widely separated (from near Cape Egmont in the north, to north of Wanganui in the south – see Appendix 1) and this gives a greater chance of capturing the range of conditions along the coast. The area of each site is different (unlike the hill country sites), as is the single 'area of interest' defined in each site. The 'area of interest' represents the extent of sand dunes within each site where monitoring was carried out.

As with the hill country monitoring sites, the boundaries for the four sand country monitoring sites were re-established on the new 2007 imagery, although the lack of topographic relief on these sites meant site boundary distortion due to relief displacement was negligible. Within each site boundary, the area of sand country (the 'area of interest' referred to in Jessen et al. 2000) was defined by an irregular polygon that was generated for each site and stored as an 'area of interest' (.aoi) file in ERDAS IMAGINE as part of the 2000 study. These .aoi files were retrieved and converted to NZTM coordinates using the online coordinate conversion calculator on the Land Information New Zealand website (see http://www.linz.govt.nz/apps/coordinateconversions/index.html). For consistency the sand areas were recalculated but the resulting differences in area are negligible and can be ignored. Sand country monitoring site details are described in Table 3.

Sampling (random) errors due to the dot grid sampling method are low – between ±0.5% and ±1.5%. A description of how these errors are calculated using the sand country sampling strategy can be found in Dymond et al. (2001).

Table 2 Locations and dimensions of the 25 hill country monitoring sites

Site	NZTM coordinates (Easting, Northing)				Actual site area (hectares)	Nominal site area in 1994 and 2000 (hectares)	Difference (%)
	NW corner	NE corner	SE corner	SW corner			
1	1738379, 5709781	1741366, 5709791	1741307, 5706792	1738382, 5706781	886.62	900.00	-1.49
2	1738384, 5699768	1741363, 5699736	1741392, 5696783	1738366, 5696795	889.63	900.00	-1.15
3	1728397, 5689757	1731304, 5689801	1731343, 5686805	1728399, 5686795	871.56	900.00	-3.16
4	1718383, 5679760	1721319, 5679701	1721305, 5676747	1718418, 5676743	869.20	900.00	-3.42
5	1728388, 5679711	1731409, 5679809	1731381, 5676745	1728356, 5676739	912.19	900.00	1.35
6	1738474, 5679786	1741388, 5679787	1741481, 5676841	1738495, 5676833	870.13	900.00	-3.32
7	1718422, 5669799	1721419, 5669718	1721413, 5666766	1718434, 5666771	893.40	900.00	-0.73
8	1728449, 5669702	1731457, 5669741	1731442, 5666791	1728467, 5666786	877.41	900.00	-2.51
9	1718455, 5659733	1721445, 5659779	1721368, 5656793	1718402, 5656809	879.90	900.00	-2.23
10	1728394, 5659711	1731457, 5659718	1731403, 5656748	1728410, 5656717	902.91	900.00	0.32
11	1738431, 5659787	1741381, 5659767	1741296, 5656927	1738411, 5656778	852.88	900.00	-5.24
12	1728405, 5649777	1731407, 5649763	1731419, 5646802	1728486, 5646834	875.90	900.00	-2.68
13	1738516, 5649799	1741268, 5649719	1741298, 5646886	1738374, 5646785	829.63	900.00	-7.82
14	1728404, 5639689	1731310, 5639686	1731433, 5636766	1728435, 5636813	855.30	900.00	-4.97
15	1738538, 5639363	1741402, 5639628	1741394, 5637114	1738472, 5636844	727.03	900.00	-19.22
16	1718402, 5629720	1721433, 5629733	1721425, 5626737	1718432, 5626740	899.99	900.00	0.00
17	1728443, 5629723	1731373, 5629651	1731387, 5626830	1728451, 5626790	843.81	900.00	-6.24
18	1748456, 5619717	1751536, 5619823	1751508, 5616879	1748433, 5616779	904.83	900.00	0.54
19	1758460, 5619811	1761444, 5619757	1761380, 5616675	1758427, 5616799	904.93	900.00	0.55
20	1728446, 5609779	1731449, 5609780	1731492, 5606739	1728437, 5606752	918.99	900.00	2.11
21	1738162, 5609877	1741578, 5609810	1741650, 5606765	1738340, 5606794	1029.82	900.00	14.42
22	1748428, 5609715	1751337, 5609785	1751407, 5606838	1748490, 5606815	851.92	900.00	-5.34
23	1758456, 5609737	1761441, 5609774	1761425, 5606867	1758462, 5606833	864.08	900.00	-3.99
24	1748427, 5599830	1751412, 5599853	1751489, 5596755	1748540, 5596585	941.90	900.00	4.66
25	1758430, 5599837	1761339, 5599798	1761277, 5596958	1758443, 5596919	826.70	900.00	-8.14
Total					**21980.67**	**22500.00**	**-2.31**

Table 3 Details of the four sand country monitoring sites

Site	NZTM coordinates of site		Actual sand area within site (hectares)	Sand area reported for 1994 and 2000 (hectares)	Difference (%)
	Easting	Northing			
A (Egmont)	1665481 1666467 1667845 1666840	5646976 5642055 5642330 5647242	209.9	210.0	0.0
B (Hawera)	1718094 1719654 1722962 1721346	5605782 5606903 5602365 5601194	580.7	580.7	0.0
C (Patea)	1731018 1733653 1735458 1732440 1730379 1730259	5595764 5595940 5594576 5591920 5593549 5594704	1228.3	1228.3	0.0
D (Wanganui)	1743100 1741661 1746335 1747791	5591028 5588776 5585725 5588006	1320.3	1320.2	0.0

3.3 Methodology: Eastern hill country

Review of methodology used in 1994 and 2000

The method used in this study was piloted by Stephens et al. (1995), comprehensively documented in O'Leary et al. (1996), and explained further in O'Leary and Stephens (1996). The physically sustainable land-use classes against which the 1994 and 2000 land uses were compared in Jessen et al. (2000) were established for Taranaki in a study by Blaschke et al. (1992a), and are listed in Table 4 below.

After consultation with the Council, Jessen et al. (2000) modified this method for the 2000 monitoring episode such that the 'Pasture with trees' (PT) sustainable land-use class was interpreted differently from that used in O'Leary et al. (1996). The 2000 study considered meat and wool farming on this sustainable land-use class to be physically sustainable (although improved land management, such as more planting of trees, would normally be needed), whereas the O'Leary et al. (1996) study considered this land use/sustainable land-use class association to be physically unsustainable. The revised interpretation by Jessen et al. (2000) was arrived at after considering advice in Hicks (1998), closer consideration of modern research findings (Blaschke et al. 1992b; Trustrum & Blaschke 1992; DeRose et al. 1993, 1995), and considering the Council's own view (post-1996) of the 'Pasture with trees' sustainable land-use class. Consequently, the O'Leary et al. (1996) sustainability-change data were re-calculated for the 2000 study, and the revised interpretation of the 'Pasture with trees' sustainable land-use class is also used in the present (2007) study.

The monitoring carried out in 1994 and 2000 used aerial photography that was processed by Landcare Research as follows:

- The photographs were scanned on a desktop scanner at a resolution of 400 dots per inch (dpi) for the 1994 photographs, and at 1200 dpi for the 2000 photographs

- The scanned images were rectified to NZMG using a second-order polynomial transformation. Orthorectification was not carried out in 1994 or 2000 because of the considerably higher cost and time required using the resources available at the time (relating particularly to limitations on computing power and software capability)

- The imagery was then resampled to a ground pixel size of three metres (for the 1994 photography) and one metre (for the 2000 photography)

- The resampled images were produced as hard copy base maps at a scale of 1:5750, and vegetation and land-use classes (see Table 5 below) were delineated manually on transparent overlays

- The vegetation and land-use classes were digitised from the transparent overlays using ARC/INFO GIS software to create ARC/INFO coverages of vegetation and land use for each site for 1994 and 2000. These digital coverages were then overlaid, changes between 1994 and 2000 calculated and the results tabulated

- To assess land-use sustainability, the land-use classes were compared against physically sustainable land-use classes (Table 4, held as a spatial coverage for Taranaki and established by Blaschke et al. 1992a, and as re-interpreted at 1:27 500 scale by O'Leary et al. 1996). Movements either toward or away from sustainability were measured/analysed and tabulated.

Table 4 Physically sustainable land-use classes for Taranaki (from Blaschke et al. 1992a)

Sustainable land-use class	Most intensive sustainable land use	Range of sustainable land uses						
IH	Intensive horticulture	Intensive horticulture	Cash cropping	Dairying	Drystock grazing	Pasture with trees	Forestry	Protection
CC	Cash cropping		Cash cropping	Dairying	Drystock grazing	Pasture with trees	Forestry	Protection
DY	Dairying			Dairying	Drystock grazing	Pasture with trees	Forestry	Protection
GR	Drystock grazing				Drystock grazing	Pasture with trees	Forestry	Protection
PT	Pasture with trees					Pasture with trees	Forestry	Protection
FO	Forestry						Forestry	Protection
PR	Protection							Protection

Note on the use of this table: Taranaki has been categorised (and mapped) into these sustainable land-use classes by Blaschke et al. 1992a). The land-use classes mapped in the present study (Table 10) have been compared with these sustainable land-use classes to determine if the mapped land uses are physically sustainable. Using GIS, years 2000 and 2007 land uses have been overlaid onto sustainable land-use classes, and the areas where the mapped land use corresponds (or not) to physical sustainability for that use have been recorded. An example of unsustainability is where the land-use 'meat and wool farming' is mapped on sustainable land-use class 'Forestry' (FO), because, from Table 5, the only physically sustainable land uses for this class are 'Forestry' and 'Protection'

Table 5 Vegetation and land-use classes mapped

Mapped vegetation class	Mapped land-use class	Link to sustainable land-use class (from Table 4)
Pasture	Horticulture/cash cropping (lumped together, as both are rare in the hill lands)	IH, CC
Crops	Dairying	DY
Plantation forest	Meat and wool farming (alternative names in earlier studies include drystock grazing and sheep and beef farming)	GR
Indigenous forest	Revegetated meat and wool (once farmed but now abandoned and scrub-covered)	FO
Indigenous scrub spp. >3 m (older scrub in earlier studies)	Plantation forestry	FO
Indigenous scrub spp. <3 m (inferred as young scrub)	Meat and wool farming with trees	PT
Weeds (rush, fern, gorse, etc.)	Indigenous forest (protection)	PR
River/other water body	Water	Not linked

Methodology used in the present study

The 1994, 2000 and 2007 studies were based on interpretations of aerial photography. The 2007 imagery was supplied in digital form by the Council, and additional steps were needed to arrive at valid and robust comparisons with the earlier imagery on account of the following:

- The 2007 imagery was orthorectified to remove relief displacement (related to topography) and other distortion effects;
- It was of higher resolution (0.75 metres/pixel) than imagery used in 1994 and 2000, enabling a higher-resolution interpretation of vegetation and land-use classes than was previously possible;
- It was projected onto NZTM, which supersedes the older NZMG onto which the 1994 and 2000 imagery had been projected.

Given that the use of orthorectified imagery has become the standard in recent years, as has the use of NZTM, the ARC/INFO coverages from 1994 and 2000 were converted from NZMG into NZTM.

Because the 1994 and 2000 imagery was not orthorectified, it contained slight distortions relating to topography and camera/lens geometry that were not removed when the images were rectified to NZMG. As a result the hill country monitoring site boundaries, while representing regular 900 hectare squares on the 1994 and 2000 imagery, did not in fact represent regular 900 hectare squares on the ground.

The ARC/INFO vegetation and land-use coverages generated from the 1994 and 2000 imagery therefore contained the same distortions as the imagery they were derived from, and also did not represent 900-hectare squares on the ground. When this issue became apparent, Landcare Research and the Council agreed the actual area on the ground should be reported on rather than the nominal 900 hectare area for each site. Although this approach means each site boundary has been distorted slightly, and will remain distorted, it does ensure each monitoring episode will continue to compare like with like because the same area on the ground is being reported on each time. The alternative approach, which would have been to re-establish the 900 hectare square boundary for each site, would have meant that areas lying outside the site boundaries in 1994 and 2000 might have been included in the present study and would have skewed the results.

Consequently, the hill country site boundaries were re-established on the 2007 imagery by visually transferring the four corner points for each site from the 2000 imagery onto the 2007 imagery and extracting the new NZTM coordinates of these corner points. The area of each site changed slightly as a result: changes ranged from –19.2% to +14.4%, with an average change of –2.3%. The total area surveyed in the 25 sites has been recalculated at 21 981 hectares, compared with the original 22 500 hectares. (Refer to Table 1 for full details).

To provide valid and robust comparisons of vegetation and land use from 1994 and 2000 to 2007, the ARC/INFO vegetation and land-use coverages for 1994 and 2000 were transformed to fit the re-established study area boundaries on the 2007 imagery. The 1994 and 2000 vegetation, land use and land-use sustainability data were then re-calculated.

It is noted that, because the same transformation was applied to both the 1994 and 2000 layers at each site, the percentage changes in vegetation, land-use and land-use sustainability reported in Jessen et al. (2000) are essentially unchanged as are the conclusions drawn in that report. The actual areas involved have changed slightly, however, and for consistency the revised 1994 and 2000 data are included in this report.

3.4 Methodology: Coastal sand country

The method originally established by Stephens and Dymond (1999), and modified by Jessen et al. (2000), was repeated. The only additional processing step required in this study was the conversion of the 1994 and 2000 imagery and site boundaries from NZMG to NZTM as described above.

This method generates low sampling (random) errors of between ±0.5 and ±1.0% (errors calculate differently for different sites), contributing to defensible comparative datasets produced from each monitoring episode. The low errors result from a high number of observation points (~ 4000) used at each site. More information about error estimates using this sampling strategy may be found in Dymond et al. (2001).

Stephens and Dymond (1999) provide full details of the original method used for assessing bare sand at each site. The method used in the present study is summarised below:

- The1994 and 2000 imagery was retrieved from archive, along with the “area of interest” (.aoi) files containing the sand site boundaries and the areas of sand within each boundary;

- The sand site boundaries and the coordinates of the .aoi files were converted from NZMG to NZTM and overlaid onto the 2007 imagery supplied by the Council;

- The size of the ‘area of interest’ (i.e. the sand country as delineated by Jessen et al. (2000)) within each monitoring site was recalculated to confirm the accuracy of the conversion to NZTM, and the required sample point spacing to achieve 4000 sample points within each area of interest was determined;

- Using ERDAS IMAGINE GIS software, a virtual grid was established for each sand area based on the sample point spacing calculated for each area of interest;

- The area of bare sand was determined for each area of interest in 2007 by examining the imagery under each of the 4000 virtual dot grid points for each site.

Table 6 Vegetation cover classes in 1994 and 2000 (revised), and 2007 (new data) for all hill country monitoring sites (hectares)

Site	Pasture			Crops			Plantation Forest			Indigenous Forest			Scrub >3 m			Scrub < 3 m			Weeds			Water			Total		
	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007
1	169.17	157.32	145.37	0.00	0.00	0.00	0.38	0.38	0.00	407.74	407.74	386.26	0.00	0.00	3.01	76.52	88.37	118.49	0.00	0.00	0.00	232.81	232.81	233.50	886.62	886.62	886.62
2	299.51	294.65	285.46	0.00	0.00	0.00	3.02	6.13	10.61	506.94	507.25	496.70	34.71	30.53	15.14	32.61	38.23	67.18	0.00	0.00	0.00	12.84	12.84	14.53	889.63	889.63	889.63
3	313.96	249.86	241.57	0.00	0.00	3.78	6.10	6.53	13.51	300.21	299.92	370.33	142.20	119.60	64.51	106.17	187.48	95.22	2.23	7.47	81.99	0.71	0.71	0.66	871.56	871.56	871.56
4	617.58	613.85	615.73	0.00	0.00	0.00	13.35	24.58	29.27	97.95	92.14	86.27	76.64	69.55	74.57	63.68	65.81	59.52	0.00	3.27	3.84	0.00	0.00	0.00	869.20	869.20	869.20
5	341.73	347.00	360.88	0.00	0.00	0.00	8.04	11.18	8.36	0.00	0.00	0.00	407.31	396.83	454.59	142.78	144.86	88.35	12.33	12.33	0.00	0.00	0.00	0.00	912.19	912.19	912.19
6	397.99	406.67	409.62	0.00	0.00	0.00	12.59	12.59	12.07	321.43	321.43	315.99	40.25	40.25	26.48	97.87	89.18	105.96	0.00	0.00	0.00	0.00	0.00	0.00	870.13	870.13	870.13
7	646.73	612.15	610.10	0.00	0.00	0.00	10.96	46.64	56.74	164.07	154.71	126.73	29.66	33.15	37.78	41.98	35.27	57.86	0.00	11.48	4.18	0.00	0.00	0.00	893.40	893.40	893.40
8	218.53	137.43	115.34	0.00	0.00	0.00	1.67	78.68	66.45	499.55	497.56	494.51	60.18	35.02	75.38	90.78	122.78	112.52	6.37	5.60	12.56	0.34	0.34	0.65	877.41	877.41	877.41
9	635.04	588.61	584.29	0.00	0.00	0.00	51.82	108.51	118.67	22.92	22.92	21.82	50.73	49.14	51.52	118.02	101.45	102.18	0.00	7.91	0.00	1.37	1.37	1.42	879.90	879.90	879.90
10	289.03	267.50	221.72	0.00	0.00	0.00	8.14	20.99	34.40	275.68	275.60	279.32	52.56	50.85	46.23	272.95	281.32	312.96	0.00	2.08	3.22	4.57	4.57	5.06	902.91	902.91	902.91
11	262.72	262.23	217.18	0.00	0.00	0.00	282.31	312.28	308.64	15.64	15.64	14.09	126.20	125.84	106.00	164.07	134.95	206.55	1.79	1.79	0.00	0.15	0.15	0.42	852.88	852.88	852.88
12	847.56	850.78	824.39	0.00	0.00	8.60	3.91	3.91	1.83	2.18	2.18	0.00	1.79	1.79	4.60	10.76	7.55	30.21	0.00	0.00	0.00	9.69	9.69	6.27	875.90	875.90	875.90
13	694.42	664.93	669.73	0.00	0.00	0.00	3.46	32.37	24.34	5.32	5.32	1.02	56.08	56.08	42.80	60.84	61.41	83.09	0.00	0.00	0.00	9.52	9.52	8.65	829.63	829.63	829.63
14	689.42	697.31	716.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.12	5.12	6.44	160.76	146.34	132.82	0.00	6.53	0.00	0.00	0.00	0.00	855.30	855.30	855.30
15	55.05	58.63	58.86	0.00	0.00	0.00	0.00	0.00	0.00	135.95	135.17	126.45	178.91	175.56	324.90	357.13	357.67	216.81	0.00	0.00	0.00	0.00	0.00	0.00	727.03	727.03	727.03
16	862.06	862.06	869.69	0.00	0.00	0.00	1.61	1.61	1.42	0.52	0.52	0.33	4.64	4.64	16.03	31.17	31.17	12.15	0.00	0.00	0.37	0.00	0.00	0.00	899.99	899.99	899.99
17	137.77	149.17	130.37	0.00	0.00	0.00	0.00	0.00	0.00	58.21	58.21	48.02	61.59	61.42	81.48	491.70	481.43	485.96	0.00	0.56	0.00	94.54	93.03	97.97	843.81	843.81	843.81
18	241.66	241.66	232.75	0.00	0.00	0.00	0.00	0.00	0.00	322.64	322.64	299.71	233.83	233.83	261.33	105.52	105.52	110.17	0.00	0.00	0.00	1.18	1.18	0.87	904.83	904.83	904.83
19	754.18	716.85	682.11	0.00	0.00	0.00	0.77	38.99	44.54	0.00	0.00	0.00	34.04	34.71	15.67	114.20	112.64	160.39	0.00	0.00	0.00	1.74	1.74	2.22	904.93	904.93	904.93
20	609.12	591.04	539.11	0.00	0.00	13.17	12.63	33.37	74.01	0.00	0.00	0.00	28.60	19.60	23.15	265.28	264.61	258.16	0.00	6.99	7.87	3.37	3.37	3.53	918.99	918.99	918.99
21	266.55	282.21	262.92	0.00	0.00	0.00	48.42	55.36	101.34	0.00	0.00	0.00	423.00	420.49	417.17	291.86	255.20	242.02	0.00	16.56	6.38	0.00	0.00	0.00	1029.82	1029.82	1029.82
22	336.42	338.64	373.00	0.00	0.00	0.00	16.33	19.25	39.80	0.00	0.00	0.00	131.41	131.10	139.86	353.42	352.90	295.77	14.33	10.03	3.49	0.00	0.00	0.00	851.92	851.92	851.92
23	458.75	505.27	500.95	0.00	0.00	0.00	9.07	21.37	26.59	154.78	154.35	140.36	5.86	7.28	18.95	221.98	155.27	164.49	0.00	6.90	0.00	13.64	13.64	12.74	864.08	864.08	864.08
24	499.67	455.97	442.08	0.00	0.00	0.00	31.68	50.83	57.98	0.00	0.57	0.00	65.65	65.86	32.97	344.90	259.16	325.14	0.00	109.51	83.58	0.00	0.00	0.14	941.90	941.90	941.90
25	127.27	101.43	70.23	0.00	0.00	0.00	2.07	2.38	4.22	87.97	87.29	86.59	40.83	36.60	49.40	568.57	568.96	568.66	0.00	25.77	47.60	0.00	4.27	0.00	826.70	826.70	826.70
Total	**10771.88**	**10453.25**	**10179.50**	**0.00**	**0.00**	**25.55**	**528.33**	**887.92**	**1034.78**	**3379.68**	**3361.14**	**3294.50**	**2291.78**	**2204.83**	**2389.98**	**4585.53**	**4449.54**	**4412.65**	**37.04**	**234.79**	**255.09**	**386.44**	**389.20**	**388.64**	**21980.67**	**21980.67**	**21980.67**
%	**49.01**	**47.56**	**46.31**	**0.00**	**0.00**	**0.12**	**2.40**	**4.04**	**4.71**	**15.38**	**15.29**	**14.99**	**10.43**	**10.03**	**10.87**	**20.86**	**20.24**	**20.08**	**0.17**	**1.07**	**1.16**	**1.76**	**1.77**	**1.77**	**100.00**	**100.00**	**100.00**

Table 7 Vegetation change summary, 1994–2000 (revised), in hectares

Vegetation cover changes, 1994-2000		Pasture	Cropping	Plantation forest	Indigenous forest	Tall scrub (>3m)	Short scrub (<3m)	Weeds	Water	Total ha (2000)	Total % (2000)
		1994	1994	1994	1994	1994	1994	1994	1994		
Pasture	**2000**	**10123.59**	0.00	3.34	1.91	14.65	303.11	6.64	0.00	**10453.25**	**47.56**
Cropping	**2000**	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.00**
Plantation forest	**2000**	284.02	0.00	**518.31**	0.31	0.32	84.20	0.76	0.00	**887.92**	**4.04**
Indigenous forest	**2000**	0.81	0.00	0.00	**3358.63**	0.53	1.17	0.00	0.00	**3361.14**	**15.29**
Tall scrub (>3 m)	**2000**	5.81	0.00	0.00	7.66	**2182.04**	9.32	0.00	0.00	**2204.83**	**10.03**
Short scrub (<3 m)	**2000**	215.19	0.00	1.81	11.16	94.24	**4124.30**	1.32	1.53	**4449.54**	**20.24**
Weeds	**2000**	142.45	0.00	4.88	0.00	0.00	58.78	**28.32**	0.36	**234.79**	**1.07**
Water	**2000**	0.00	0.00	0.00	0.00	0.00	4.65	0.00	**384.55**	**389.20**	**1.77**
Total ha (1994)		**10771.88**	**0.00**	**528.33**	**3379.68**	**2291.78**	**4585.53**	**37.04**	**386.44**	**21980.67**	**100.00**
Total % (1994)		**49.01**	**0.00**	**2.40**	**15.38**	**10.43**	**20.86**	**0.17**	**1.76**	**100.00**	

Reading rules for this Table (also used for Tables 8, 9, 11, 12 and 13):

* Bold numbers represent the area of the vegetation class common to both monitoring years (1994 and 2000). Other numbers either in the row or column where the bold number appears, represent the ha value of the vegetation class change

* Examples to work out what went to what and by how much:

1) Reading down the column headed Pasture on the LHS of the table. The bold number of 10 123.59 is the area (ha) of pasture common to both monitoring years (1994 and 2000). Reading further down this column, the number 284.02 indicates that 284.02 ha of the pasture mapped in 1994 has gone to plantation forest, 215.19 ha to short scrub <3 m, and so on. The bottom two cells of the column give area totals (ha, %) mapped as pasture in 1994.

2) Reading across the table along the row headed Plantation forest. The bold number of 518.31 is the area (ha) of plantation forest common to both monitoring years (1994 and 2000). The first number (284.02) of this row indicates that 284.02 ha of the plantation forest mapped in the year 2000 came from pasture and, reading further along the row, 84.20 ha of short scrub <3 m converted to plantation forest, and so on. The final two cells of the row give area totals (ha, %) mapped in 2000.

3) Using the totals. For example, the third entry down the totals (ha) column shows that 887.92 ha (4.04% of the total monitoring area) were under plantation forest in 2000, and the third entry along the totals row shows that in 1994 the area of plantation forest covered 528.33 ha (2.4%).

Table 8 Vegetation change summary, 2000–2007 (hectares)

Vegetation cover changes, 2000-2007		Pasture	Cropping	Plantation forest	Indigenous forest	Tall scrub (>3m)	Short scrub (<3m)	Weeds	Water	Total ha (2007)	Total % (2007)
		2000	2000	2000	2000	2000	2000	2000	2000		
Pasture	**2007**	**9201.89**	0.00	70.23	68.76	138.58	593.98	72.77	33.29	**10179.50**	**46.31**
Cropping	**2007**	24.60	**0.00**	0.00	0.00	0.09	0.87	0.00	0.00	**25.55**	**0.12**
Plantation forest	**2007**	189.96	0.00	**674.64**	7.01	38.01	109.56	15.43	0.17	**1034.78**	**4.71**
Indigenous forest	**2007**	53.11	0.00	12.44	**3034.32**	114.86	75.41	1.10	3.26	**3294.50**	**14.99**
Tall scrub (>3 m)	**2007**	122.02	0.00	19.61	122.77	**1572.19**	547.87	0.73	4.78	**2389.98**	**10.87**
Short scrub (<3 m)	**2007**	769.90	0.00	108.10	124.02	328.41	**2980.46**	88.16	13.59	**4412.65**	**20.08**
Weeds	**2007**	59.12	0.00	2.70	2.43	9.76	126.15	**54.79**	0.14	**255.09**	**1.16**
Water	**2007**	32.66	0.00	0.19	1.84	2.94	15.24	1.80	**333.98**	**388.64**	**1.77**
Total ha (2000)		**10453.25**	**0.00**	**887.92**	**3361.14**	**2204.83**	**4449.54**	**234.79**	**389.20**	**21980.67**	**100.00**
Total % (2000)		**47.56**	**0.00**	**4.04**	**15.29**	**10.03**	**20.24**	**1.07**	**1.77**	**100.00**	

To read this table easily, refer to the notes under Table 7.

Table 9 Vegetation change summary, 1994–2007 (hectares)

Vegetation cover changes, 1994-2007		Pasture	Cropping	Plantation forest	Indigenous forest	Tall scrub (>3m)	Short scrub (<3m)	Weeds	Water	Total ha (2007)	Total % (2007)
		1994	1994	1994	1994	1994	1994	1994	1994		
Pasture	**2007**	**9094.58**	0.00	49.87	76.34	155.95	747.10	23.97	31.69	**10179.50**	**46.31**
Cropping	**2007**	25.41	**0.00**	0.00	0.00	0.09	0.05	0.00	0.00	**25.55**	**0.12**
Plantation forest	**2007**	410.55	0.00	**383.00**	7.53	39.76	189.86	3.93	0.14	**1034.78**	**4.71**
Indigenous forest	**2007**	76.74	0.00	2.23	**3038.09**	116.26	57.57	0.36	3.26	**3294.50**	**14.99**
Tall scrub (>3 m)	**2007**	127.85	0.00	12.51	128.25	**1594.92**	520.38	1.68	4.39	**2389.98**	**10.87**
Short scrub (<3 m)	**2007**	901.34	0.00	77.98	125.43	373.50	**2917.22**	5.39	11.79	**4412.65**	**20.08**
Weeds	**2007**	101.87	0.00	2.68	2.21	8.04	138.57	**1.71**	0.00	**255.09**	**1.16**
Water	**2007**	33.52	0.00	0.06	1.84	3.26	14.77	0.00	**335.18**	**388.64**	**1.77**
Total ha (1994)		**10771.88**	**0.00**	**528.33**	**3379.68**	**2291.78**	**4585.53**	**37.04**	**386.44**	**21980.67**	**100.00**
Total % (1994)		**49.01**	**0.00**	**2.40**	**15.38**	**10.43**	**20.86**	**0.17**	**1.76**	**100.00**	

To read this table easily, refer to the notes under Table 7.

Table 10 Land-use classes in 1994 and 2000 (revised), and 2007 (new data) for all hill country monitoring sites (hectares)

Site	Horticulture/cash cropping			Dairying			Meat & wool farming			Revegetated meat and wool farming			Plantation Forestry			Meat & wool farming with trees			Indigenous Forest			Water			Total		
	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007
1	0.00	0.00	0.00	0.00	0.00	0.00	169.16	156.94	150.00	76.53	88.75	118.38	0.38	0.38	0.00	0.00	0.00	0.00	407.74	407.74	384.78	232.82	232.82	233.47	886.62	886.62	886.62
2	0.00	0.00	0.00	0.00	0.00	0.00	319.03	315.92	286.86	48.56	48.56	81.29	3.02	6.13	10.61	0.00	0.00	0.00	506.18	506.18	496.34	12.84	12.84	14.53	889.63	889.63	889.63
3	0.00	0.00	8.43	0.00	0.00	91.47	407.60	299.75	189.10	160.88	268.51	207.92	6.19	6.62	5.72	0.00	0.00	0.00	296.08	295.86	368.27	0.83	0.83	0.66	871.56	871.56	871.56
4	0.00	0.00	0.00	0.00	0.00	0.00	678.20	665.24	623.27	81.08	86.21	130.37	12.38	23.75	28.43	0.98	0.98	0.84	96.57	93.02	86.28	0.00	0.00	0.00	869.20	869.20	869.20
5	0.00	0.00	0.00	0.00	0.00	0.00	389.90	393.35	366.22	514.25	511.45	536.92	4.48	3.83	5.08	3.56	3.56	3.97	0.00	0.00	0.00	0.00	0.00	0.00	912.19	912.19	912.19
6	0.00	0.00	0.00	0.00	0.00	0.00	502.08	502.08	418.36	34.03	34.03	123.70	9.08	9.08	12.07	3.51	3.51	0.00	321.43	321.43	316.00	0.00	0.00	0.00	870.13	870.13	870.13
7	0.00	0.00	0.00	0.00	0.00	0.00	693.78	656.70	621.36	44.40	45.24	99.44	9.53	45.77	58.33	1.43	1.43	0.00	144.26	144.26	114.27	0.00	0.00	0.00	893.40	893.40	893.40
8	0.00	0.00	0.00	0.00	0.00	0.00	305.07	171.04	134.02	70.79	119.45	181.79	1.67	89.03	80.14	0.00	0.00	0.00	499.54	497.56	480.83	0.34	0.34	0.65	877.41	877.41	877.41
9	0.00	0.00	0.00	0.00	0.00	0.00	735.90	682.84	591.85	66.13	66.13	146.14	52.18	105.24	118.67	3.84	3.84	0.00	20.48	20.48	21.82	1.37	1.37	1.42	879.90	879.90	879.90
10	0.00	5.81	0.00	0.00	0.00	0.00	320.96	286.38	243.82	293.58	309.58	340.64	8.14	20.99	34.40	0.00	0.00	0.00	275.68	275.60	279.00	4.56	4.56	5.06	902.91	902.91	902.91
11	0.00	0.00	0.00	0.00	0.00	0.00	273.82	272.97	227.12	245.22	245.22	307.71	318.06	318.91	303.54	0.00	0.00	0.00	15.64	15.64	14.09	0.15	0.15	0.42	852.88	852.88	852.88
12	0.00	0.00	8.60	0.00	0.00	0.00	860.68	860.68	835.79	1.62	1.62	23.40	3.91	3.91	1.83	0.00	0.00	0.00	0.00	0.00	0.00	9.68	9.68	6.27	875.90	875.90	875.90
13	0.00	0.00	0.00	0.00	0.00	0.00	774.54	745.63	688.83	42.12	42.12	107.81	3.46	32.37	24.34	0.00	0.00	0.00	0.00	0.00	0.00	9.51	9.51	8.65	829.63	829.63	829.63
14	0.00	0.00	0.00	0.00	0.00	0.00	855.30	855.30	721.66	0.00	0.00	133.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	855.30	855.30	855.30
15	0.00	0.00	0.00	0.00	0.00	0.00	55.05	58.63	58.86	536.04	533.23	541.72	0.00	0.00	0.00	0.00	0.00	0.00	135.95	135.17	126.45	0.00	0.00	0.00	727.03	727.03	727.03
16	0.00	0.00	0.00	0.00	0.00	0.00	879.69	879.69	870.06	18.17	18.17	28.18	1.61	1.61	1.42	0.00	0.00	0.00	0.52	0.52	0.33	0.00	0.00	0.00	899.99	899.99	899.99
17	0.00	0.00	0.00	0.00	0.00	0.00	275.12	206.15	133.45	415.95	484.93	564.36	0.00	0.00	0.00	0.00	0.00	0.00	58.21	58.21	48.02	94.53	94.53	97.97	843.81	843.81	843.81
18	0.00	0.00	0.00	0.00	0.00	0.00	243.50	243.50	232.75	337.51	337.51	371.50	0.00	0.00	0.00	0.00	0.00	0.00	322.64	322.64	299.71	1.18	1.18	0.87	904.83	904.83	904.83
19	0.00	0.00	0.00	0.00	0.00	0.00	857.06	818.74	676.29	45.36	45.47	182.61	0.77	38.98	44.54	0.00	0.00	0.00	0.00	0.00	0.00	1.74	1.74	1.49	904.93	904.93	904.93
20	0.00	0.00	13.17	435.43	432.43	405.16	223.32	210.78	138.53	244.26	244.72	284.60	12.61	27.69	74.01	0.00	0.00	0.00	0.00	0.00	0.00	3.37	3.37	3.53	918.99	918.99	918.99
21	0.00	0.00	0.00	42.55	42.21	0.00	265.77	262.53	262.93	673.08	669.72	665.55	48.42	55.36	101.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1029.82	1029.82	1029.82
22	0.00	1.69	0.00	0.00	0.00	0.00	363.82	351.57	376.97	471.78	479.43	438.54	16.32	19.24	36.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	851.92	851.92	851.92
23	0.00	0.00	0.00	0.00	0.00	0.00	618.50	582.15	538.93	68.08	92.14	145.46	4.94	17.24	26.59	4.13	4.13	0.00	154.78	154.78	140.36	13.64	13.64	12.74	864.08	864.08	864.08
24	0.00	0.00	0.00	61.75	61.75	68.27	505.19	483.08	415.41	343.28	346.24	396.84	31.68	50.83	61.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	941.90	941.90	941.90
25	0.00	0.00	0.00	0.00	0.00	0.00	276.31	261.55	114.67	460.36	475.11	621.23	2.07	2.07	4.22	0.00	0.00	0.00	87.97	87.97	86.59	0.00	0.00	0.00	826.70	826.70	826.70
Total	0.00	7.50	30.20	539.73	536.40	564.89	11849.36	11223.19	9917.10	5293.05	5593.53	6779.74	550.88	879.00	1032.93	17.45	17.45	4.80	3343.66	3337.05	3263.12	386.55	386.55	387.88	21980.67	21980.67	21980.67
%	0.00	0.03	0.14	2.46	2.44	2.57	53.91	51.06	45.12	24.08	25.45	30.84	2.51	4.00	4.70	0.08	0.08	0.02	15.21	15.18	14.85	1.76	1.76	1.76	100.00	100.00	100.00

Table 11 Land-use change summary, 1994–2000 (revised), in hectares

Land-use changes, 1994-2000		Horticulture/cash cropping	Dairying	Meat & wool farming	Revegetated meat and wool farming	Plantation Forestry	Meat & wool farming with trees	Indigenous Forest	Water	Total ha (2000)	Total % (2000)
		1994	1994	1994	1994	1994	1994	1994	1994		
Hort/cash cropping	**2000**	**0.00**	0.00	7.50	0.00	0.00	0.00	0.00	0.00	**7.50**	**0.03**
Dairying	**2000**	0.00	**536.01**	0.27	0.11	0.00	0.00	0.00	0.00	**536.40**	**2.44**
Meat & wool	**2000**	0.00	0.00	**11200.18**	19.10	2.93	0.00	0.98	0.00	**11223.19**	**51.06**
Rev. meat and wool	**2000**	0.00	0.00	333.90	**5247.49**	6.69	0.00	5.45	0.00	**5593.53**	**25.45**
Plantation Forestry	**2000**	0.00	3.71	307.36	26.34	**541.27**	0.00	0.31	0.00	**879.00**	**4.00**
M & W with trees	**2000**	0.00	0.00	0.00	0.00	0.00	**17.45**	0.00	0.00	**17.45**	**0.08**
Indigenous Forest	**2000**	0.00	0.00	0.14	0.00	0.00	0.00	**3336.91**	0.00	**3337.05**	**15.18**
Water	**2000**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**386.55**	**386.55**	**1.76**
Total ha (1994)		**0.00**	**539.73**	**11849.36**	**5293.05**	**550.88**	**17.45**	**3343.66**	**386.55**	**21980.67**	**100.00**
Total % (1994)		**0.00**	**2.46**	**53.91**	**24.08**	**2.51**	**0.08**	**15.21**	**1.76**	**100.00**	

To read this table easily, refer to the notes under Table 7.

Table 12 Land-use change summary, 2000–2007 (hectares)

Land-use changes, 2000-2007		Horticulture/cash cropping	Dairying	Meat & wool farming	Revegetated meat and wool farming	Plantation Forestry	Meat & wool farming with trees	Indigenous Forest	Water	Total ha (2007)	Total % (2007)
		2000	2000	2000	2000	2000	2000	2000	2000		
Hort/cash cropping	**2007**	**0.00**	13.01	15.68	0.05	1.45	0.00	0.00	0.00	**30.20**	**0.14**
Dairying	**2007**	0.00	**421.99**	129.71	5.98	7.21	0.00	0.00	0.00	**564.89**	**2.57**
Meat & wool	**2007**	6.33	66.17	**9242.31**	438.55	65.83	3.51	62.81	31.59	**9917.10**	**45.12**
Rev. meat and wool	**2007**	1.16	15.83	1540.77	**4852.86**	107.35	0.21	245.19	16.37	**6779.74**	**30.84**
Plantation Forestry	**2007**	0.00	19.40	183.74	119.75	**693.03**	9.83	7.03	0.14	**1032.93**	**4.70**
M & W with trees	**2007**	0.00	0.00	0.90	0.00	0.00	**3.90**	0.00	0.00	**4.80**	**0.02**
Indigenous Forest	**2007**	0.00	0.00	71.79	163.66	3.93	0.00	**3020.46**	3.28	**3263.12**	**14.85**
Water	**2007**	0.00	0.00	38.28	12.67	0.19	0.00	1.56	**335.17**	**387.88**	**1.76**
Total ha (2000)		**7.50**	**536.40**	**11223.19**	**5593.53**	**879.00**	**17.45**	**3337.05**	**386.55**	**21980.67**	**100.00**
Total % (2000)		**0.03**	**2.44**	**51.06**	**25.45**	**4.00**	**0.08**	**15.18**	**1.76**	**100.00**	

To read this table easily, refer to the notes under Table 7.

Table 13 Land-use change summary, 1994–2007 (hectares)

Land-use changes, 1994-2007		Horticulture/cash cropping	Dairying	Meat & wool farming	Revegetated meat and wool farming	Plantation Forestry	Meat & wool farming with trees	Indigenous Forest	Water	Total ha (2007)	Total % (2007)
		1994	1994	1994	1994	1994	1994	1994	1994		
Hort/cash cropping	**2007**	**0.00**	13.01	15.83	0.05	1.31	0.00	0.00	0.00	**30.20**	**0.14**
Dairying	**2007**	0.00	**422.31**	130.46	7.14	4.98	0.00	0.00	0.00	**564.89**	**2.57**
Meat & wool	**2007**	0.00	66.48	**9322.61**	381.82	47.10	3.51	63.99	31.59	**9917.10**	**45.12**
Rev. meat and wool	**2007**	0.00	15.76	1795.70	**4627.72**	76.57	0.21	247.42	16.37	**6779.74**	**30.84**
Plantation Forestry	**2007**	0.00	22.17	453.09	121.71	**418.64**	9.83	7.35	0.14	**1032.93**	**4.70**
M & W with trees	**2007**	0.00	0.00	0.90	0.00	0.00	**3.90**	0.00	0.00	**4.80**	**0.02**
Indigenous Forest	**2007**	0.00	0.00	90.11	144.18	2.21	0.00	**3023.34**	3.28	**3263.12**	**14.85**
Water	**2007**	0.00	0.00	40.65	10.43	0.07	0.00	1.56	**335.17**	**387.88**	**1.76**
Total ha (1994)		**0.00**	**539.73**	**11849.36**	**5293.05**	**550.88**	**17.45**	**3343.66**	**386.55**	**21980.67**	**100.00**
Total % (1994)		**0.00**	**2.46**	**53.91**	**24.08**	**2.51**	**0.08**	**15.21**	**1.76**	**100.00**	

To read this table easily, refer to the notes under Table 7.

Table 14 Physical sustainability of land-use at all hill country monitoring sites (hectares): 1994 (revised)

Site	Horticulture/cash cropping			Dairying			Meat & wool farming			Revegetated meat and wool farming			Plantation Forestry			Meat & wool farming with trees			Indigenous Forest			Water			Total		
	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.
1	0.00	0.00	0.00	0.00	0.00	0.00	169.16	136.52	32.64	76.53	76.53	0.00	0.38	0.38	0.00	0.00	0.00	0.00	407.74	407.74	0.00	232.82	232.82	0.00	**886.62**	**853.98**	**32.64**
2	0.00	0.00	0.00	0.00	0.00	0.00	319.03	302.16	16.87	48.56	48.56	0.00	3.02	3.02	0.00	0.00	0.00	0.00	506.18	506.18	0.00	12.84	12.84	0.00	**889.63**	**872.76**	**16.87**
3	0.00	0.00	0.00	0.00	0.00	0.00	407.60	355.45	52.15	160.88	160.88	0.00	6.19	6.19	0.00	0.00	0.00	0.00	296.08	296.08	0.00	0.83	0.83	0.00	**871.56**	**819.41**	**52.15**
4	0.00	0.00	0.00	0.00	0.00	0.00	678.20	610.85	67.34	81.08	81.08	0.00	12.38	12.38	0.00	0.98	0.04	0.94	96.57	96.57	0.00	0.00	0.00	0.00	**869.20**	**800.92**	**68.28**
5	0.00	0.00	0.00	0.00	0.00	0.00	389.90	329.55	60.35	514.25	514.25	0.00	4.48	4.45	0.03	3.56	0.86	2.70	0.00	0.00	0.00	0.00	0.00	0.00	**912.19**	**849.11**	**63.07**
6	0.00	0.00	0.00	0.00	0.00	0.00	502.08	261.38	240.71	34.03	34.03	0.00	9.08	9.08	0.00	3.51	1.08	2.42	321.43	321.43	0.00	0.00	0.00	0.00	**870.13**	**627.00**	**243.13**
7	0.00	0.00	0.00	0.00	0.00	0.00	693.78	665.95	27.83	44.40	44.40	0.00	9.53	9.53	0.00	1.43	1.43	0.00	144.26	144.26	0.00	0.00	0.00	0.00	**893.40**	**865.57**	**27.83**
8	0.00	0.00	0.00	0.00	0.00	0.00	305.07	272.12	32.95	70.79	70.79	0.00	1.67	1.67	0.00	0.00	0.00	0.00	499.54	499.54	0.00	0.34	0.34	0.00	**877.41**	**844.46**	**32.95**
9	0.00	0.00	0.00	0.00	0.00	0.00	735.90	633.33	102.57	66.13	66.13	0.00	52.18	52.18	0.00	3.84	3.84	0.00	20.48	20.48	0.00	1.37	1.37	0.00	**879.90**	**777.33**	**102.57**
10	0.00	0.00	0.00	0.00	0.00	0.00	320.96	201.00	119.96	293.58	293.58	0.00	8.14	8.14	0.00	0.00	0.00	0.00	275.68	275.68	0.00	4.56	4.56	0.00	**902.91**	**782.95**	**119.96**
11	0.00	0.00	0.00	0.00	0.00	0.00	273.82	258.75	15.08	245.22	245.22	0.00	318.06	316.53	1.53	0.00	0.00	0.00	15.64	15.64	0.00	0.15	0.15	0.00	**852.88**	**836.28**	**16.61**
12	0.00	0.00	0.00	0.00	0.00	0.00	860.68	793.50	67.18	1.62	1.62	0.00	3.91	3.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.68	9.68	0.00	**875.90**	**808.72**	**67.18**
13	0.00	0.00	0.00	0.00	0.00	0.00	774.54	612.37	162.17	42.12	42.12	0.00	3.46	3.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.51	9.51	0.00	**829.63**	**667.46**	**162.17**
14	0.00	0.00	0.00	0.00	0.00	0.00	855.30	501.04	354.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**855.30**	**501.04**	**354.26**
15	0.00	0.00	0.00	0.00	0.00	0.00	55.05	54.70	0.35	536.04	536.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	135.95	135.95	0.00	0.00	0.00	0.00	**727.03**	**726.68**	**0.35**
16	0.00	0.00	0.00	0.00	0.00	0.00	879.69	603.28	276.41	18.17	18.17	0.00	1.61	1.61	0.00	0.00	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.00	**899.99**	**623.59**	**276.41**
17	0.00	0.00	0.00	0.00	0.00	0.00	275.12	126.83	148.29	415.95	415.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.21	58.21	0.00	94.53	94.53	0.00	**843.81**	**695.51**	**148.29**
18	0.00	0.00	0.00	0.00	0.00	0.00	243.50	32.19	211.31	337.51	337.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	322.64	322.64	0.00	1.18	1.18	0.00	**904.83**	**693.52**	**211.31**
19	0.00	0.00	0.00	0.00	0.00	0.00	857.06	430.63	426.44	45.36	45.36	0.00	0.77	0.04	0.73	0.00	0.00	0.00	0.00	0.00	0.00	1.74	1.74	0.00	**904.93**	**477.77**	**427.17**
20	0.00	0.00	0.00	435.43	402.86	32.57	223.32	171.30	52.03	244.26	244.26	0.00	12.61	12.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37	3.37	0.00	**918.99**	**834.39**	**84.60**
21	0.00	0.00	0.00	42.55	37.92	4.63	265.77	135.90	129.87	673.08	673.08	0.00	48.42	42.26	6.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1029.82**	**889.16**	**140.66**
22	0.00	0.00	0.00	0.00	0.00	0.00	363.82	175.44	188.38	471.78	471.78	0.00	16.32	16.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**851.92**	**663.54**	**188.38**
23	0.00	0.00	0.00	0.00	0.00	0.00	618.50	238.17	380.34	68.08	68.08	0.00	4.94	4.94	0.00	4.13	0.23	3.90	154.78	154.78	0.00	13.64	13.64	0.00	**864.08**	**479.84**	**384.24**
24	0.00	0.00	0.00	61.75	61.18	0.58	505.19	365.23	139.96	343.28	343.28	0.00	31.68	29.91	1.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**941.90**	**799.59**	**142.31**
25	0.00	0.00	0.00	0.00	0.00	0.00	276.31	110.17	166.13	460.36	460.36	0.00	2.07	2.07	0.00	0.00	0.00	0.00	87.97	87.97	0.00	0.00	0.00	0.00	**826.70**	**660.57**	**166.13**
Total	**0.00**	**0.00**	**0.00**	**539.73**	**501.95**	**37.78**	**11849.35**	**8377.80**	**3471.55**	**5293.05**	**5293.05**	**0.00**	**550.88**	**540.67**	**10.22**	**17.45**	**7.50**	**9.95**	**3343.66**	**3343.66**	**0.00**	**386.55**	**386.55**	**0.00**	**21980.67**	**18451.17**	**3529.49**
%	**0.00**	**0.00**	**0.00**	**2.46**	**2.28**	**0.17**	**53.91**	**38.11**	**15.79**	**24.08**	**24.08**	**0.00**	**2.51**	**2.46**	**0.05**	**0.08**	**0.03**	**0.05**	**15.21**	**15.21**	**0.00**	**1.76**	**1.76**	**0.00**	**100.00**	**83.94**	**16.06**

Table 15 Physical sustainability of land-use at all hill country monitoring sites (hectares): 2000 (revised)

Site	Horticulture/cash cropping			Dairying			Meat & wool farming			Revegetated meat and wool farming			Plantation Forestry			Meat & wool farming with trees			Indigenous Forest			Water			Total		
	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.
1	0.00	0.00	0.00	0.00	0.00	0.00	156.94	128.93	28.01	88.75	88.75	0.00	0.38	0.38	0.00	0.00	0.00	0.00	407.74	407.74	0.00	232.82	232.82	0.00	**886.62**	**858.61**	**28.01**
2	0.00	0.00	0.00	0.00	0.00	0.00	315.92	299.05	16.87	48.56	48.56	0.00	6.13	6.13	0.00	0.00	0.00	0.00	506.18	506.18	0.00	12.84	12.84	0.00	**889.63**	**872.76**	**16.87**
3	0.00	0.00	0.00	0.00	0.00	0.00	299.75	294.27	5.48	268.51	268.51	0.00	6.62	6.62	0.00	0.00	0.00	0.00	295.86	295.86	0.00	0.83	0.83	0.00	**871.56**	**866.08**	**5.48**
4	0.00	0.00	0.00	0.00	0.00	0.00	665.24	599.81	65.43	86.21	86.21	0.00	23.75	23.75	0.00	0.98	0.04	0.94	93.02	93.02	0.00	0.00	0.00	0.00	**869.20**	**802.84**	**66.36**
5	0.00	0.00	0.00	0.00	0.00	0.00	393.35	330.74	62.61	511.45	511.45	0.00	3.83	3.75	0.08	3.56	0.86	2.70	0.00	0.00	0.00	0.00	0.00	0.00	**912.19**	**846.80**	**65.38**
6	0.00	0.00	0.00	0.00	0.00	0.00	502.08	261.38	240.71	34.03	34.03	0.00	9.08	9.08	0.00	3.51	1.08	2.42	321.43	321.43	0.00	0.00	0.00	0.00	**870.13**	**627.00**	**243.13**
7	0.00	0.00	0.00	0.00	0.00	0.00	656.70	631.88	24.82	45.24	45.24	0.00	45.77	45.77	0.00	1.43	1.43	0.00	144.26	144.26	0.00	0.00	0.00	0.00	**893.40**	**868.58**	**24.82**
8	0.00	0.00	0.00	0.00	0.00	0.00	171.04	160.59	10.45	119.45	119.45	0.00	89.03	89.03	0.00	0.00	0.00	0.00	497.56	497.56	0.00	0.34	0.34	0.00	**877.41**	**866.96**	**10.45**
9	0.00	0.00	0.00	0.00	0.00	0.00	682.84	589.57	93.27	66.13	66.13	0.00	105.24	105.24	0.00	3.84	3.84	0.00	20.48	20.48	0.00	1.37	1.37	0.00	**879.90**	**786.64**	**93.27**
10	5.81	0.00	5.81	0.00	0.00	0.00	286.38	182.27	104.12	309.58	309.58	0.00	20.99	20.99	0.00	0.00	0.00	0.00	275.60	275.60	0.00	4.56	4.56	0.00	**902.91**	**792.99**	**109.92**
11	0.00	0.00	0.00	0.00	0.00	0.00	272.97	257.90	15.08	245.22	245.22	0.00	318.91	317.38	1.53	0.00	0.00	0.00	15.64	15.64	0.00	0.15	0.15	0.00	**852.88**	**836.28**	**16.61**
12	0.00	0.00	0.00	0.00	0.00	0.00	860.68	793.50	67.18	1.62	1.62	0.00	3.91	3.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.68	9.68	0.00	**875.90**	**808.72**	**67.18**
13	0.00	0.00	0.00	0.00	0.00	0.00	745.63	592.08	153.55	42.12	42.12	0.00	32.37	31.83	0.54	0.00	0.00	0.00	0.00	0.00	0.00	9.51	9.51	0.00	**829.63**	**675.54**	**154.09**
14	0.00	0.00	0.00	0.00	0.00	0.00	855.30	501.04	354.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**855.30**	**501.04**	**354.26**
15	0.00	0.00	0.00	0.00	0.00	0.00	58.63	58.28	0.35	533.23	533.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	135.17	135.17	0.00	0.00	0.00	0.00	**727.03**	**726.68**	**0.35**
16	0.00	0.00	0.00	0.00	0.00	0.00	879.69	603.28	276.41	18.17	18.17	0.00	1.61	1.61	0.00	0.00	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.00	**899.99**	**623.59**	**276.41**
17	0.00	0.00	0.00	0.00	0.00	0.00	206.15	111.50	94.65	484.93	484.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.21	58.21	0.00	94.53	94.53	0.00	**843.81**	**749.16**	**94.65**
18	0.00	0.00	0.00	0.00	0.00	0.00	243.50	32.19	211.31	337.51	337.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	322.64	322.64	0.00	1.18	1.18	0.00	**904.83**	**693.52**	**211.31**
19	0.00	0.00	0.00	0.00	0.00	0.00	818.74	409.73	409.01	45.47	45.47	0.00	38.98	37.00	1.98	0.00	0.00	0.00	0.00	0.00	0.00	1.74	1.74	0.00	**904.93**	**493.95**	**410.99**
20	0.00	0.00	0.00	432.43	401.36	31.07	210.78	162.19	48.59	244.72	244.72	0.00	27.69	27.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37	3.37	0.00	**918.99**	**839.33**	**79.66**
21	0.00	0.00	0.00	42.21	37.75	4.47	262.53	132.92	129.61	669.72	669.72	0.00	55.36	49.63	5.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1029.82**	**890.01**	**139.81**
22	1.69	0.00	1.69	0.00	0.00	0.00	351.57	172.71	178.85	479.43	479.43	0.00	19.24	19.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**851.92**	**671.38**	**180.55**
23	0.00	0.00	0.00	0.00	0.00	0.00	582.15	227.86	354.29	92.14	92.14	0.00	17.24	17.24	0.00	4.13	0.23	3.90	154.78	154.78	0.00	13.64	13.64	0.00	**864.08**	**505.89**	**358.19**
24	0.00	0.00	0.00	61.75	61.18	0.58	483.08	358.62	124.46	346.24	346.24	0.00	50.83	46.08	4.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**941.90**	**812.11**	**129.79**
25	0.00	0.00	0.00	0.00	0.00	0.00	261.55	107.65	153.90	475.11	475.11	0.00	2.07	2.07	0.00	0.00	0.00	0.00	87.97	87.97	0.00	0.00	0.00	0.00	**826.70**	**672.81**	**153.90**
Total	**7.50**	**0.00**	**7.50**	**536.40**	**500.29**	**36.11**	**11223.19**	**7999.94**	**3223.25**	**5593.53**	**5593.53**	**0.00**	**879.00**	**864.39**	**14.61**	**17.45**	**7.50**	**9.95**	**3337.05**	**3337.05**	**0.00**	**386.55**	**386.55**	**0.00**	**21980.67**	**18689.25**	**3291.41**
%	**0.03**	**0.00**	**0.03**	**2.44**	**2.28**	**0.16**	**51.06**	**36.40**	**14.66**	**25.45**	**25.45**	**0.00**	**4.00**	**3.93**	**0.07**	**0.08**	**0.03**	**0.05**	**15.18**	**15.18**	**0.00**	**1.76**	**1.76**	**0.00**	**100.00**	**85.03**	**14.97**

Table 16 Physical sustainability of land-use at all hill country monitoring sites (hectares): 2007 (new data)

Site	Horticulture/cash cropping			Dairying			Meat & wool farming			Revegetated meat and wool farming			Plantation Forestry			Meat & wool farming with trees			Indigenous Forest			Water			Total		
	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.	Total	Sust.	Unsust.
1	0.00	0.00	0.00	0.00	0.00	0.00	150.00	123.15	26.85	118.38	118.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	384.78	384.78	0.00	233.47	233.47	0.00	**886.62**	**859.77**	**26.85**
2	0.00	0.00	0.00	0.00	0.00	0.00	286.86	279.82	7.04	81.29	81.29	0.00	10.61	10.51	0.10	0.00	0.00	0.00	496.34	496.34	0.00	14.53	14.53	0.00	**889.63**	**882.48**	**7.14**
3	8.43	7.58	0.85	91.47	66.36	25.11	189.10	175.48	13.61	207.92	207.92	0.00	5.72	5.72	0.00	0.00	0.00	0.00	368.27	368.27	0.00	0.66	0.66	0.00	**871.56**	**831.99**	**39.57**
4	0.00	0.00	0.00	0.00	0.00	0.00	623.27	567.12	56.16	130.37	130.37	0.00	28.43	28.43	0.00	0.84	0.13	0.70	86.28	86.28	0.00	0.00	0.00	0.00	**869.20**	**812.34**	**56.86**
5	0.00	0.00	0.00	0.00	0.00	0.00	366.22	319.55	46.67	536.92	536.92	0.00	5.08	5.08	0.00	3.97	1.21	2.75	0.00	0.00	0.00	0.00	0.00	0.00	**912.19**	**862.76**	**49.42**
6	0.00	0.00	0.00	0.00	0.00	0.00	418.36	245.09	173.27	123.70	123.70	0.00	12.07	11.69	0.39	0.00	0.00	0.00	316.00	316.00	0.00	0.00	0.00	0.00	**870.13**	**696.47**	**173.66**
7	0.00	0.00	0.00	0.00	0.00	0.00	621.36	602.44	18.92	99.44	99.44	0.00	58.33	58.33	0.00	0.00	0.00	0.00	114.27	114.27	0.00	0.00	0.00	0.00	**893.40**	**874.48**	**18.92**
8	0.00	0.00	0.00	0.00	0.00	0.00	134.02	127.85	6.16	181.79	181.79	0.00	80.14	80.14	0.00	0.00	0.00	0.00	480.83	480.83	0.00	0.65	0.65	0.00	**877.41**	**871.25**	**6.16**
9	0.00	0.00	0.00	0.00	0.00	0.00	591.85	524.10	67.75	146.14	146.14	0.00	118.67	118.67	0.00	0.00	0.00	0.00	21.82	21.82	0.00	1.42	1.42	0.00	**879.90**	**812.15**	**67.75**
10	0.00	0.00	0.00	0.00	0.00	0.00	243.82	160.09	83.73	340.64	340.64	0.00	34.40	34.40	0.00	0.00	0.00	0.00	279.00	279.00	0.00	5.06	5.06	0.00	**902.91**	**819.18**	**83.73**
11	0.00	0.00	0.00	0.00	0.00	0.00	227.12	223.38	3.74	307.71	307.71	0.00	303.54	300.63	2.91	0.00	0.00	0.00	14.09	14.09	0.00	0.42	0.42	0.00	**852.88**	**846.24**	**6.65**
12	8.60	0.00	8.60	0.00	0.00	0.00	835.79	773.93	61.87	23.40	23.40	0.00	1.83	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.27	6.27	0.00	**875.90**	**805.43**	**70.47**
13	0.00	0.00	0.00	0.00	0.00	0.00	688.83	543.47	145.35	107.81	107.81	0.00	24.34	24.30	0.03	0.00	0.00	0.00	0.00	0.00	0.00	8.65	8.65	0.00	**829.63**	**684.24**	**145.39**
14	0.00	0.00	0.00	0.00	0.00	0.00	721.66	459.07	262.58	133.64	133.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**855.30**	**592.71**	**262.58**
15	0.00	0.00	0.00	0.00	0.00	0.00	58.86	57.60	1.26	541.72	541.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.45	126.45	0.00	0.00	0.00	0.00	**727.03**	**725.77**	**1.26**
16	0.00	0.00	0.00	0.00	0.00	0.00	870.06	602.56	267.50	28.18	28.18	0.00	1.42	1.42	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	**899.99**	**632.49**	**267.50**
17	0.00	0.00	0.00	0.00	0.00	0.00	133.45	77.54	55.91	564.36	564.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48.02	48.02	0.00	97.97	97.97	0.00	**843.81**	**787.90**	**55.91**
18	0.00	0.00	0.00	0.00	0.00	0.00	232.75	30.21	202.54	371.50	371.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	299.71	299.71	0.00	0.87	0.87	0.00	**904.83**	**702.29**	**202.54**
19	0.00	0.00	0.00	0.00	0.00	0.00	676.29	355.37	320.93	182.61	182.61	0.00	44.54	44.23	0.31	0.00	0.00	0.00	0.00	0.00	0.00	1.49	1.49	0.00	**904.93**	**583.70**	**321.23**
20	13.17	12.93	0.24	405.16	360.06	45.10	138.53	117.38	21.14	284.60	284.60	0.00	74.01	72.55	1.46	0.00	0.00	0.00	0.00	0.00	0.00	3.53	3.53	0.00	**918.99**	**851.04**	**67.95**
21	0.00	0.00	0.00	0.00	0.00	0.00	262.93	141.11	121.82	665.55	665.55	0.00	101.34	94.93	6.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1029.82**	**901.59**	**128.24**
22	0.00	0.00	0.00	0.00	0.00	0.00	376.97	172.25	204.73	438.54	438.54	0.00	36.41	35.36	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**851.92**	**646.15**	**205.77**
23	0.00	0.00	0.00	0.00	0.00	0.00	538.93	214.00	324.93	145.46	145.46	0.00	26.59	26.14	0.45	0.00	0.00	0.00	140.36	140.36	0.00	12.74	12.74	0.00	**864.08**	**538.70**	**325.38**
24	0.00	0.00	0.00	68.27	64.26	4.01	415.41	311.25	104.16	396.84	396.84	0.00	61.24	54.43	6.82	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	**941.90**	**826.91**	**114.99**
25	0.00	0.00	0.00	0.00	0.00	0.00	114.67	57.44	57.23	621.23	621.23	0.00	4.22	4.22	0.00	0.00	0.00	0.00	86.59	86.59	0.00	0.00	0.00	0.00	**826.70**	**769.48**	**57.23**
Total	**30.20**	**20.51**	**9.69**	**564.89**	**490.67**	**74.22**	**9917.10**	**7261.24**	**2655.86**	**6779.74**	**6779.74**	**0.00**	**1032.93**	**1013.00**	**19.93**	**4.80**	**1.35**	**3.46**	**3263.12**	**3263.12**	**0.00**	**387.87**	**387.87**	**0.00**	**21980.67**	**19217.52**	**2763.15**
%	**0.14**	**0.09**	**0.04**	**2.57**	**2.23**	**0.34**	**45.12**	**33.03**	**12.08**	**30.84**	**30.84**	**0.00**	**4.70**	**4.61**	**0.09**	**0.02**	**0.01**	**0.02**	**14.85**	**14.85**	**0.00**	**1.76**	**1.76**	**0.00**	**100.00**	**87.43**	**12.57**

Table 17 The meat and wool land-use class examined according to three key sustainable land-use classes for all sites (hectares): 1994 and 2000 (revised), and 2007 (new data)

Site	Selected land-use classes where meat and wool farming was mapped — 1994, 2000 and 2007											
	Other sustainable land-use class (Sustainable)			Pasture with trees (PT) (Sustainable)			Forestry (FO) (Unsustainable)			Protection (PR) (Unsustainable)		
	1994	2000	2007	1994	2000	2007	1994	2000	2007	1994	2000	2007
1	85.21	85.20	82.76	51.32	43.73	40.38	31.30	26.68	25.30	1.34	1.34	1.55
2	243.50	242.98	241.17	58.66	56.07	38.66	13.74	13.74	7.03	3.13	3.13	0.01
3	274.31	253.80	128.09	81.14	40.47	47.39	51.39	4.85	13.26	0.76	0.63	0.35
4	511.51	501.96	490.13	99.34	97.85	76.98	67.34	65.43	56.16	0.00	0.00	0.00
5	186.09	185.88	174.65	143.46	144.86	144.90	52.74	55.06	42.45	7.61	7.55	4.22
6	88.99	88.99	87.92	172.38	172.38	157.17	189.86	189.86	145.60	50.84	50.84	27.67
7	578.01	549.67	523.71	87.94	82.21	78.72	27.83	24.82	18.92	0.00	0.00	0.00
8	143.67	110.61	98.05	128.45	49.98	29.80	32.95	10.45	6.16	0.00	0.00	0.00
9	412.78	401.34	377.69	220.55	188.23	146.41	102.57	93.27	67.75	0.00	0.00	0.00
10	106.24	94.21	80.57	94.76	88.06	79.52	115.50	100.10	77.88	4.46	4.01	5.85
11	197.40	196.55	185.23	61.34	61.34	38.15	15.08	15.08	3.74	0.00	0.00	0.00
12	615.25	615.25	601.67	178.25	178.25	172.26	67.18	67.18	61.87	0.00	0.00	0.00
13	334.12	328.50	299.38	278.25	263.58	244.09	159.88	151.80	144.49	2.29	1.75	0.86
14	188.97	188.97	185.69	312.07	312.07	273.38	311.46	311.46	237.28	42.80	42.80	25.30
15	54.14	57.68	52.66	0.56	0.60	4.94	0.35	0.35	1.26	0.00	0.00	0.00
16	337.54	337.54	338.17	265.74	265.74	264.39	276.41	276.41	267.50	0.00	0.00	0.00
17	68.10	65.41	52.54	58.73	46.08	25.00	138.79	87.37	55.18	9.50	7.27	0.73
18	4.10	4.10	3.32	28.10	28.10	26.90	208.75	208.75	200.86	2.56	2.56	1.68
19	159.21	144.81	129.90	271.42	264.92	225.47	365.62	349.72	286.17	60.81	59.29	34.76
20	130.74	122.92	99.91	40.56	39.27	17.47	51.14	47.70	20.99	0.89	0.89	0.15
21	87.38	86.32	103.35	48.53	46.60	37.76	126.19	125.48	118.58	3.68	4.13	3.24
22	111.23	110.39	107.80	64.21	62.32	64.45	184.71	175.92	201.28	3.68	2.94	3.45
23	158.28	156.06	147.51	79.88	71.80	66.49	347.34	321.29	294.14	33.00	33.00	30.79
24	271.09	267.54	243.79	94.14	91.07	67.45	131.50	118.90	98.07	8.45	5.56	6.09
25	43.77	43.77	24.72	66.41	63.89	32.72	157.72	145.55	51.66	8.41	8.35	5.57
Total (ha)	**5391.62**	**5240.48**	**4860.39**	**2986.19**	**2759.46**	**2400.85**	**3227.35**	**2987.20**	**2503.59**	**244.20**	**236.05**	**152.27**
Total (%)	**45.50**	**46.69**	**49.01**	**25.20**	**24.59**	**24.21**	**27.24**	**26.62**	**25.25**	**2.06**	**2.10**	**1.54**

Table 18 Physical sustainability changes from 1994 to 2000 and from 2000 to 2007 – all hill country monitoring sites (hectares)

Site	1994		2000		2007		Sustainability change, 1994–2000		Sustainability change, 2000–2007		Sustainability change, 1994–2007	
	Sustainable	Unsustain-able	Sustainable	Unsustain-able	Sustainable	Unsustain-able	Area of change (Ha)	Degree of change*	Area of change (Ha)	Degree of change*	Area of change (Ha)	Degree of change*
1	853.98	32.64	858.61	28.01	859.77	26.85	4.63	?	1.16	?	5.79	?
2	872.76	16.87	872.76	16.87	882.48	7.14	0.00	n.c.	9.73	?	9.73	?
3	819.41	52.15	866.08	5.48	831.99	39.57	46.67	√	-34.09	x	12.58	√
4	800.92	68.28	802.84	66.36	812.34	56.86	1.92	?	9.50	?	11.42	√
5	849.11	63.07	846.80	65.38	862.76	49.42	-2.31	?	15.96	√	13.65	√
6	627.00	243.13	627.00	243.13	696.47	173.66	0.00	n.c.	69.47	√	69.47	√
7	865.57	27.83	868.58	24.82	874.48	18.92	3.01	?	5.90	?	8.90	?
8	844.46	32.95	866.96	10.45	871.25	6.16	22.50	√	4.29	?	26.78	√
9	777.33	102.57	786.64	93.27	812.15	67.75	9.31		25.52	√	34.82	√
10	782.95	119.96	792.99	109.92	819.18	83.73	10.04	√	26.19	√	36.23	√
11	836.28	16.61	836.28	16.61	846.24	6.65	0.00	n.c.	9.96	?	9.96	?
12	808.72	67.18	808.72	67.18	805.43	70.47	0.00	n.c.	-3.28	?	-3.28	?
13	667.46	162.17	675.54	154.09	684.24	145.39	8.08	?	8.70	?	16.78	√
14	501.04	354.26	501.04	354.26	592.71	262.58	0.00	n.c.	91.67	√	91.67	√
15	726.68	0.35	726.68	0.35	725.77	1.26	0.00	n.c.	-0.91	?	-0.91	?
16	623.59	276.41	623.59	276.41	632.49	267.50	0.00	n.c.	8.91	?	8.91	?
17	695.51	148.29	749.16	94.65	787.90	55.91	53.64	√	38.74	√	92.38	√
18	693.52	211.31	693.52	211.31	702.29	202.54	0.00	n.c.	8.77	?	8.77	?
19	477.77	427.17	493.95	410.99	583.70	321.23	16.18	√	89.76	√	105.93	√
20	834.39	84.60	839.33	79.66	851.04	67.95	4.94	?	11.71	√	16.65	√
21	889.16	140.66	890.01	139.81	901.59	128.24	0.85	?	11.57	√	12.43	√
22	663.54	188.38	671.38	180.55	646.15	205.77	7.84	?	-25.22	x	-17.39	x
23	479.84	384.24	505.89	358.19	538.70	325.38	26.05	√	32.81	√	58.86	√
24	799.59	142.31	812.11	129.79	826.91	114.99	12.52	√	14.80	√	27.32	√
25	660.57	166.13	672.81	153.90	769.48	57.23	12.23	√	96.67	√	108.91	√
Total (ha)	**18451.17**	**3529.49**	**18689.25**	**3291.41**	**19217.52**	**2763.15**	**238.08**	√	**528.26**	√	**766.34**	√
Total (%)	**83.94**	**16.06**	**85.03**	**14.97**	**87.43**	**12.57**	**1.08 ± 0.7**		**2.40 ± 1.5**		**3.49 ± 1.6**	

* Degree of change: n.c. = no change
? = no significant change (i.e., changes of <10 ha)
√ = significant change towards sustainability
x = significant change away from sustainability

Table 19 Physical sustainability changes from 1994 to 2000 and from 2000 to 2007 – considering the 17 hill country monitoring sites reported by O'Leary et al. (1996) (hectares)

Site	1994		2000		2007		Sustainability change, 1994–2000		Sustainability change, 2000–2007		Sustainability change, 1994–2007	
	Sustainable	Unsustain-able	Sustainable	Unsustain-able	Sustainable	Unsustain-able	Area of change (Ha)	Degree of change*	Area of change (Ha)	Degree of change*	Area of change (Ha)	Degree of change*
1	853.98	32.64	858.61	28.01	859.77	26.85	4.63	?	1.16	?	5.79	?
3	819.41	52.15	866.08	5.48	831.99	39.57	46.67	√	-34.09	x	12.58	√
4	800.92	68.28	802.84	66.36	812.34	56.86	1.92	?	9.50	?	11.42	√
5	849.11	63.07	846.80	65.38	862.76	49.42	-2.31	?	15.96	√	13.65	√
7	865.57	27.83	868.58	24.82	874.48	18.92	3.01	?	5.90	?	8.90	?
8	844.46	32.95	866.96	10.45	871.25	6.16	22.50	√	4.29	?	26.78	√
9	777.33	102.57	786.64	93.27	812.15	67.75	9.31		25.52	√	34.82	√
10	782.95	119.96	792.99	109.92	819.18	83.73	10.04	√	26.19	√	36.23	√
11	836.28	16.61	836.28	16.61	846.24	6.65	0.00	n.c.	9.96	?	9.96	?
12	808.72	67.18	808.72	67.18	805.43	70.47	0.00	n.c.	-3.28	?	-3.28	?
13	667.46	162.17	675.54	154.09	684.24	145.39	8.08	?	8.70	?	16.78	√
15	726.68	0.35	726.68	0.35	725.77	1.26	0.00	n.c.	-0.91	?	-0.91	?
16	623.59	276.41	623.59	276.41	632.49	267.50	0.00	n.c.	8.91	?	8.91	?
17	695.51	148.29	749.16	94.65	787.90	55.91	53.64	√	38.74	√	92.38	√
18	693.52	211.31	693.52	211.31	702.29	202.54	0.00	n.c.	8.77	?	8.77	?
19	477.77	427.17	493.95	410.99	583.70	321.23	16.18	√	89.76	√	105.93	√
20	834.39	84.60	839.33	79.66	851.04	67.95	4.94	?	11.71	√	16.65	√
Total (ha)	**12957.66**	**1893.52**	**13136.25**	**1714.93**	**13363.03**	**1488.16**	**178.59**	√	**226.77**	√	**405.36**	√
Total (%)	**87.25**	**12.75**	**88.45**	**11.55**	**89.98**	**10.02**	**1.20 ± 1.1**		**1.53 ± 1.7**		**2.73 ± 2.0**	

* Degree of change: n.c. = no change
? = no significant change (i.e., changes of <10 ha)
√ = significant change towards sustainability
x = significant change away from sustainability

4. Results

Note on data presentation: *Data tabulated in this report are rounded to two decimal places . Where a cell in a table contains the sum of other cells, the raw data is first summed and then rounded to avoid the cumulative effect of rounding data in individual cells prior to calculating sums. In discussion text, areal data are presented in hectares and rounded to the nearest hectare except in Section 4.2 where figures are given to one decimal place on account of the smaller areas discussed. Percentages and error limits are given to one decimal place.*

4.1 Eastern hill country

Vegetation

Vegetation cover by site
Table 6 sets out, for each site, the vegetation cover classes mapped for 1994 (O'Leary et al. 1996), 2000 (Jessen et al. 2000) and 2007 (this study).

Revision of changes between 1994 and 2000: For consistency, the results given in Jessen et al. (2000) are repeated in this section with revised data:

Most change (from 1994 to 2000) is small over all sites and, in the main, at each site. This, and an observation that many year 2000 vegetation mapping boundaries are the result of modest adjustments to 1994 boundaries, suggests that vegetation change occurs in small increments. The main changes are:

- *a small reduction in the area of pasture from 10 772 ha to 10 453 ha (49.0% to 47.6%), with sites 3 and 8 having the largest reductions, many other sites have reductions of <50 ha, while 9 sites show very small increases of <20 ha except for site 23 that has 47 ha more pasture (increases in pasture cover are usually the result of scrub <3 m clearance)*

- *a small increase in plantation forest from 528 ha to 888 ha (2.4% to 4.0%), with sites 7, 8, 9, 11, 13, 19, and 20 having the largest increase. Nine other sites show increases of <20 ha, and no sites have reductions in the area of plantation forest. While the area of plantation forest has nearly doubled, the total area remains very small (4.0%) by comparison with many other hill country areas of the North Island*

- *a very small reduction in the area of tall (>3 m) and short (<3 m) scrub covers taken together, from 6877ha to 6654 ha. The total area of scrub, whilst falling slightly from 31.3% to 30.3%, remains very large*

- *an apparent (but probably insignificant) increase in weediness from 37 ha to 235 ha (0.2% to 1.1%). Much of this is due to a more permissive treatment of weedy hill slopes in the year 2000 interpretation, and caution needs to be applied in drawing too many management inferences from these weed data.*

***Changes between 2000 and 2007*:** From 2000 to 2007, the main changes in vegetation cover were:

- A continued reduction in the total area under pasture, from 10 453 ha in 2000 to 10 180 ha in 2007 (47.6% to 46.3%). Site 20 showed the largest reduction (52 ha), 16 sites showed reductions in the area of pasture by <50 ha, while three sites (Sites 5, 14 and 22) showed small increases (the largest increase was 34 ha at Site 22)

- A very small amount of tillage, classified as cropping, was recorded at Sites 3, 12 and 20, totalling 26 ha (0.1%). This is most likely to be maize cropping which has become more common in Taranaki in recent years

- A continued, albeit small, increase in the area under plantation forestry from 888 ha to 1035 ha (4.0% to 4.7%). The total area under plantation forestry remains very small relative to many other North Island hill country areas

- A small increase in the combined area covered by tall (>3 m) and short (<3 m) scrub, from 6654 ha to 6803 ha (30.3% to 31.0%). This is a reversal of the slight decrease in scrub cover recorded from 1994 to 2000.

Overall changes between 1994 and 2007: From 1994 to 2007, the main changes in vegetation cover were:

- A reduction in the area under pasture by 592 ha (2.7%), from 10 772 ha (49.0%) to 10 180 ha (46.3%)

- A doubling in the area under plantation forestry, from 528 ha (2.4%) to 1035 ha (4.7%)

- Only a very slight overall change in the total area under tall or short scrub (a reduction of 75 ha, or 0.3%), although this comprises a decrease of 223 ha (1.0%) between 1994 and 2000 followed by an increase of 148 ha (0.7%) between 2000 and 2007.

Vegetation change analysis

Tables 7, 8 and 9 summarise the changes in vegetation cover mapped between 1994 (O'Leary et al. 1996), 2000 (Jessen et al. 2000) and 2007 (this study).

Revision of 1994–2000 change analysis (Table 7): The results given in Jessen et al. (2000) are revised thus:

- *It seems that the major change from scrubby vegetation to pasture indicated from the historic data (O'Leary et al. 1996) ceased by the year 2000. 318 ha of pasture had been created from scrubland, and nearly as much (221 ha) scrubland established from pasture.*

- *Overall, pasture cover decreased slightly, and most of this (284 ha) is explained by pasture going to plantation forest. Low scrub (<3 m) contributed to a very small part of the change toward plantation forest (84 ha).*

- *There are now no significant conversions of scrub to pasture as reported in an examination of long-term changes (O'Leary et al. 1996), some pasture has converted to weedy covers (142 ha), and there are few significant changes to other land covers. Overall, the changes in vegetation covers over the 6-year monitoring period have been small.*

***Change analysis, 2000–2007 (Table 8)*:**

- There was a net change from pasture to scrub of 160 ha: 892 ha of pasture reverted to scrub, while 732 ha of scrub was converted to pasture

- Plantation forestry increased overall by 147 ha, from 888 ha to 1035 ha. Land formerly under pasture (190 ha) and scrub (148 ha) were the main contributors to increased plantation forestry. At the same time, 128 ha of plantation forest went to scrub and another 70 ha to pasture

- Apparent changes between the scrub and indigenous forest classes should be regarded with caution, owing to the sometimes indistinct boundaries between these vegetation classes. Stereoscopic prints were not available for the 2007 imagery, which increased the possibility for confusion between the tall and short scrub classes in particular. The higher resolution of the 2007 imagery also enabled smaller scale features to be mapped, for example, patches of scrub within indigenous forest areas that result from natural erosion on steep slopes under indigenous forest cover. It could be argued, however, that these patches of scrub also be classified as 'indigenous forest'.

***Overall change analysis, 1994–2007 (Table 9)*:** The most notable changes between vegetation cover classes between 1994 and 2007 were:

- A general shift away from pasture. While a net 903 ha of scrub was cleared for pasture between 1994 and 2007, a net 1029 ha of pasture reverted to scrub during the same period. An additional 411 ha of pasture land was converted to plantation forestry.

- Little net change in the overall area of scrubland (a net decrease of 75 ha, or 0.3%, from 6877 ha (31.3%) to 6803 ha (31.0%)). This, however, masks a significant change in trend between the 1994–2000 and 2000–2007 monitoring episodes, in that total scrub cover declined from 1994 to 2000 but then increased again between 2000 and 2007. A very small amount of plantation forestry was also cleared and subsequently reverted to scrub

- A general increase in the overall area under plantation forestry, established mainly on what was formerly pasture land with a smaller amount going onto scrubland.

Land use

Land use by site
Table 10 sets out, for each site, the land-use classes mapped for 1994 (O'Leary et al. 1996), 2000 (Jessen et al. 2000) and 2007 (this study).

***Revision of changes between 1994 and 2000*:** The results given in Jessen *et al.* (2000) are revised thus:

Most change (from 1994 to 2000) was small over all sites and, in the main, at each site. This, and an observation that many year 2000 land-use mapping boundaries were simply the result of modest adjustments to 1994 boundaries, suggests that land-use change mainly occurs in small increments.

The changes were:

- *a reduction in the area of meat and wool farming from 11 849 ha to 11 223 ha (53.9% to 51.1%). Sites 3, 8, 9, and 17 show the largest reductions, 14 sites have reductions of <50 ha, and no sites show a significant increase in this land use*

- *meat and wool farming with trees was largely unrecorded in 1994 and 2000*

- *a small increase in the area of revegetated meat and wool farming from 5293 ha to 5594 ha (24.1% to 25.5%). Sites 3, 8 and 17 show the greatest change, and other sites show very small (<25 ha) changes*

- *a small increase in plantation forestry from 551 ha to 879 ha (2.5% to 4.0%). Sites 7, 8, 9, 13 and 19 show the greatest increase, other sites have increases of <25 ha, and no sites show a significant decrease in this land use. The total area remains very small by comparison with many other hill country areas of the North Island.*

***Changes between 2000 and 2007*:** The most notable changes were:

- An accelerated reduction in the area of meat and wool farming, from 11 223 ha to 9917 ha (51.1% to 45.1%). Sites 3, 6, 9, 13, 14, 17, 19, 20, 24 and 25 showed the greatest reductions, 12 other sites showed reductions of <50 ha, while only Site 22 showed a significant increase (25 ha)

- Correspondingly, a marked overall increase in the area of revegetated meat and wool farming (scrubland) from 5594 ha to 6780 ha (25.5% to 30.8%). Increases of >50 ha occurred at Sites 6, 7, 8, 9, 11, 13, 14, 17, 19, 23, 24 and 25, most other sites showed increases of <50 ha, while small decreases were recorded at Sites 3 and 22

- A further small increase in the area of plantation forestry from 879 ha to 1033 ha (4.0% to 4.7%).

Overall changes between 1994 and 2007: From 1994 to 2007, the main changes in land use were:

- A sustained decrease in the area of meat and wool farming, from 11 849 ha (53.9%) to 9917 ha (45.1%)

- A sustained increase in the area of revegetated meat and wool farming, from 5293 ha (24.1%) to 6780 ha (30.8%)

- A small increase in the area of plantation forestry, from 551 ha (2.5%) to 1033 ha (4.7%).

Land-use change analysis

Tables 11, 12 and 13 summarise the changes in land-use mapped between 1994 (O'Leary et al. 1996), 2000 (Jessen et al. 2000) and 2007 (this study).

***Revision of 1994–2000 change analysis (Table 11)*:** The results given in Jessen et al. (2000) are revised thus:

While changes are small, analysis of the direction of change reveals trends that may have physical sustainability implications. Analysis of Table 11 shows:

- *a reduced area of meat and wool farming (11223 ha in 2000, down from 11 849 ha in 1994), with about one half of this area of change (334 ha) reverting to scrub (no longer used for meat and wool farming, and largely unused) and 307 ha going to plantation forestry*

- *that the clear increase in plantation forestry (from 551 to 879 ha) is mainly at the expense of meat and wool farming (contributing 307 ha of the increase), rather than the unused scrubland (accounting for just 26 ha of the change).*

***Change analysis, 2000–2007** (Table 12)*: As for the 1994–2000 period, most land-use changes between 2000 and 2007 were relatively small. However, the trend away from meat and wool farming identified from 1994 to 2000 (Jessen et al. 2000) accelerated after 2000, and this change has significance in terms of overall physical sustainability. Specifically, the most notable changes were:

- A further, significant, reduction in the area of meat and wool farming land, from 11 223 ha (51.1%) in 2000 to 9917 ha (45.1%) in 2007. The bulk of this reduction (1541 ha) was due to reversion to scrub, with 184 ha going into plantation forestry. A small area (130 ha) appears to have converted to dairy farming

- The clearance of 439 ha of scrubland for meat and wool farming, while a further 120 ha of scrubland was cleared for plantation forestry.

- The clearance of 107 ha of plantation forest land which then reverted to scrubland, with a further 66 ha being cleared for meat and wool farming

- The clearance of 245 ha of indigenous forest for meat and wool farming.

Overall change analysis, 1994–2007 (Table 13): The most notable changes between land-use classes between 1994 and 2007 were:

- A significant reduction in the area of meat and wool farming from 11 849 ha (53.9%) to 9917 ha (45.1%). The majority of this change was reversion to scrub (1796 ha), with a smaller proportion (453 ha) going into plantation forestry. *(**Note**: the apparent contradiction between the increase in 'revegetated meat and wool farming' and a corresponding very small change in scrub cover in Table 6 is a result of the way small patches of scrub in farmland have been classified. While the farm remains in operation, scrub patches or 'rough' pasture within the farm are also classified as 'meat and wool farming', on account of cattle and sheep still being able to access and graze these areas. Once it is apparent that part or all of a farm has been abandoned, that area, including the pre-existing scrub patches, becomes classified as 'revegetated meat and wool farming').*

- A small amount of revegetated meat and wool farming land was cleared and returned to meat and wool farming

- An increase in the area under plantation forest from 551 ha (2.5%) to 1033 ha (4.7%), with most of that increase coming from meat and wool farming land and a smaller amount from revegetated meat and wool farming land. Over the same period, a very small amount of plantation forest land was returned to meat and wool farming or revegetated meat and wool farming.

Physical sustainability of land use

This section first revises, re-presents and discusses the 1994 and 2000 sustainability data from Jessen et al. (2000), and then compares these to the 2007 data.

Tables 14, 15 and 16 set out the area of each land use considered to be physically sustainable (and unsustainable) for each site, according to the sustainability definitions listed under 'Definitions of terms and expressions', and the sustainable land-use classes in Table 5. The sustainability data were developed by laying the mapped land uses for 1994, 2000 and 2007 over the physically sustainable land uses spatial database (Blaschke et al. 1992a), using ARC/INFO GIS. Because the sustainable land-use classes were set to reflect the accelerated erosion issue (Issue 1 in Section 4 of the Council's Regional Soil Plan for Taranaki), the cause of any potential unsustainability of land use recorded would be the higher susceptibility for soil slip erosion on much of the steeper (specifically, where slopes are >28°) grassland in the eastern hill country (Blaschke et al. 1992b; Trustrum & Blaschke 1992; DeRose et al. 1993).

Physical land-use sustainability as at 1994 — revised

The majority of the monitoring area (18451 ha, or 83.9%) was sustainably managed in 1994, while 3529 ha, or 16.1%, had unsustainable land uses. Of the monitoring area that was unsustainably managed, the major contributor was the 'Meat and wool farming' land-use class. Meat and wool farming occupied 11 849 ha (53.9%) of the total monitoring area in 1994, with 70.7% of it (8378 ha) being physically sustainable and 29.3% (3472 ha) considered to be physically unsustainable.

Meat and wool farming was the dominant land-use class, and also accounted for 98.4% of the unsustainably managed land at that time (3472 ha out of a total of 3529 ha). Table 17 examines more closely the physical sustainability for this land-use class on a site-by-site basis, focussing on two sustainable land-use classes on which meat and wool farming is considered unsustainable. These are:

1. where the meat and wool farming land-use class is recorded on the 'Forestry' (FO) sustainable land-use class. The minimum land-use standard for sustainability here is production forestry. Land-use capability units (from Fletcher 1987) in the FO class are: 6e7, 10, 12, 13, 21, and 23 where the dominant slope is F; 7e3, 5, and 15; and 7e9, 11, 17 and 20 where the dominant slope is F – the emphasis is on steep class 6 land and class 7 land

2. where the meat and wool farming land-use class is recorded on the 'Protection' (PR) sustainable land-use class. The minimum standard for sustainability is to have primary protection purpose. Land-use

   capability units in the PR class are 6c5; 7e9, 11, 17, and 20 where the dominant slope is G; and all of the class 8 LUC units – the emphasis is on class 8 land and the very steep class 7 land

Also from Table 17, 25.2% (2986 ha) of the area of meat and wool farming is recorded on the 'Pasture with trees' (PT) sustainable land-use class. While this combination of land use and sustainable land-use class is

considered sustainable, this is precisely the area where land management (and the degree of sustainability) could be further improved by the planting of more trees.

Physical land-use sustainability as at 2000 – revised
By 2000, sustainable land uses occupied 18 689 ha (85.0%) of the monitoring area, while 3291 ha or 15.0% had unsustainable land uses.

As in 1994, the greatest contribution to unsustainable land use came from the meat and wool farming land-use class, which made up 3223 ha or 97.9% of the total area of unsustainable land use. The overall area of meat and wool farming had reduced from 11 849 ha (53.9% of the total monitoring area) to 11 223 ha (51.1%).

From the examination of the meat and wool farming class in Table 17, there was a reduction by 248 ha of unsustainable meat and wool farming on the sustainable land use classes FO and PR, with the remaining amount of decrease (378 ha) occurring on other sustainable land use classes on which continued meat and wool farming would have been regarded as potentially physically sustainable.

Physical land-use sustainability as at 2007
By 2007, sustainable land uses made up 19 218 ha (87.4%) of the monitoring area, while unsustainable land uses accounted for 2763 ha (12.6%).

The meat and wool farming land-use class continued to account for the majority (2656 ha, or 96.1%) of the unsustainably managed land – although the total area of meat and wool farming also fell significantly by 1306 ha. Of this decrease, 567 ha had been unsustainable meat and wool farming (on sustainable land use classes FO and PR), while the remaining 739 ha had been sustainable (Table 17).

Changes in physical land-use sustainability
Tables 18 and 19 present the overall land-use sustainability data for the monitoring sites, which was obtained by summing the sustainable and unsustainable uses separately for 1994, 2000 and 2007 for each site.

For the reporting of land-use sustainability as at 1994 and the changes up to 1994, O'Leary et al. (1996) used data from 17, not 25, sites. The 1996 study omitted sites 2, 6, 14, 21 to 24 because these had no pre-1994 land use and vegetation data, and their main objective was to obtain information about changes in land-use sustainability before 1994. The omitted sites 2, 6, and 14, are scattered in the northern and central parts of the eastern Taranaki hill country (see Appendix 1), and sites 21 to 24 form a block in the southern part.

While data for the 17 sites were necessary for measuring changes up to 1994, using only the 17 sites as a measure of sustainability as at 1994 is less appropriate due to an increase in sampling error and poorer eastern Taranaki hill country representation. The 17-site sustainability data as at 1994 were used by the Council to set a baseline for sustainability targets, largely as a result of this figure being emphasised in the 1996 report, and it not being picked-up as unsatisfactory in a later report prepared for the Council (Stephens and Harmsworth 1999).

For completeness, the present study gives sustainability change data for both the current 25-site dataset (Table 18) and the smaller 17-site dataset (Table 19). Given that the use of data from 25 sites gives the most representative measure of sustainability changes since 1994, the following discussion concentrates on the full dataset in Table 18. Long-term (since pre-1994) sustainability changes with respect to the 17 sites used by O'Leary et al. (1996) are discussed separately below under 'Long-term changes in physical land-use sustainability (pre-1994 to 2007) – 17 sites' (p. 45).

Changes in physical land-use sustainability, 1994–2000
Table 18 shows that, between 1994 and 2000, sustainable land uses increased by 238.08 ha (1.1 ± 0.7%). Most of this improvement resulted from the reduction of the total area of meat and wool farming from 11 849 ha to 11 223 ha, and the increase in plantation forestry from 551 ha to 879 ha.

Many movements toward sustainability on a site-by-site basis were within the margin for error (changes of 10 ha or less in Tables 18 and 19 were considered to be insignificant). Nevertheless, four sites (3, 8, 17, and 23) were definitely being used more sustainably in 2000 than in 1994, and Sites 10, 19, and 23 to 25 were probably being used more sustainably. While Sites 19 and 23 were more sustainably used by 2000 than in 1994, their total areas of unsustainable land use, along with that of Site 14, were still relatively large by 2000.

Changes in physical land-use sustainability, 2000–2007
Between 2000 and 2007, a stronger move towards sustainability, by 528 ha (2.4 ± 1.5%), was detected. As occurred between 1994 and 2000, the majority of this improvement came from a reduction in area of meat and wool farming (a decrease of 1306 ha, from 11 223 to 9917 ha), and an increase in the area under plantation forestry (an increase of 154 ha, from 879 ha to 1033 ha). An increase in the area of revegetated meat and wool farming land (by 1186 ha from 5594 ha to 6780 ha) was also detected.

Most sites again recorded insignificant changes in sustainability of less than 10 ha. Of those that showed improved sustainability, Sites 6, 9, 10 14, 17, 19, 23 and 25 were definitely being used more sustainably in 2007 than in 2000, while Sites 5, 20, 21 and 24 were probably being used more sustainably. Sites 3, and 22, however, appear to have been used less sustainably in 2007 than in 2000.

Overall, 2000 to 2007 recorded an increased rate of movement towards sustainable land use than that which occurred between 1994 and 2000, and an increased number of sites showed significant improvements in sustainability of land use.

Changes in physical land-use sustainability, 1994–2007
From 1994 to 2007, a total of 766 ha went from unsustainable to sustainable land uses, an overall improvement in sustainability of 3.5 ± 1.6%. This was mostly the result of a reduction in the area of meat and wool farming (down by 1932 ha, from 11 849 ha to 9917 ha), and increases in the areas of revegetated meat and wool farming land (up by 1487 ha, from 5293 ha to 6780 ha) and plantation forestry (up by 482 ha, from 551 ha to 1033 ha).

The majority of the monitoring sites recorded increases in land-use sustainability between 1994 and 2000. One site (Site 22) recorded a slight decrease in sustainability of land-use, ten sites (Sites 6, 8, 9, 10, 14, 17, 19, 23, 24 and 25) were definitely more sustainably used, and another 6 sites (Sites 3, 4, 5, 13, 20 and 21) were probably more sustainably used. The remaining 7 sites (Sites 1, 2, 7, 11, 12, 15 and 18) recorded insignificant changes.

Long-term changes in physical land-use sustainability (pre-1994–2007) — considering the 17 sites from O'Leary et al. (1996)
As in Jessen et al. (2000), pre-1994 sustainability data from O'Leary *et al.* (1996) is considered here in two parts: **long-term** (mostly from the early to mid-1970s, and a few sites from the 1950s); and **short-term** (from the early 1980s, roughly a decade before 1994). Both use the 17 sites listed in Table 19, as these sites had available historical primary data (aerial photography) for assessing land cover/land use.

In the **long-term**, from early 1950s–1970s to1994, O'Leary et al. (1996) found sustainability for the 17 sites decreased from 90.0% to 87.3% (–2.7 ± 0.8%)**.** The main cause for this decline was a decrease in the area of physically sustainable meat and wool farming, associated with the clearing of steepland and a consequent

large reduction in the area of revegetated meat and wool farming. In the **short-term**, from the early 1980s to 1994, the proportion of sustainable to unsustainable land uses remained unchanged, although the area of unsustainable meat and wool farming land had declined.

The sustainability of land use improved from 87.3% in 1994 to 88.5% (+1.2 ± 1.1%) over the 17 sites by 2000, though this improvement was only marginally significant in the context of the sampling error. A further improvement was noted between 2000 and 2007 to 90.0% (+1.5 ± 1.7%), although the magnitude of change fell inside the sampling error and so was not significant in its own right. However, at 2.7 ± 2.0% the overall change from 1994 to 2007 was significant. This indicates that, when the 2007 sustainability results for the 17 sites are viewed in this historical context, the decline in sustainability since the early 1950s to at least the early 1980s has essentially been fully reversed, after about a decade (early 1980s to 1994) of steady-state sustainability conditions.

This, and the 25-site results detailed above, would indicate that the Council has made good progress towards their target of 89% sustainable land use in the eastern hill country by the end of the ten-year period covered by the Council's 2001 Regional Soil Plan. Further improvements in land use sustainability are required, however, to meet this target – a further increase of 1.6% by 2011 is implied. Given the relatively small total area of plantation forestry in the eastern hill country monitoring area, the Council may consider the promotion of additional afforestation, particularly on the presently-farmed land classes that are most vulnerable to accelerated erosion, as an effective way of further improving the overall sustainability of hill country land use.

4.2 Coastal sand country

Tables 20 to 23 below detail the results of monitoring for bare sand for each coastal sand country site for 1994 (baseline), 2000 (Jessen et al. 2000) and 2007.

Table 20 Site A: Egmont – bare sand baseline (1994) and monitoring (2000 and 2007) results

Site area: 209.9 ha						
Cursor spacing (on ground) required to achieve 4000 virtual dot grid points: 22.9 m						
Area represented by virtual dot grid point: 524 m^2						
	1994	**2000**	**2007**	**Change 1994-2000**	**Change 2000-2007**	**Change 1994-2007**
Bare sand count	61	119	151	+58	+32	+90
Area of bare sand (hectares)	3.2	6.2	7.9	+3.0	+1.7	+4.7
Percentage of site	1.5 ± 0.5	3.0 ± 0.5	3.8 ± 0.5	+1.5 ± 1.0	+0.8 ± 1.0	+2.3 ± 1.0

Table 21 Site B: Hawera – bare sand baseline (1994) and monitoring (2000 and 2007) results

Site area: 580.7 ha						
Cursor spacing (on ground) required to achieve 4000 virtual dot grid points: 38.1 m						
Area represented by virtual dot grid point: 1452 m^2						
	1994	**2000**	**2007**	**Change 1994-2000**	**Change 2000-2007**	**Change 1994-2007**
Bare sand count	138	188	182	+50	-6	+44
Area of bare sand (hectares)	20.0	27.3	26.4	+7.3	-0.9	+6.4
Percentage of site	3.5 ± 0.5	4.7 ± 0.5	4.6 ± 0.5	+1.2± 1.0	-0.1 ± 1.0	+1.1 ± 1.0

Table 22 Site C: Patea – bare sand baseline (1994) and monitoring (2000 and 2007) results

Site area: 1228.2 ha						
Cursor spacing (on ground) required to achieve 4000 virtual dot grid points: 55.4 m						
Area represented by virtual dot grid point: 3069 m^2						
	1994	**2000**	**2007**	**Change 1994-2000**	**Change 2000-2007**	**Change 1994-2007**
Bare sand count	143	156	159	+13	+3	+16
Area of bare sand (hectares)	43.9	47.9	48.8	+4.0	+0.9	+4.9
Percentage of site	3.6 ± 0.5	3.9 ± 0.5	4.0 ± 0.5	+0.3 ± 1.0	+0.1 ± 1.0	+0.4 ± 1.0

Table 23 Site D: Wanganui – bare sand baseline (1994) and monitoring (2000 and 2007) results

Site area: 1320.3 ha						
Cursor spacing (on ground) required to achieve 4000 virtual dot grid points: 57.5 m						
Area represented by virtual dot grid point: 3306 m^2						
	1994	**2000**	**2007**	**Change 1994-2000**	**Change 2000-2007**	**Change 1994-2007**
Bare sand count	517	439	447	-78	+8	-70
Area of bare sand (hectares)	170.9	145.1	147.8	-25.8	+2.7	-23.1
Percentage of site	12.9 ± 1.0	11.0 ± 1.0	11.2 ± 1.0	-1.9 ± 1.5	+0.2 ± 1.5	-1.7 ± 1.5

Site A: Egmont

The area of bare sand at Site A increased by 1.5 ± 1.0% (3.0 ha) from 1994 to 2000, mainly as a result of sand blowouts in the southern part of the site that could have been attributable to tracking (Jessen et al. 2000). From 2000 to 2007, a further small, though insignificant, increase of 0.8 ± 1.0% (1.7 ha) was recorded, resulting mainly from the development of a small sand sheet behind the foredune in the northern part of the site. This may have resulted from tracking, or, alternatively, deflation following marine erosion of the foredune face (a high scarp was noted on the 2000 imagery). Overall, the proportion of bare sand at Site A is small (3.8 ± 0.5%, or 7.9 ha).

Site B: Hawera

Jessen et al. (2000) recorded an increase of 1.2 ± 1.0% (7.3 ha) in the area of bare sand between 1994 and 2000, relating primarily to a single area near Geary Road that may have been attributable to stock treading damage. Between 2000 and 2007 pastoral farming on this area near Geary Road and surrounding dunelands has intensified, with dunelands appearing to have been re-contoured and re-sown in pasture. Most of this new pasture land appears to be intact with few signs of wind erosion. A ~6.6 ha area of bare sand is noted between the end of Lower Manutahi Road and the coast, much of which appears to have been recent ploughing, adjacent to a small area of earthworks.

Most bare sand areas in the remainder of the monitoring site were largely unchanged between 2000 and 2007, with no significant change in the overall area of bare sand during this time (–0.1 ± 1.0%, or –0.9 ha). Between 1994 and 2007, the area of bare sand increased by 6.4 ha (1.1 ± 1.0%), from 20.0 ha (3.5 ± 0.5%) to 26.4 ha (4.6 ± 0.5%), though this increase was only just significant. The area of apparent ploughing near the end of Manutahi Road is viewed as a temporary bare sand exposure, though subsequent imagery would be needed to verify this. Outside this area, the overall proportion of bare sand at Site B is small.

Site C: Patea

An insignificant change of 0.3 ± 1.0% (4.0 ha) was recorded at Site C between 1994 and 2000 by Jessen et al. (2000). Between 2000 and 2007 the area of bare sand also remained unchanged (up 0.1 ± 1.0% (0.9 ha). Most of the bare sand in 2007 comprises a small sand sheet, adjoining the foredune and extending inland near the southern corner of the site, which appears to have spread from an area of bare sand developing blowout dunes that was apparent behind the beach on the 2000 imagery. In contrast, much of this original bare area in 2000 had stabilised by 2007, leaving no significant net change in the total area of bare sand for that period. Overall, from 1994 to 2007, the area of bare sand at Site C changed by an insignificant 0.4 ± 1.0% (4.9 ha).

Site D: Wanganui

From 1994 to 2000, the area of bare sand at Site D decreased by 1.9 ± 1.5% (25.8 ha), attributable mainly to canopy closure in some young plantation forests, new afforestation, and the stabilisation of some major blowout dunes (Jessen et al. 2000). From 2000 onwards, a small sand sheet developed immediately inland of the foredune just west of the Waitotara River mouth, but this was offset by the continued stabilisation of existing blowout dunes elsewhere in the study site. Between 2000 and 2007, the total area of bare sand did not change significantly, increasing by 0.2 ± 1.5% (2.7 ha). From 1994 to 2007, there was a net decrease in the area of bare sand of 1.7 ± 1.5% (23.1 ha).

5. Conclusions

5.1 Eastern hill country

Vegetation and land-use

- From 1994 to 2000, Jessen et al. (2000) recorded mainly small changes in vegetation over the 25 monitoring sites. The most notable changes were a reduction in the area of pasture by 1.5% (from 49.0% to 47.6%) while the area of plantation forestry increased by 1.6% (from 2.4% to 4.0%), mostly as a result of plantings on former pasture. From 2000 to 2007 the area under pasture declined a further 1.3% (to 46.3%), plantation forestry increased a further 0.7% (to 4.7%), while other vegetation changes remained small. Overall, the period 1994–2007 saw the total area of pasture reduce by 2.7% (from 49.0% to 46.3%), while forestry increased by 2.3% (from 2.4% to 4.7%).

- Land-use changes reported by Jessen et al. (2000) for the 1994–2000 period showed a reduction in the area of meat and wool farming by 2.9% (from 53.9% to 51.1%). At the same time, plantation forestry increased by 1.5% (from 2.5% to 4.0%), and revegetated meat and wool farming land increased by 1.4% (from 24.1% to 25.5%). From 2000 to 2007, a more substantial move away from meat and wool farming occurred: The total area of meat and wool farming fell a further 5.9% to 45.1%, most of which went to revegetated meat and wool farming (up by 5.4% to 30.8%) and more plantation forestry (up 0.7% to 4.7%).

Physical sustainability of land-use

- From 1994 to 2000, overall land-use sustainability improved over the 25 monitoring sites: in 1994, 83.9% of the monitoring area was used sustainably, and 16.1% used unsustainably. By 2000, this had improved to 85.0% and 15.0% respectively, an improvement in sustainability of 1.1 ± 0.7%. Most of this improvement resulted from a reduction in the area of meat and wool farming and an increase in the area of plantation forestry. From 2000 to 2007, an accelerated trend towards sustainability was recorded: by 2007, 87.4% of the monitoring area was used sustainably, and 12.6% was used unsustainably (an improvement in sustainability of 2.4 ± 1.5%. This was the result of a stronger move away from meat and wool farming after 2000 and a consequent increase in the area of revegetated meat and wool farming land. Increases in the area under plantation forestry also contributed to improved land-use sustainability. Overall, from 1994 to 2007, monitoring of the 25 hill country sites showed an improvement in land-use sustainability of 3.5 ± 1.6%.

- Meat and wool farming was the greatest contributor to the area of physically unsustainable land use, although the magnitude of this contribution fell over time. In 1994, meat and wool farming made up 53.9% (11849 ha) of the monitoring area, with 29.3% of that area (3472 ha) being regarded as physically unsustainable. By 2000, meat and wool farming occupied 51.1% (11223 ha) of the monitoring area, and 28.7% (3223 ha) of that area was regarded as physically unsustainable. From 2000 to 2007, meat and wool farming fell further to 45.1% (9917 ha), and, of that, 26.8% (2656 ha) was physically unsustainable. The total area of unsustainable meat and wool farming recorded in 1994 had therefore fallen by 816 ha, or nearly one-quarter, by 2007.

- Around one quarter of the area of physically sustainable meat and wool farming occurs on the ‘Pasture with trees’ (PT) sustainable land-use class. This comprises mostly land-use capability Class 6 land, which carries a moderate risk of accelerated erosion, and tree planting would further improve

land management on these areas. The meat and wool farming land that is considered physically unsustainable occurs on sustainable land-use classes 'Forestry' (FO) and 'Protection' (PR), which has a severe to very severe risk of accelerated erosion. Rapid sustainability gains could be made on this land by the use of forestry plantings, or allowing it to revert to scrub and, ultimately, indigenous forest cover. It is noted that the 'meat and wool farming with trees' land-use class was barely recorded on any of the imagery for 1994, 2000 and 2007, indicating most of the sustainability gains made between 1994 and 2007 have come from the reversion of meat and wool farming land to scrub, or its conversion to plantation forestry.

- The longer-term trend, from the early 1950s to 1994, showed a decrease in land-use sustainability from 90.0% to 87.3% (-2.7 ± 0.8%), based on long-term monitoring by O'Leary et al. (1996) of the 17 monitoring sites that had available historical data. (It should be noted, however, that the use of 17-site data is less robust than the 25-site data on account of a larger sampling error and poorer geographic representation of the eastern Taranaki hill country). Most of the decrease in sustainability happened before the early 1980s, and the last decade of the pre-1994 period showed little change in sustainability. By 2000, land-use sustainability on these 17 sites had improved, though only barely significantly based on the higher sampling error when using 17 sites, to 88.5% (+1.2 ± 1.1%). By 2007, a further improvement by 1.5 ± 1.7% was noted, though this was not significant in the context of the sampling error involved. The overall trend for 1994 to 2007, however, was a significant improvement of 2.7 ± 2.0%, to 90.0%.

- Overall, the Council have made good progress, particularly since 2000, in their efforts to manage the issue of accelerated erosion in the eastern Taranaki hill country. To achieve the target of 89% sustainable land use by 2011 set down in the Council's 2001 Regional Soil Plan, land-use sustainability needs to improve by a further 1.6% between 2007 and 2011. Given the relatively small total area of plantation forestry in the hill country monitoring area, the Council may consider the promotion of additional afforestation, particularly on the presently-farmed land classes that are most vulnerable to accelerated erosion, as an effective way of further improving the overall sustainability of hill country land use.

5.2 Coastal sand country

From 1994 to 2000, Jessen et al. (2000) found that the area of bare sand increased at Sites A (+1.5 ± 0.5%) and B (+1.2 ± 1.0%), remained unchanged at Site C (+0.3 ± 1.0%), and decreased at Site D (–1.9 ± 1.0%). Management issues (tracking and treading damage) were identified as possible causes for the increases at Sites A and B, while afforestation at Site D helped reduce the bare sand count there.

From 2000 to 2007, no significant change was recorded in the area of bare sand at any of the sites. Most of the changes noted after 2000, albeit insignificant, appeared to be related to natural causes (blowouts of unstable dunes near the beach) rather than land management issues, although tracking may have contributed to the slight change recorded at Site A.

Overall, from 1994 to 2007, small increases in bare sand counts were noted at Sites A and B and a small decrease occurred at Site D, while Site C showed no significant change.

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8. Appendix

Appendix 1
Taranaki monitoring sites: Eastern hill country and coastal sand country