Environment Waikato Technical Report 2009/30

Changes in Soil Stability in the Waikato Region from 2002 to 2007

www.ew.govt.nz
ISSN 1172-4005 (Print)
ISSN 1177-9284 (Online)

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REGIONAL COUNCIL

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December 2009

Document #: 1578802

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Acknowledgements

Acknowledgments are due to Environment Waikato for commissioning the survey; to Reece Hill (EW soil scientist) for initial discussions which facilitated survey design and for comments on the draft reports; to Dan Borman (EW geographic information systems specialist) for setting up a Geomedia procedure for on-screen photo-interpretation and assisting with its use; to Janice Stokes (EW Team Leader – Customer Support) for document formatting; and to Amy Taylor (ARC soil scientist) for making ARC report and table templates available.

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Introduction

This report compares surveys of soil stability (intactness and disturbance) undertaken for Environment Waikato (EW) in 2003 and 2009. Data were point-sampled from aerial photographic cover of the region in 2002 and 2007 respectively. Both surveys were undertaken primarily to provide information about soil stability (intactness and disturbance) for state of environment reporting.

The monitoring was defined by the boundaries of the area that EW has statutory responsibility for. Within this area, soil stability was assessed at 6122 sample points, distributed at 2 kilometre intervals on the map grid, using digital orthophotos taken for EW in 2002 and 2007. Data recorded were land use, associated vegetation, soil stability, soil disturbance (if present), and area freshly disturbed (where present).

Region-wide changes in soil stability

Stable surfaces in the Waikato region have not changed. They were 50.9% of land in 2002 and 49.8% in 2007.

Erosion-prone surfaces (unstable but inactive) have decreased from 33.0% of land in 2002 to 22.6% in 2007. The bulk of the decrease is re-classification of surfaces as either eroded or eroding.

Recently eroded and freshly eroding surfaces have increased from 9.5% of land in 2002 to 16.8% in 2007.

Stable or erosion-prone surfaces with intact soil (well-vegetated) decreased, from 77.2% of land in 2002 to 49.4% in 2007. The decrease is partly re-classification of surfaces as either eroded or eroding; but also an increase in soil temporarily disturbed by land use.

On stable and erosion-prone surfaces, temporary disturbance of soil by land use increased, from 6.7% of land in 2002 to 23.0% in 2007. This increase denotes that soil disturbed by land use is present on part (not all) of the surfaces' area.

Recently eroded surfaces with recovering soil (revegetating) increased, from 6.2% of land in 2002 to 9.3% in 2007.

On freshly eroding surfaces, long-term disturbance of soil by natural processes increased, from 3.3% of land in 2002 to 7.5% in 2007. This increase denotes that soil disturbed by natural processes is present on part (not all) of the surfaces' area.

Extensively disturbed surfaces have increased from 6.5% of land in 2002 to 7.0% in 2007. The bulk of the increase is disturbance associated with rural buildings, yards, quarries and mines.

The balance of the region was surfaces which could not be classified because photo cover was unavailable; up from 0.2% of land in 2002 to 3.9% in 2007.

Region-wide changes in soil disturbance

The area of bare ground exposed by all forms of disturbance increased significantly between 2002 and 2007, doubling from 1.37% to 2.85% of regional area.

Land use-related activities which have significantly increased area of bare soil on stable and erosion-prone surfaces are :

- Cultivation, up from 0.14% to 0.81%
- Tracks, up from 0.40% to 0.89%

The increase in soil bared by cultivation is caused by maize cropping, vegetable growing, and pasture renewal on dairy or drystock farms. Our conclusion after cross-checking 2007 with 2002 photographs is that the area of land in maize and vegetable crops has gone down slightly. The increased bare soil here appears due to 2007 photographs being taken earlier in the cultivation cycle, when more soil was visible amongst freshly sown crops. On dairy and drystock farms, the increased bare soil is also due to timing of 2007 photography which detected spring cultivation for pasture renewal.

The increase in ground bared by tracks is partly construction of tracks for forest harvest, but the greater part is extension or improvement of dairy races, plus some new tracking on drystock farms. Our conclusion after cross-checking 2007 with 2002 photographs is that the contributions from logging tracks (+0.04%) and dairy races (+0.27%) are new. However the contribution from drystock farm tracks (+0.13%) may not be, because many of the tracks where bare soil was recorded in 2007, were recorded as re-vegetating tracks in 2002.

Other land use-related activities have not contributed significantly to the increase in bare soil, apart from unsealed rural roads (which were present in 2002 though not recorded). Bare soil due to :

- harvest stayed the same, 0.15% of regional area at both dates,
- grazing pressure changed from 0.10% of regional area to 0.08%,
- spraying declined from 0.02% to <0.01%,
- drains went down from 0.04% to 0.03%,
- earthworks from 0.10% to 0.07%,
- rural roads went up, from unrecorded to 0.08%.

Natural processes of erosion or deposition, on eroded and eroding surfaces, have increased bare soil from 0.39% to 0.57% of the region's area. However this change is not significant because there is 0.06% overlap in error margins between the two measurements.

Landslides, streambank scour and deposition, sand-blow, sheet-wash and rock outcrops have all increased, but the individual increases are small and statistically insignificant.

Slumps and earthflow, gullies, and geothermal disturbance have decreased. Of these only the decrease in slumps and earthflows is statistically significant (from 0.04% to 0.01% of regional area).

On extensively disturbed surfaces, bare soil, sediment and rock increased significantly, from 0.05% of the region's area to 0.21%.

Disturbance associated with rural buildings contributed a substantial part of this increase (0.09%) although the increase was not statistically significant due to slight overlap of error margins (by 0.02% between measurements). Other components of the apparent increase were disturbance associated with urban areas (0.02%) and natural disturbance along shorelines (0.05%). Bare ground at these points was not recorded in 2002, but was detected in 2007 (due to a change in survey procedure), so these components are unlikely to be new.

Changes in soil disturbance on land in rural use

66.1% of Waikato's land was under rural uses in 2002, compared with 62.2% in 2007. Of the 1.28% region-wide increase in bare soil exposed by land use between 2002 and 2007 :

- horticulture and cropping contributed 0.46% of the increase,
- dairy farms contributed 0.45%,
- drystock pasture contributed 0.17%,
- forest plantations contributed 0.08%.

Of the 0.18% region-wide increase in bare soil exposed by natural processes between 2002 and 2007 :

- horticulture and cropping contributed <0.01%,
- dairy farms contributed 0.01%,
- drystock farms contributed 0.04%,
- forest plantations contributed 0.01%.

Changes in soil disturbance on land in conservation use

27.3% of Waikato's land was under conservation uses in 2002, compared with 26.9% in 2007. Of the 1.28% region-wide increase in bare soil exposed by land use between 2002 and 2007 :

- natural forest contributed 0%,
- natural scrub contributed 0.01%,
- exotic scrub contributed 0.01%,
- wetland and coastal vegetation contributed 0%,
- tussock and mountain vegetation contributed 0%.

Of the 0.18% region-wide increase in bare soil exposed by natural processes between 2002 and 2007 :

- natural forest contributed 0.01%,
- natural scrub contributed 0.01%,
- exotic scrub contributed -0.01%,
- wetland and coastal vegetation contributed 0.01%,
- tussock and mountain vegetation contributed 0.07%.

Changes in soil disturbance on land in other use

6.5% of Waikato's land was under other uses (urban, rural buildings etc., shorelines or waterbodies) in 2002, compared with 7.0% in 2007. Of the 1.28% region-wide increase in bare soil exposed by land use between 2002 and 2007 :

- rural buildings, yards, quarries and mines contributed 0.09%,
- urban areas contributed 0.02%,
- shorelines and waterbodies contributed <0.01%.

Of the 0.18% region-wide increase in soil exposed by natural processes between 2002 and 2007 :

- rural buildings, yards, quarries and mines contributed <0.01%,
- urban areas contributed <0.01%,
- shorelines and waterbodies contributed 0.04%.

1 Introduction

This report compares surveys of soil stability (intactness and disturbance) undertaken for Environment Waikato (EW) in 2003 and 2009. Data were point-sampled from aerial photographic cover of the region in 2002 and 2007 respectively. Both surveys were undertaken primarily to provide information about soil stability (intactness and disturbance) for state of environment reporting.

The document is the second of two reports:

- Soil Stability in the Waikato Region 2007
- **Changes in Soil Stability in the Waikato Region from 2002 to 2007**

2 Methods

Analysis methods for 2002/2007 comparisons are as described in Appendix 1 of the first report, except for the following features.

Data recording

Five problems were experienced with 2002 - 2007 comparisons due to differences in the way data were recorded:

1. No data for 10 points with no orthophoto cover in 2002, and no data for 241 points with no orthophoto cover in 2007

   These omissions precluded region-wide comparison of all 6122 points. Rather than attempt "cut-down" comparisons of change at 5881 points which were recorded at both dates, all comparisons were expressed as percentages of 6122. This has the effect that all numbers in region-wide tables for 2007 are under-estimates. One way to adjust for this would be to scale up by 3.9% (241/6122). For instance, total bare soil due to fresh disturbance of all types would rise from 2.85% to 2.96% of the region's area. However rises are small enough to be contained within the error margins for each category (for example +/-0.17% in 2002 and +/-0.24% in 2007), so there seems little point in applying a scaling factor, particularly as the effect on comparisons for each land use is less. For instance, 2002 records for the 241 missing points indicate that just 41 were dairy pasture at that date. Unless there was a great deal of fresh disturbance in 2007 at those particular points, their addition would have minimal effect on 2002-2007 change in soil disturbance for dairy farms (0.84% of the region's area, at 661 out of 1403 points).

2. The 2007 survey measured an additional category of soil disturbance (for consistency with LMF procedure)

   This was unsealed rural roads. Most if not all of these would have been present in 2002, so associated bare soil (0.08% of regional area) should not be regarded as new.

3. The 2007 survey appears to have detected far more unsealed farm tracks than were recorded in 2002.

   This has boosted bare soil by 0.49% of regional area. Some of the increase is undoubtedly genuine, but there is a possibility that tracks were either under-recorded in 2002 or over-recorded in 2007.

   In sections 4 and 5, text accompanying each table indicates whether the overall increases in bare soil region-wide/for each land use, are attributable to tracks and roads, or to other categories of disturbance measured consistently at both dates

(farming or forestry practices; natural processes of erosion and deposition), or to other changes in measurement practice between surveys.

4. There was some noticeable difference in the quality of aerial photography between 2002 and 2007. Colour balance and scanning resolution varied both between the two years and within each year and related mainly to. This necessitated some caution when interpreting vegetation cover in particular.

   Many 2007 photographs were taken during summer drought so improved pasture had a dry appearance. This had to be kept in mind when deciding whether to classify it as improved or unimproved. Cross-checking with the 2002 photos was helpful when making the decision. Unimproved pasture typically had a dark brown or purple tinge due to weed persistence in drought conditions. Another effect of photographic timing was that more pasture was recorded as sparse in 2007 than in 2002. This change was due to drought rather than land management.

   2002 photographs were scanned at a lower resolution during ortho-rectification than was the case in 2007. This had the effect that scattered secondary cover in pasture, also secondary cover interspersed with tree canopy, appeared de-focussed on 2002 photos so was sometimes hard to identify. Different secondary cover codes were recorded at some sample points because they could be seen more clearly on the 2007 photographs. Where this was done, a comment was inserted into the 2007 database, so that these alterations can be separated from genuine changes in secondary cover between the two dates.

   At a number of points where primary cover/land use appeared to have been incorrectly recorded in 2002 (on account of photo quality or other reasons), a comment was inserted into the 2007 database, so that altered land use codes can be differentiated from genuine land use changes.

5. The 2002 survey did not measure soil disturbance in urban areas, or along shorelines.

   Measurements at these points are now a part of LMF survey procedure, so were carried out in 2007. They have added an extra 0.02% bare ground in urban areas, and 0.05% along shorelines. Most if not all this bare ground is likely to have been present in 2002.

These problematical categories were retained in 2002-2007 comparisons, but are discussed separately in text accompanying each table where they occur. This was done in order to make clear whether the overall increases in bare soil region-wide/for each land use, are attributable to categories of disturbance measured consistently at both dates (farming or forestry practices; natural processes of erosion and deposition), or to changes in measurement practice for the problematic ones (roads, tracks, urban areas, shorelines).

The above problems are not expected to recur in a future survey, so long as all points can be re-sampled from new aerial photography, and so long as the same LMF categories are used for data recording, as have been adopted for the 2007 re-survey.

Data comparisons

Data comparisons between the 2007 and 2002 point sample were achieved, though some residual problems had to be taken into account, when preparing and interpreting comparative tables :

- 6 points where 2002 land use was recorded as bare ground, had to be re-distributed into other land uses to enable comparison of 2002-2007 soil disturbance. This had the effect of raising point numbers and bare soil

percentages for the affected land use tables (tussock and mountain vegetation), compared with what appears in the 2002 report's data tables.

- 29 points where 2002 land use was recorded as broadleaved trees, had to be re-assigned from the forest plantation tables into the wetland and coastal tables, because during re-survey it became obvious that they are willows growing in swamps. This dropped or raised point numbers in the respective tables, but had no effect on soil disturbance percentages because none was recorded at these points.

- 379 points were recorded as re-vegetating after land use disturbance in 2002. This soil stability category is no longer part of the standard LMF procedure, because revegetation after land use disturbance is rapid. So these points had to be re-assigned to the stable(vegetated) or erosion-prone (vegetated) category, to enable comparisons with 2007 data.

- 407 points were recorded as re-vegetating after natural disturbance in 2002. This soil stability category is retained in the standard LMF procedure, because re-vegetation after natural disturbance is slow. These points now appear in tables as the eroded and eroding (re-vegetating) category, to enable comparisons with 2007 data.

Significance of comparisons

Whether 2002-2007 comparisons indicate genuine change depends on several factors:

1. Scale of soil disturbance by various land uses over the five years.
2. Incidence of storms and floods i.e. soil disturbance by natural processes.
3. Any disturbance picked up at the second date because of differences in measurement procedure.
4. Sample error margins at each date.

The question is whether effects of 1 and 2 are detectable given the effects of 3 and 4. Comments about the significance or otherwise of changes are made in text accompanying each table (Sections 4 and 5).

Allowing for the balance between 1 and 2 on the one hand, and 3 and 4 on the other, there is 95% confidence that the following changes are significant:

- No change in stable surfaces; region-wide and for all land uses.
- Decline in erosion-prone surfaces; region-wide and for all land uses except horticulture and cropping.
- Increase in eroded and eroding surfaces; region-wide and for all land uses except wetland and coastal.
- Increase in points with soil disturbed by land use, on stable and erosion-prone surfaces; region-wide and for all land uses except: wetland and coastal, tussock and mountain vegetation.
- Increase in points with soil disturbed by natural processes on eroded and roding surfaces; region-wide and for all land uses except: horticulture and cropping, wetland and coastal.
- No change in extensively disturbed surfaces.
- Increase in other surfaces i.e. points with no aerial photo cover.
- Increase in bare soil caused by rural land use disturbance, region-wide; also for horticulture and cropping, dairy farms and drystock farms, but not for other land uses.
- No change in bare soil caused by natural disturbance, region-wide and for all land uses (slight increases were measured for all, but were within error margins in all instances).
- Increase in bare soil, sediment and rock caused by extensive disturbance.

Four important technical conclusions for point sample re-survey are that:

- re-survey every 5 years can detect significant changes in area of bare soil caused by land-use disturbance (aggregated) and natural disturbance (aggregated);
- re-survey every 5 years can detect significant changes in soil stability, soil intactness, and soil disturbance (aggregated).
- a longer interval will be required to detect significant change in area of bare soil for individual disturbance types.
- a longer interval will be required to detect significant changes in extent of individual disturbance types.

Overall comments on survey procedure

This is the second time that a regional council's point sample has been repeated. It was less of a test case than Auckland Regional Council's (from which much was learned about what needs to be standardised to enable comparison between dates). Most aspects of Waikato's 2007 re-survey proceeded smoothly in accordance with now-established LMF procedure (Burton *et al* 2009). Data comparisons between the 2007 and 2002 point sample were achieved, though some residual problems had to be taken into account, when preparing and interpreting comparative tables :

Key lessons for the contractors - and for other councils contemplating re-survey - are that :

- for region-wide change detection, all points need to measured at both dates.

- points with large percentages of bare ground need to be assigned to an appropriate land use, instead of appearing in tables as a separate category.

- any points previously recorded as re-vegetating after land use disturbance, need to be re-assigned as stable (vegetated) or erosion-prone (vegetated), to enable comparison of previous survey data with categories in the current LMF procedure.

- cata analysis is more straightforward if the same soil disturbance categories are recorded each time, so that they don't have to be combined or sub-divided to enable comparisons.

Similar problems will need to be resolved when three other trial point samples are re-measured e.g. Manawatu-Wanganui, Gisborne, Tasman, but should not attach to point samples carried out from 2004 onwards. They have been discussed at some length in section 2, to stress the importance of avoiding them in future re-surveys. It would be best to do so, not just from a time and cost perspective; but more importantly in terms of providing councils with comparisons that are easily made, and easy to follow.

3 Report structure

Initially the report will focus on region wide comparisons presented in two tables (Tables 4.1 and 4.2) of soil stability and soil disturbance.

The report then compares data for each land use between 2002 and 2007 (Tables 5.1 – 5.20).

For ease of comparison, 2002 and 2007 data are presented in adjoining columns in each table and a further column indicates if the difference is significant with respect to the 95% confidence limits calculated for each result. Explanatory text is provided after each table.

4 Regional changes 2002 - 2007

4.1 Soil stability

Table 1: Changes in soil stability throughout the Waikato region, 2002 - 2007

Points as % of sample:	2002	2007	Significant change:
Stable surfaces			
with intact soil	**46.0**	**33.1**	*Y*
95% c.i.	*1.2*	*1.2*	
with soil disturbed by land use	**4.9**	**16.7**	*Y*
95% c.i.	*0.5*	*0.9*	
Erosion-prone surfaces			
with intact soil	**31.2**	**16.3**	*Y*
95% c.i.	*1.2*	*0.9*	
with soil disturbed by land use	**1.8**	**6.3**	*Y*
95% c.i.	*0.3*	*0.6*	
Eroded and eroding surfaces			
with re-vegetating soil	**6.2**	**9.3**	
95% c.i.	*0.6*	*0.7*	
with soil disturbed by natural processes	**3.3**	**7.5**	*Y*
95% c.i.	*0.4*	*0.7*	
Extensively disturbed surfaces			
rural buildings etc.	**2.0**	**2.5**	*N*
95% c.i.	*0.3*	*0.4*	
urban areas etc.	**0.8**	**1.0**	*N*
95% c.i.	*0.2*	*0.3*	
shorelines etc.	**3.7**	**3.5**	*N*
95% c.i.	*0.5*	*0.5*	
Other surfaces			
unclassified points	**0.0**	**0.0**	-
95% c.i.	*0.0*	*0.0*	
points with no aerial photos	**0.2**	**3.9**	*Y*
95% c.i.	*0.1*	*0.5*	
All surfaces			
as percentage of sample	**100.0**	**100.0**	-
95% c.i.	*0.0*	*0.0*	

Note 1: % of sample' sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

4.1.1 Stable surfaces

Stable surfaces (no signs of present or past erosion) in the Waikato region have not changed (50.9% of sample points in 2002 to 49.8% in 2007).

Stable surfaces with intact soil have significantly decreased from 46.0% in 2002 to 33.1% in 2007, while surfaces where soil is disturbed by land use activities have increased significantly from 4.9% to 16.7%. These changes indicate soil intactness has temporarily declined in 2007, but that the decline is land-use related and reversible.

4.1.2 Erosion- prone surfaces

Erosion-prone surfaces (unstable, signs of past erosion but presently inactive) in the Waikato region have decreased between 2002 and 2007, from 33.0% of sample points

to 22.6%. A little of the decrease is simply due to reclassification of erosion-prone surfaces as stable at a few points, but that change is not significant. The bulk of the decrease is attributed to reclassification of erosion-prone surfaces as either eroded or eroding.

Surfaces with intact soil decreased significantly from 31.2% of sample points to 16.3% between 2002 and 2007. Of the 14.9% change, 4.5% is due to land use disturbance, and 10.4% is due to natural disturbance, i.e. an increase in surfaces where eroded and eroding soil is recorded.

4.1.3 Eroded and eroding surfaces

Recently eroded (re-vegetating) and freshly eroding (bare) surfaces increased from 9.5% of sample points in 2002 to 16.8% in 2007, as a result of natural erosion or deposition.

Re-vegetating surfaces increased significantly from 6.2% of sample points to 9.3%, whereas surfaces with bare soil more than doubled, from 3.3% to 7.5%. These changes indicate that soil intactness has also decreased long-term between 2002 and 2007 due to natural disturbance.

4.1.4 Extensively disturbed Surfaces

Extensively disturbed surfaces (soil partly or completely removed by erosion or earthworks) increased from 6.5% of sample points in 2002 to 7.0% in 2007. Most of the increase (0.5%) was attributable to rural buildings, although there was also a small increase in urban housing (0.2%). A 0.2% decrease in shorelines was recorded on account of point re-classification as land uses adjacent to shorelines (with shorelines recorded as associated). None of the individual changes were statistically significant.

4.1.5 Other surfaces

In 2007, data could not be recorded for 241 points (3.9% of the regional sample) on account of some areas not being photographed. However, in 2002 only 10 points (0.2% of the region) had no photographic cover.

4.2 Soil disturbance

Table 2: Changes in soil disturbance throughout the Waikato region, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure	**0.10**	**0.08**	*N*
95% c.i.	*0.02*	*0.02*	
cultivation	**0.14**	**0.81**	***Y***
95% c.i.	*0.07*	*0.19*	
harvest	**0.15**	**0.15**	*N*
95% c.i.	*0.05*	*0.05*	
spraying	**0.02**	**<0.01**	*N*
95% c.i.	*0.02*	*<0.01*	
drains	**0.04**	**0.03**	*N*
95% c.i.	*0.03*	*0.01*	
tracks	**0.40**	**0.89**	***Y***
95% c.i.	*0.06*	*0.07*	
earthworks	**0.10**	**0.07**	*N*
95% c.i.	*0.05*	*0.06*	
roads	**not rec. in 2002**	**0.08**	
95% c.i.	*-*	*0.02*	

	Bare soil as % of region:		Significant change:
	2002	2007	
All rural land use disturbance	**0.94**	**2.12**	***Y***
95% c.i.	*0.15*	*0.21*	
By natural processes:			
landslide	**0.04**	**0.06**	*N*
95% c.i.	*0.02*	*0.01*	
debris avalanche	**0.03**	**0.03**	*N*
95% c.i.	*0.02*	*0.02*	
slump or earth-flow	**0.04**	**0.01**	***Y***
95% c.i.	*0.02*	*<0.01*	
tunnel gully	**0.02**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
gully	**0.04**	**0.03**	*N*
95% c.i.	*0.02*	*0.01*	
streambank scour	**0.02**	**0.03**	*N*
95% c.i.	*0.01*	*0.01*	
streambank deposit	**0.02**	**0.03**	*N*
95% c.i.	*0.01*	*0.01*	
sandblow	**0.03**	**0.05**	*N*
95% c.i.	*0.03*	*0.05*	
sheetwash	**0.05**	**0.09**	*N*
95% c.i.	*0.04*	*0.05*	
rockfall or bare rock	**0.09**	**0.15**	*N*
95% c.i.	*0.07*	*0.08*	
geothermal	**0.03**	**0.02**	*N*
95% c.i.	*0.04*	*0.03*	
All rural natural disturbance	**0.39**	**0.53**	*N*
95% c.i.	*0.09*	*0.11*	
Other:			
rural buildings etc.	**0.05**	**0.14**	*N*
95% c.i.	*0.05*	*0.06*	
urban areas etc.	**not rec. in 2002**	**0.02**	
95% c.i.	*-*	*0.02*	
shorelines etc:	**not rec. in 2002**	**0.05**	
95% c.i.	*-*	*0.03*	
All other disturbance	**0.05**	**0.21**	***Y***
95% c.i.	*0.05*	*0.06*	
All disturbance:	**1.37**	**2.85**	***Y***
95% c.i.	*0.17*	*0.24*	

Note 1: % of sample' sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Overall, the area of bare ground from all forms of disturbance increased significantly between 2002 and 2007, doubling from 1.37% to 2.85% of regional area.

4.2.1 Land-use related disturbance

Land use activities which have resulted in significant changes in area of bare ground include:

- Cultivation, from 0.14% to 0.81% (six-fold increase)
- Tracks, from 0.40% to 0.89% (two-fold increase)

These two activities dominate the increase in bare soil caused by rural land-use disturbance from 0.94% to 2.12% of regional area. The increase in soil bared by cultivation is caused by maize cropping and outdoor vegetable production. To what extent this is a real change or a seasonal effect, is discussed in Section 5.1 (Horticulture and Cropping). Our conclusion, after cross-checking 2007 with 2002 photographs, is that it is a seasonal effect because 2007 photographs were taken in spring or early summer. The increase in apparent bare ground from tracks is partly due to construction of tracks for forest harvest, but the greater part is attributed to extension or improvement of dairy races, plus some new tracking on dry-stock farms. Whether these are real changes, seasonal effects, or artefacts of recording procedure, varies depending on each land use and is discussed in Sections 5.2 to 5.4. Our conclusion after cross-checking 2007 with 2002 photographs is that the contributions from logging tracks (+0.04%) and dairy races (+0.27%) are new. However the contribution from drystock farm tracks (+0.13%) may not be, because many of the tracks where bare soil was recorded in 2007, were recorded as re-vegetating tracks in 2002.

Other forms of land-use related disturbance have not contributed significantly to the increase in bare soil region-wide, apart from unsealed rural roads (which were present in 2002 though not recorded).

4.2.2 Disturbance by natural processes

Bare soil or rock, exposed by natural processes of erosion or deposition on rural land, has increased from 0.39% to 0.53% of the region's area. However, this change is not statistically significant, because there is 0.06% overlap in error margins.

Landslides, stream-bank scour and deposition, sand-blow, sheet-wash, and rock outcrops have all increased but the individual increases are small and statistically insignificant.

Slumps and earth-flows, gullies, and geothermal disturbance have decreased. Of these, only the decrease in slumps and earth-flows is statistically significant.

4.2.3 Other disturbance

Bare soil or rock exposed by activities which extensively disturb soil, increased significantly from 0.05% of the region’s area to 0.21%. Bare soil associated with rural buildings (e.g. earthworks) contributed a substantial part of this increase (0.09%) although the increase was not statistically significant due to 0.02% overlap of error margins. The other components of the apparent increase were from urban areas and shorelines/water-bodies. However, bare ground at these points was not recorded in 2002.

4.3 Land use

Summary land-use data are presented in this table as a background to discussions of soil stability under each land use.

Table 3: Changes in land use in Waikato region 2002 - 2007

Land use	Composition	Points 2002	Points 2007	Points as% of region 2002[1]	Points as% of region 2007[1]
horticulture and cropping	vineyards incl. kiwifruit		4	Incl with orchards	<0.1
	orchards incl. avocado		8	0.2	0.1
	vegetable crops		18	0.1	0.3
	grain crops		62	1.1	1.0
	greenfeed crops		16	0.4	0.3
	sub-total	**114**	**108**	**1.9**	**1.8**
Dairy	improved, hard-grazed		280	4.5	4.6
	improved, lax-grazed or spelled		1067	19.4	17.4
	improved, harvested		56	0.3	0.9
	sub-total	**1482**	**1403**	**24.2**	**22.9**
Drystock	improved, hard-grazed		453	4.7	7.4
	improved, lax-grazed or spelled		923	17.8	15.1
	improved, harvested		17	0.5	0.3
	unimproved		151	3.9	2.5
	sub-total	**1638**	**1544**	**26.8**	**25.2**
Forest plantations	open-canopy pines		173	4.0	2.8
	maturing pines		468	7.4	7.6
	harvested pines		84	1.8	1.4
	broadleaved trees		24	Incl. with pines	0.4
	sub-total	**807**	**749**	**13.2**	**12.2**
Natural forest	closed canopy		346	5.8	5.7
	with natural scrub		222	3.4	3.6
	with exotic grass, scrub or trees		58	0.3	0.9
	with other, principally houses		3	Incl. with exotic grass etc	<0.1
	sub-total	**583**	**629**	**9.5**	**10.3**
Natural scrub	closed canopy		167	4.7	2.7
	with forest trees		298	5.0	4.9
	with exotic grass, scrub or trees		182	1.6	3.0
	with other, principally houses		6	Incl. with exotic grass etc	0.1
	sub-total	**692**	**653**	**11.3**	**10.7**

Land use	Composition	Points 2002	Points 2007	Points as% of region 2002[1]	Points as% of region 2007[1]
Exotic scrub	closed canopy		29	0.7	0.5
	with natural scrub or forest trees		70	1.6	1.1
	with exotic grass or trees		82	1.0	1.3
	with other, principally houses		1	Incl. with exotic grass etc	<0.1
	sub-total	**202**	**182**	**3.3**	**3.0**
Tussock and mountain	tussock		20	0.2	0.3
	sub-alpine		58	0.9	0.9
	alpine		41	0.9	0.7
	bare rock		6	0.1	0.1
	sub-total	**130**	**125**	**2.1**	**1.9**
Wetland and coastal	wetland		52	1.0	0.8
	mangrove		1	Incl. with wetland	<0.1
	coastal grass and scrub		6	0.1	0.1
	sub-total	**69**	**59**	**1.1**	**1.0**
Other	rural buildings etc.		151	2.0	2.5
	urban areas etc.		63	0.8	1.0
	shorelines etc.		215	3.7	3.5
	unclassified points		0	0.0	-
	points with no photo cover		241	0.2	3.9
	sub-total	**404**	**670**	**6.6**	**10.9**
All region	**total**	**6122**	**6122**	**100**	**100**

Note 1: '% of sample' sub-totals/totals may differ by 0.1% due to rounding

5 Rural land-use changes 2002 - 2007

5.1 Cropping and horticulture changes

5.1.1 Soil stability amongst cropping and horticulture

Table 4: Changes in soil stability amongst cropping and horticulture, 2002 - 2007

Points as % of sample:	2002	2007	Significant change:
Stable surfaces			
with intact soil	**1.4**	**0.5**	***Y***
95% c.i.	*0.3*	*0.2*	
with soil disturbed by land use	**0.2**	**1.1**	***Y***
95% c.i.	*0.1*	*0.3*	
Erosion-prone surfaces			
with intact soil	**0.2**	**<0.1**	*N*
95% c.i.	*0.1*	*0.1*	
with soil disturbed by land use	**<0.1**	**0.1**	*N*
95% c.i.	*<0.1*	*0.1*	
Eroded and eroding surfaces			
with revegetating soil	**<0.1**	**<0.1**	*N*
95% c.i.	*<0.1*	*<0.1*	
with soil disturbed by natural processes	**<0.1**	**<0.1**	*N*
95% c.i.	*0.0*	*<0.1*	
All surfaces in land use			
as percentage of sample	**1.9**	**1.8**	*N*
95% c.i.	*0.3*	*0.3*	

Note 1: '% of sample' sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Overall, soil stability has not changed between 2002 and 2007 on stable surfaces (1.6% of region-wide sample points at both dates). The only changes apparent are surfaces with intact soil which have decreased significantly from 1.4% to 0.5%, with a corresponding increase in surfaces with disturbed soil from 0.2% to 1.1%. The increase is due to land use disturbance at a greater number of points in 2007 (see section 5.1.2 for causes).

There has been a slight drop in erosion-prone surfaces between 2002 and 2007 (from 0.2% to 0.1% of region-wide sample points). Erosion-prone surfaces with intact soil have decreased (0.2% to <0.1%), while surfaces with disturbed soil have increased (<0.1% to 0.1%). However, these changes are not statistically significant.

There has been no significant change in eroded and eroding surfaces, on account of either land use activities or natural processes.

5.1.2 Soil disturbance amongst cropping and horticulture

Table 5: Changes in soil disturbance amongst horticulture and cropping, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	2007	
By land use:			
grazing pressure			
95% c.i.			
cultivation	**0.03**	**0.48**	***Y***
95% c.i.	*0.04*	*0.15*	
harvest	**0.02**	**0.01**	*N*
95% c.i.	*0.02*	*0.01*	
spraying			
95% c.i.			
drains		**<0.01**	
95% c.i.		*<0.01*	
tracks	**0.01**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
earthworks			
95% c.i.	*not recorded in 2002*	*<0.01*	
roads			
95%c.i.	*not recorded in 2002*	*<0.01*	
all land use disturbance	**0.06**	**0.52**	***Y***
95% c.i.	*0.05*	*0.16*	
By natural processes:			
landslide			
95% c.i.			
debris avalanche			
95% c.i.			
slump or earthflow			
95% conf			
tunnel gully			
95% conf			
gully			
95% conf			
streambank scour			
95% c.i.			
streambank deposit		**<0.01**	
95% c.i.		*<0.01*	
sandblow			
95% c.i.			
sheetwash			
95% c.i.			
rockfall or bare rock			
95% c.i.			
geothermal			
95% c.i.			
all natural disturbance	**0.00**	**<0.01**	*N*
95% c.i.	*0.00*	*<0.01*	
All disturbance:	**0.06**	**0.52**	***Y***
95% c.i.	*0.05*	*0.16*	

Note 1: '% of sample' sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Soil disturbance has increased eight-fold between 2002 and 2007. This is almost entirely due to disturbance by land use. The main increase in bare soil has been cultivation, up from 0.03% (735 ha) to 0.48% (11760 ha) of the region's area (16-fold increase). Other changes (bare soil exposed by harvest, drainage or earthworks) are insignificant.

Orchards and vineyards remained the same, at 12 points, between 2002 and 2007. Vegetable production increased from 12 to 18, while grain crops (including maize) and green-feed crops decreased, (67 to 62 and 23 to 16 respectively). The increase in bare soil, as it is recorded at fewer points, is not due to an increase in cropped area but appears due to 2007 photographs being taken earlier in the cultivation cycle, when more soil was visible amongst freshly sown crops.

Soil disturbance from natural processes has not changed significantly between 2002 and 2007. Under horticulture and cropping, it remains negligible at less than 0.01% (less than 245 ha) of the region's area. The only form of erosion recorded in 2007 was stream bank deposition (one point).

5.1.3 Contribution to regional change, 2002 - 2007

Horticulture and cropping have contributed 1.0% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Bare soil exposed by land use disturbance has increased from 0.99% to 2.27% of the region's area. Of this increase, more than a third (0.46%) is attributable to horticulture and cropping, almost entirely due to an increase in cultivation. This is very high in proportion to the regional area occupied by horticulture and cropping (1.9% of regional points in 2002, 1.8% in 2007).

Horticulture and cropping made a negligible contribution (<0.1%) to the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007.

Bare soil exposed by natural processes has increased from 0.39% to 0.57% of the region's area. Horticulture and cropping's share of the increase is negligible at <0.01%.

5.2 Dairy pasture changes

5.2.1 Soil stability amongst dairy pasture

Table 6: Changes in soil stability amongst dairy pasture, 2002 – 2007

	Points as % of sample:		Significant change:
	2002	**2007**	
Stable surfaces			
with intact soil	**16.7**	**9.9**	***Y***
95% c.i.	*0.9*	*0.7*	
with soil disturbed by land use	**2.5**	**8.9**	***Y***
95% c.i.	*0.4*	*0.7*	
Erosion-prone surfaces			
with intact soil	**4.0**	**1.2**	***Y***
95% c.i.	*0.5*	*0.3*	
with soil disturbed by land use	**0.4**	**1.1**	***Y***
95% c.i.	*0.1*	*0.3*	
Eroded and eroding surfaces			
with revegetating soil	**0.4**	**1.0**	***Y***
95% c.i.	*0.2*	*0.2*	

with soil disturbed by natural processes	**0.3**	**0.8**	***Y***
95% c.i.	*0.1*	*0.2*	
All surfaces in land use			
as percentage of sample	**24.2**	**22.9**	*N*
95%c.i.	*1.1*	*1.1*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Stable surfaces have not changed significantly between 2002 and 2007 (19.2% to 18.8% of region-wide sample points). Some of the decrease is land that has gone out of dairying, and some is re-classification of stable points as erosion-prone. However, stable surfaces with intact soil have decreased significantly, from 16.7% to 9.9%. Stable surfaces with soil disturbed by dairy activities have correspondingly increased from 2.5% to 8.9%.

Erosion-prone surfaces have decreased between 2002 and 2007 from 4.4% to 2.3% of region-wide sample points. The causes are partly a decline in area of dairy pasture by 1.3%, and partly a transfer of points to eroded and eroding surfaces (adding 1.1%). Erosion-prone surfaces with intact soil have decreased significantly from 4.0% to 1.2% of regional sample points, while surfaces with soil disturbed by land use have increased from 0.4% to 1.1%.

Eroded and eroding surfaces under dairy pasture have increased significantly, from 0.4% to 1.0% of regional sample points for eroded surfaces (with re-vegetating soil), and from 0.3% to 0.8% for eroding surfaces (with soil disturbed by natural processes). Clearly, there has been an increase in natural disturbance of dairy pasture over the 5 year period, although the affected land is still a small percentage of the Waikato's area.

5.2.2 Soil disturbance amongst dairy pasture

Table 7: Changes in soil disturbance amongst dairy pasture, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure	**0.06**	**0.03**	*N*
95% c.i.	*0.04*	*0.01*	
cultivation	**0.04**	**0.25**	***Y***
95% c.i.	*0.04*	*0.09*	
harvest	**0.02**	**<0.01**	*N*
95% c.i.	*0.03*	*<0.01*	
spraying	**<0.01**		
95% c.i.	*<0.01*		
drains	**0.01**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
tracks	**0.21**	**0.48**	***Y***
95% c.i.	*0.04*	*0.05*	
earthworks	**0.02**	**0.01**	*N*
95% c.i.	*0.01*	*0.01*	
roads	**not rec. in 2002**	**0.02**	
95% c.i.	*not rec. in 2002*	*0.01*	
all land use disturbance	**0.36**	**0.81**	***Y***
95% c.i.	*0.08*	*0.10*	
By natural processes:			
landslide		**<0.01**	
95% c.i.		*<0.01*	

	Bare soil as % of region:		Significant change:
	2002	2007	
debris avalanche		**<0.01**	
95% c.i.		*<0.01*	
slump or earthflow		**<0.01**	
95% c.i.		*<0.01*	
tunnel gully	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
gully	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank scour	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank deposit	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
sandblow	**<0.01**	**<0.01**	*N*
95% c.i.			
sheetwash			
95% c.i.			
rockfall or bare rock	**0.01**	**0.01**	*N*
95% c.i.	*0.01*	*<0.01*	
geothermal			
95% c.i.			
all natural disturbance	**0.02**	**0.03**	***Y***
95% c.i.	*0.01*	*0.01*	
All disturbance:	**0.38**	**0.84**	***Y***
95% c.i.	*0.08*	*0.10*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Soil disturbance under dairy pasture has significantly increased from 0.38% of the region (9310 ha) in 2002 to 0.84% (20580 ha) in 2007.

Two land use-related activities - cultivation and tracks (+0.21% and +0.27% respectively) account for all the increase (natural disturbance increase is minimal). Slight though insignificant changes in other activities, e.g. grazing pressure, are offset against the cultivation and tracking increases to give a net change of 0.46% in disturbed soil.

The increased bare soil under cultivation may be attributable to more pasture renewal and supplementary feed. However, the increase is also partly due to timing of the aerial photography in 2007 compared with 2002. The 2002 photography was undertaken later in the spring/summer.

The increase in bare ground associated with tracks is partly bare soil, and partly improvement or extension of dairy races i.e. soil has been disturbed but surface-coated.

Soil disturbance from natural processes has not changed significantly between 2002 and 2007 for any single form of erosion. The overall increase in bare soil from 0.02% (490 ha) to 0.03% (735 ha) of the region's area is statistically significant but still small.

5.2.3 Contribution to regional change, 2002 - 2007

Dairy farms have contributed 7.1% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Of the 1.28% increase in bare soil exposed by land use disturbance, more than a third (0.45%) is attributable to dairy farming, mainly bare soil from tracks and cultivation. This is large in proportion to the regional area occupied by dairy farming (24.2% of the region in 2002 to 22.9% in 2007), and is a large increase given that the area under dairy farming has declined.

Dairy farms contributed 0.5% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007. This is a result of new erosion on formerly inactive surfaces.

Bare soil exposed by natural processes has increased from 0.39% to 0.57% of the region's area. However, dairy farming is only a minor contributor (0.01%) to the regional increase in bare soil between 2002 and 2007.

5.3 Dry-stock pasture changes

5.3.1 Soil stability amongst dry-stock pasture

Table 8: Changes in soil stability amongst dry-stock pasture, 2002 - 2007

	Points as % of sample:		Significant change:
	2002	**2007**	
Stable surfaces			
with intact soil	**11.1**	**7.8**	***Y***
95% c.i.	*0.8*	*0.7*	
with soil disturbed by land use	**1.2**	**4.3**	***Y***
95% c.i.	*0.3*	*0.5*	
Erosion-prone surfaces			
with intact soil	**9.6**	**3.8**	***Y***
95% c.i.	*0.7*	*0.5*	
with soil disturbed by land use	**0.8**	**2.8**	***Y***
95% c.i.	*0.2*	*0.4*	
Eroded and eroding surfaces			
with revegetating soil	**2.4**	**2.8**	*N*
95% c.i.	*0.4*	*0.4*	
with soil disturbed by natural processes	**1.7**	**3.7**	***Y***
95% c.i.	*0.3*	*0.5*	
All surfaces in land use			
as percentage of sample	**26.8**	**25.3**	*N*
95%c.i.	*1.1*	*1.1*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Stable surfaces have scarcely changed between 2002 and 2007, (12.3% and 12.1% of the regional sample respectively). However, surfaces with intact soil have decreased significantly from 11.1% to 7.8%, while surfaces with soil disturbed by land use have increased significantly from 1.2% to 4.3%.

Erosion-prone surfaces have decreased from 10.4% to 6.6% of the regional sample, due to land use change (-1.4%) and transfer of points into the eroded and eroding categories, by natural disturbance between 2002 and 2007. The balance between surfaces with intact soil and disturbed soil has shifted significantly, due to greater land use disturbance.

Eroded surfaces with re-vegetating soil have not changed significantly between 2002 and 2007, but surfaces disturbed by natural processes have increased significantly, from 1.7% to 3.7% of the regional sample.

5.3.2 Soil disturbance amongst dry-stock pasture

Table 9: Changes in soil disturbance amongst dry-stock pasture, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure	**0.04**	**0.06**	***Y***
95% c.i.	*0.01*	*0.01*	
cultivation	**0.05**	**0.08**	*N*
95% c.i.	*0.04*	*0.05*	
harvest	**0.01**	**<0.01**	*N*
95% c.i.	*0.01*	*<0.01*	

	Bare soil as % of region:		Significant change:
	2002	**2007**	
spraying	**0.02**	**<0.01**	*N*
95% c.i.	*0.02*	*<0.01*	
drains	**0.02**	**<0.01**	*N*
95% c.i.	*0.02*	*<0.01*	
tracks	**0.09**	**0.22**	***Y***
95% c.i.	*0.03*	*0.03*	
earthworks	**0.02**	**0.04**	*N*
95% c.i.	*0.02*	*0.02*	
roads	**not rec. in 2002**	**0.01**	
95% c.i.	*not rec. in 2002*	*0.01*	
all land use disturbance	**0.25**	**0.42**	***Y***
95% c.i.	*0.07*	*0.06*	
By natural processes:			
landslide	**0.03**	**0.04**	*N*
95% c.i.	*0.02*	*0.01*	
debris avalanche			
95% c.i.			
slump or earthflow	**0.04**	**<0.01**	*N*
95% c.i.	*0.02*	*<0.01*	
tunnel gully	**0.01**	**0.02**	*N*
95% c.i.	*<0.01*	*0.01*	
gully	**0.02**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
streambank scour	**<0.01**	**0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank deposit	**0.01**	**0.01**	*N*
95% c.i.	*0.01*	*0.01*	
sandblow	**0.01**	**0.04**	*N*
95% c.i.	*0.01*	*0.04*	
sheetwash			
95% c.i.			
rockfall or bare rock	**0.01**	**0.03**	*N*
95% c.i.	*0.01*	*0.02*	
geothermal			
95% c.i.			
all natural disturbance	**0.13**	**0.16**	*N*
95% c.i.	*0.03*	*0.05*	
All disturbance:	**0.38**	**0.59**	***Y***
95% c.i.	*0.08*	*0.08*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Soil disturbance has increased significantly between 2002 and 2007 on dry-stock pasture, from 0.38% (9310 ha) of the region in 2002 to 0.59% (14455 ha) in 2007.

Most of the increase is accounted for by two land use-related activities: soil bared by grazing pressure significantly increased from 0.04% to 0.06% of the region's area; and soil disturbed by farm tracks increased from 0.09% to 0.22%. Other changes in land use disturbance are individually insignificant, but collectively contribute an extra 0.02%. The increase due to grazing pressure is explained by the dry season experienced during the summer of 2007. The apparent increase in bare soil due to tracking is partly new tracks, but part may be due to a difference in recording procedure i.e. tracks recorded as revegetating in 2002, where residual bare soil was measured in 2007 (see Methods Report).

There was no significant increase in bare soil for any category of natural disturbance under dry-stock operations. There was a slight increase in total bare soil caused by natural disturbance, from 0.13% (3185 ha) to 0.16% (4165 ha) of the region's area, but not to a statistically significant level.

5.3.3 Contribution to regional change, 2002 - 2007

Drystock farms have contributed 5.1% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Of the 1.28% region-wide increase in bare soil exposed by land use disturbance, 0.17% is attributable to tracks, cultivation, grazing pressure and earthworks associated with dry-stock farming. This is not large in relation to the regional area occupied by dry-stock farming (26.8% of the region in 2002, 25.3% in 2007), but is a considerable increase given that the area under dry-stock farming has declined slightly.

Drystock farms contributed 2.0% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007, as a result of fresh erosion on erosion-prone surfaces.

Bare soil exposed by natural processes has increased from 0.39% to 0.57% of the region's area. The contribution from dry-stock farming is 0.03%, (a quarter of the increase; about what would be expected).

5.4 Exotic forest plantation changes

5.4.1 Soil stability amongst exotic forest plantations

Table 10: Changes in soil stability amongst exotic forest plantations, 2002 -

	Points as % of sample		Significant change:
	2002	**2007**	
Stable surfaces			
with intact soil	**6.7**	**5.2**	***Y***
95% c.i.	*0.6*	*0.6*	
with soil disturbed by land use	**0.9**	**2.0**	***Y***
95% c.i.	*0.2*	*0.3*	
Erosion-prone surfaces			
with intact soil	**4.4**	**2.6**	***Y***
95% c.i.	*0.5*	*0.4*	
with soil disturbed by land use	**0.3**	**1.2**	***Y***
95% c.i.	*0.1*	*0.3*	
Eroded and eroding surfaces			
with revegetating soil	**0.7**	**0.8**	*N*
95% c.i.	*0.2*	*0.2*	
with soil disturbed by natural processes	**0.2**	**0.5**	***Y***
95% c.i.	*0.1*	*0.2*	
All surfaces in land use			
as percentage of sample	**13.2**	**12.2**	*N*
95% c.i.	*0.8*	*0.8*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Stable surfaces have decreased slightly between 2002 and 2007, from 7.6% to 7.2% of regional sample points. Surfaces with intact soil have decreased significantly from 6.7% to 5.2%, while surfaces disturbed by forest activities have increased significantly from 0.9% to 2.0%.

Erosion-prone surfaces have decreased from 4.7% to 3.8% of regional sample points. The cause is partly transfer of points to the eroded and eroding surface category (by natural erosion), but also a decline in the area of land under forest plantations (dairy or dry-stock conversions). These changes have caused part of the significant drop in

surfaces with intact soil, (from 4.4% to 2.6%), with the balance accounted for by a significant rise in surfaces with disturbed soil (from 0.3% to 1.2%).

On eroded and eroding surfaces, there has been a significant increase in surfaces with soil disturbed by natural processes (0.2% of regional sample points in 2002 to 0.5% in 2007), and a slight but insignificant increase in surfaces with re-vegetating soil (0.7% in 2002 to 0.8% in 2007).

5.4.2 Soil disturbance amongst exotic forest plantations

Table 11: Changes in soil disturbance amongst forest plantations, 2002 – 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
cultivation		**<0.01**	
95% c.i.		*<0.01*	
harvest	**0.08**	**0.13**	*N*
95% c.i.	*0.04*	*0.05*	
spraying			
95% c.i.			
drains			
95% c.i.			
tracks	**0.07**	**0.11**	*N*
95% c.i.	*0.03*	*0.03*	
earthworks	**0.03**	**0.01**	*N*
95% c.i.	*0.02*	*0.01*	
roads	**not rec. in 2002**	**0.03**	
95% c.i.	*not rec. in 2002*	*0.01*	
all land use disturbance	**0.19**	**0.27**	*N*
95% c.i.	*0.05*	*0.06*	
By natural processes:			
landslide	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
debris avalanche		**<0.01**	
95% c.i.		*<0.01*	
slump or earthflow		**<0.01**	
95% c.i.		*<0.01*	
tunnel gully	**0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
gully	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank scour	**<0.01**	**<0.01**	*N*
95% c.i.			
streambank deposit	**<0.01**	**<0.01**	
95% c.i.			
sandblow			
95% c.i.			
sheetwash			
95% c.i.			
rockfall or bare rock	**<0.01**	**0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
geothermal			

	Bare soil as % of region:		Significant change:
	2002	2007	
95% c.i.			
all natural disturbance	**0.01**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
All disturbance:	**0.20**	**0.29**	*N*
95% c.i.	*0.05*	*0.06*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There is an increase in soil disturbance under exotic forest plantations between 2002 and 2007, from 0.20% (4900 ha) to 0.29% (7105 ha) of the region. However, the change is not statistically significant because there is a slight overlap of error margins.

Bare soil disturbed by forest activities increased from 0.19% of the region's area in 2002 to 0.27% in 2007, although this increase was not statistically significant. The increase was due to harvest (0.08% to 0.13%) and tracks (0.07% to 0.11%). Some of the increase was also due to recording of bare ground associated with unsealed roads which were not recorded in 2002. There was a decrease from 0.03% to 0.01% associated with earthworks e.g. harvest platforms. None of the changes for individual disturbance types were statistically significant.

Bare soil disturbed by natural processes increased from 0.01% of the region's area (245 ha) in 2002 to 0.02% (490 ha) in 2007, although this increase was not statistically significant. The increase was mainly due to mass movement (earthflow and debris avalanche), with a small part due to bare rock which became visible after removal of tree canopy on harvested areas.

5.4.3 Contribution to regional change, 2002 - 2007

Forest plantations have contributed 2.0% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Of the increase in bare soil exposed by land use disturbance region-wide, (1.28% of the region's area), 0.09% (2205 ha) is attributable to exotic forest activities, with the larger proportion due to harvest operations and logging tracks. This is somewhat lower than would be expected in relation to the area occupied by exotic forest plantations (13.2% of the region in 2002, 12.2% in 2007), but is a moderate increase given that the regional area under exotic forestry has declined slightly.

Forest plantations contributed 0.1% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007, as a result of fresh erosion on erosion-prone surfaces.

Bare soil exposed by natural processes has increased from 0.39% to 0.57% of the region's area. The contribution of exotic forest plantations to this increase is 0.01% (245 ha), - very small considering the area of the region under this land use, but noteworthy as it represents a doubling in bare soil within plantations.

5.5 Natural forest changes

5.5.1 Soil stability amongst natural forest

Table 12: Changes in soil stability amongst natural forest, 2002 – 2007

	Points as % of sample:		Significant change:
	2002	2007	
Stable surfaces			
with intact soil	**4.1**	**4.2**	*N*
95% c.i.	*0.5*	*0.5*	
with soil disturbed by land use	**<0.1**	**0.1**	*N*
95% c.i.	*<0.1*	*0.1*	
Erosion-prone surfaces with intact soil	**4.6**	**3.6**	***Y***
95% c.i.	*0.5*	*0.5*	
with soil disturbed by land use	**<0.1**	**0.2**	***Y***
95% c.i.	*<0.1*	*0.1*	
Eroded and eroding surfaces			
with revegetating soil	**0.6**	**1.7**	***Y***
95% c.i.	*0.2*	*0.3*	
with soil disturbed by natural processes	**0.2**	**0.5**	***Y***
95% c.i.	*0.1*	*0.2*	
All surfaces in land use			
as percentage of sample	**9.5**	**10.3**	*N*
95% c.i.	*0.7*	*0.8*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Stable surfaces under natural forest have not changed significantly between 2002 and 2007 (4.1% of regional sample points to 4.2%). Almost all surfaces remain intact and surfaces disturbed by land use remain minimal.

Erosion-prone surfaces have decreased from 4.6% to 3.8% of regional sample points. There has been a significant decline in surfaces with intact soil (4.6% to 3.6%), and a significant but slight increase in surfaces with soil disturbed by land use (<0.1% to 0.2%), with the difference accounted for by points transferred into the eroded and eroding category after natural disturbance.

Eroded and eroding surfaces have increased from 0.8% to 2.2% of regional sample points. Re-classification of points from scrub to forest (+0.6%) and natural disturbance (+0.5%), has significantly increased surfaces with re-vegetating soil within forests, from 0.6% to 1.7% of the region; and fresh disturbance has increased surfaces with bare soil (scars), from 0.2% to 0.5%.

5.5.2 Soil disturbance amongst natural forest

Table 13: Changes in soil disturbance amongst natural forest, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	2007	
By land use:			
grazing pressure			
95% c.i.			
cultivation			
95% c.i.			
harvest	**0.01**	**0.00**	***Y***
95% c.i.	*0.02*	*0.00*	
Spraying			
95% c.i.			
drains			
95% c.i.			
tracks	**<0.01**	**0.01**	*N*
95% c.i.	*<0.01*	*0.01*	
earthworks		**<0.01**	*N*
95% c.i.		*<0.01*	
roads	**not rec. in 2002**	**<0.01**	
95% c.i.	-	*<0.01*	
all land use disturbance	**0.01**	**0.01**	*N*
95% c.i.	*0.02*	*0.01*	
By natural processes:			
landslide	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
debris avalanche	**<0.01**	**0.01**	*N*
95% c.i.	*0.01*	*<0.01*	
slump or earthflow			
95% c.i.			
tunnel gully			
95% c.i.			
gully	**0.01**	**0.00**	***Y***
95% c.i.	*0.01*	*0.00*	
streambank scour	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank deposit		**<0.01**	
95% c.i.		*<0.01*	
sandblow			
95% c.i.			
sheetwash			
95% c.i.			
rockfall or bare rock			
95% c.i.			
geothermal			
95% c.i.			
all natural disturbance	**0.01**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
All disturbance:	**0.02**	**0.03**	*N*
95% c.i.	*0.02*	*0.01*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There has been a slight increase in soil disturbance under natural forest between 2002 and 2007, from 0.02% (490 ha) to 0.03% (735 ha) of the region's area. However the increase is not statistically significant.

There has been no significant change in the area of bare soil as a result of land use. However, a significant decrease has been recorded for harvest as no forest clearance was recorded in 2007.

There has been no significant change in the area of bare soil as a result of natural processes (up by 0.01% of regional area or 245 ha). However, because some gully erosion was recorded in 2002 whereas it was not observed in 2007, that particular decrease appears statistically significant.

5.5.3 Contribution to regional change, 2002 - 2007

Natural forest has contributed 0.2% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Bare soil exposed by land use disturbance remains unchanged at 0.01% (245 ha) of the region's area; a small decrease in area disturbed from harvesting, balanced by a small increase in area disturbed by tracks, unsealed roads and earthworks.

Natural forest contributed 0.3% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007.

Bare soil exposed by natural processes has increased from 0.39% to 0.57% of the region's area. The contribution from natural forest to this increase is 0.01% (245 ha), - very small considering the area of the region under this land-use (9.5% in 2002 and 10.3% in 2007). Its contribution is a result of limited fresh erosion or deposition along gullies and stream-banks. While the area of bare soil within natural forest has doubled, it remains very small.

5.6 Natural scrub changes

5.6.1 Soil stability amongst natural scrub

Table 14: Changes in soil stability amongst natural scrub, 2002 - 2007

	Points as % of sample:		Significant change:
	2002	2007	
Stable surfaces			
with intact soil	**4.4**	**3.8**	*N*
95% c.i.	*0.5*	*0.5*	
with soil disturbed by land use	**<0.1**	**0.3**	***Y***
95% c.i.	*0.1*	*0.1*	
Erosion-prone surfaces			
with intact soil	**5.1**	**3.4**	***Y***
95% c.i.	*0.6*	*0.5*	
with soil disturbed by land use	**0.1**	**0.4**	***Y***
95% c.i.	*0.1*	*0.1*	
Eroded and eroding surfaces			
with revegetating soil	**1.5**	**2.0**	
95% c.i.	*0.3*	*0.4*	***Y***
with soil disturbed by natural processes	**0.2**	**0.8**	***Y***
95% c.i.	*0.1*	*0.2*	
All surfaces in land use			
as percentage of sample	**11.3**	**10.7**	*N*
95% c.i.	*0.8*	*0.8*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There has been a slight decrease in stable surfaces, from 4.4% of regional sample points to 4.1% between 2002 and 2007. Intact surfaces have dropped from 4.4% to 3.8%, though the change is not statistically significant. Surfaces disturbed by land use have increased significantly from <0.1% to 0.3%. Another 0.3% of stable points transferred to other land uses.

Erosion-prone surfaces decreased from 5.2% of regional sample points to 3.8%. Surfaces with intact soil decreased significantly from 5.1% to 3.4%; the surfaces with soil disturbed by land use increased significantly from 0.1% to 0.4%. The balance was natural disturbance transferring points to the eroded and eroding category (-1.1%), and points transferred to other land uses (-0.3%).

Eroded and eroding surfaces increased from 1.7% to 2.8% of the regional sample points. A significant increase was recorded for re-vegetating soil amongst scrub (1.5% to 2.0%) and for surfaces with bare soil also (0.2% to 0.8%).

5.6.2 Soil disturbance amongst natural scrub

Table 15: Changes in soil disturbance amongst natural scrub, 2002 – 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure		**<0.01**	
95% c.i.		*<0.01*	
cultivation			
95% c.i.			
harvest	**0.01**		
95% c.i.	*0.02*		
spraying			
95% c.i.			
drains			
95% c.i.			
tracks	**0.01**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
earthworks	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
roads	**not rec. in 2002**	**<0.01**	
95% c.i.	*-*	*0.01*	
all land use disturbance	**0.02**	**0.03**	*N*
95% c.i.	*0.02*	*0.01*	
By natural processes:			
landslide	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
debris avalanche	**<0.01**		
95% c.i.	*<0.01*		
slump or earthflow			
95% c.i.			
tunnel gully	**<0.01**		
95% c.i.	*<0.01*		
gully	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank scour		**<0.01**	*N*
95% c.i.		*<0.01*	

streambank deposit		**<0.01**	**<0.01**	*N*
	95% c.i.	*<0.01*	*<0.01*	
sandblow				
	95% c.i.			
sheetwash				
	95% c.i.			
rockfall or bare rock		**<0.01**	**<0.01**	*N*
	95% c.i.	*<0.01*	*<0.01*	
geothermal				
	95% c.i.			
all natural disturbance		**0.02**	**0.03**	*N*
	95% c.i.	*0.01*	*0.01*	
All disturbance:		**0.04**	**0.06**	*N*
	95% c.i.	*0.02*	*0.01*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There has been an increase in soil disturbance under natural scrub between 2002 and 2007, from 0.04% (980 ha) to 0.06% (1470 ha) of the region's area, but the change is statistically insignificant.

Bare soil exposed by land use increased from 0.02% to 0.03% of regional area, but the increase was insignificant. It was the cumulative result of small increases or decreases for particular activities, notably tracking and scrub harvest/clearance.

A slight increase in bare soil has been recorded under natural scrub, as a result of natural processes of erosion or deposition. Rising from 0.02% (490 ha) to 0.03% (735 ha) of regional area, the increase is statistically insignificant.

5.6.3 Contribution to regional change, 2002 - 2007

Natural scrub has contributed 0.6% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Of the 1.28% increase in bare soil caused by land use region-wide, 0.01% (245 ha) is contributed by tracking in natural scrub. This is very small in relation to the area occupied by natural scrub (11.3% of the region in 2002 to 10.7% in 2007).

Natural scrub contributed 0.6% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007. This is due to diverse types of fresh erosion, and is about the level expected in relation to the regional area in natural scrub.

Bare soil exposed by natural processes has increased from 0.39% to 0.57% of the region's area. The contribution of natural scrub to this increase is 0.01% (245 ha), - very small and statistically insignificant, reflecting low incidence of natural erosion in scrub at both dates.

5.7 Exotic scrub changes

5.7.1 Soil stability amongst exotic scrub

Table 16: Changes in soil stability amongst exotic scrub, 2002 - 2007

	Points as % of sample:		Significant change:
	2002	**2007**	
Stable surfaces with intact soil	**1.0**	**1.0**	*N*

95% c.i.	*0.3*	*0.2*	
with soil disturbed by land use	**<0.1**	**0.1**	*N*
95% c.i.	*0.1*	*0.1*	
Erosion-prone surfaces			
with intact soil	**1.6**	**0.7**	*Y*
95% c.i.	*0.3*	*0.2*	
with soil disturbed by land use	**0.1**	**0.4**	*Y*
95% c.i.	*0.1*	*0.2*	
Eroded and eroding surfaces			
with revegetating soil	**0.3**	**0.4**	*N*
95% c.i.	*0.1*	*0.2*	
with soil disturbed by natural processes	**0.2**	**0.4**	*Y*
95% c.i.	*0.1*	*0.1*	
All surfaces in land use			
as percentage of sample	**3.3**	**3.0**	*N*
95% c.i.	*0.4*	*0.4*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Stable surfaces remained the same, at 1.1% of regional sample points between 2002 and 2007. No significant change was recorded for surfaces with intact soil (1.0%), or with soil disturbed by land use (0.1%).

Erosion-prone surfaces decreased from 1.7% to 1.1% of regional sample points; half due to transfer of points into the eroded and eroding category, and half due to points converted from exotic scrub into other use. Surfaces with intact soil decreased significantly from 1.6% to 0.7%, and surfaces with soil disturbed by land use increased significantly from 0.1% to 0.4%.

Eroded and eroding surfaces increased from 0.5% to 0.8% of the regional sample, due to natural disturbance. No significant change was recorded for surfaces with re-vegetating soil (0.3% to 0.4%), however surfaces with bare soil increased significantly from 0.2% to 0.4%.

5.7.2 Soil disturbance amongst exotic scrub

Table 17: Changes in soil disturbance amongst exotic scrub, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
cultivation			
95% c.i.			
harvest	**0.01**	**0.01**	*N*
95% c.i.	*0.02*	*0.01*	
spraying			
95% c.i.			
drains	**<0.01**		
95% c.i.	*0.01*		
tracks	**0.01**	**0.02**	*N*
95% c.i.	*0.01*	*0.01*	
earthworks		**0.01**	
95% c.i.		*0.02*	

roads	**not rec. in 2002**	**<0.01**	
95% c.i.	-	*<0.01*	
all land use disturbance	**0.03**	**0.04**	*N*
95% c.i.	*0.02*	*0.03*	
By natural processes:			
landslide	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
debris avalanche	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
slump or earthflow	**<0.01**		
95% c.i.	*<0.01*		
tunnel gully			
95% c.i.			
gully	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank scour	**<0.01**	**<0.01**	*N*
95% c.i.	*<0.01*	*<0.01*	
streambank deposit		**<0.01**	
95% c.i.		*<0.01*	
sandblow		**<0.01**	
95% c.i.		*0.01*	
sheetwash			
95% c.i.			
rockfall or bare rock	**0.01**	**<0.01**	*N*
95% c.i.	*0.01*	*<0.01*	
geothermal	**0.01**	**<0.01**	*N*
95% c.i.	*0.02*	*0.01*	
all natural disturbance	**0.03**	**0.02**	*N*
95% c.i.	*0.02*	*0.01*	
All disturbance:	**0.06**	**0.07**	*N*
95% c.i.	*0.03*	*0.03*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There has been no significant change in soil disturbance under exotic scrub between 2002 and 2007. It is up from 0.06% (1470 ha) to 0.07% (1715 ha).

Bare soil exposed by land use has increased from 0.03% to 0.04% of regional area, an insignificant increase, caused by greater tracking and earthworks. The increase in earthworks is individually significant, only because none was recorded in 2002.

Bare soil exposed by natural disturbance has declined, from 0.03% (735 ha) to 0.02% (490 ha) of regional area. The decline is statistically insignificant, as are the changes for individual disturbance types.

5.7.3 Contribution to regional change, 2002 - 2007

Exotic scrub has contributed 0.4% of the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

Of the 1.28% increase in bare soil caused by land use, 0.01% (245 ha) is attributable to clearance, tracking and earthworks in exotic scrub. This is less than expected in relation to the regional area occupied by exotic scrub (3.3% in 2002 and 3.0% in 2007).

Exotic scrub contributed 0.2% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007. The contribution by exotic scrub is a result of diverse types of fresh erosion, individually small in extent.

Exotic scrub made no net contribution to the region-wide increase in bare soil exposed by natural processes (from 0.39% to 0.57%). Although the number of points with fresh erosion increased, the area of bare soil under exotic scrub decreased by 0.01% (245 ha). This was due to a decrease in the average area of bare soil at eroding points.

5.8 Tussock and mountain vegetation changes

5.8.1 Soil stability amongst tussock and mountain vegetation

Table 18: Changes in soil stability amongst tussock and mountain vegetation, 2002 – 2007

	Points as % of sample:		Significant change:
	2002	**2007**	
Stable surfaces			
with intact soil	**0.8**	**0.6**	*N*
95% c.i.	*0.2*	*0.2*	
with soil disturbed by land use	**0.0**	**0.0**	*N*
95% c.i.	*0.0*	*0.0*	
Erosion-prone surfaces			
with intact soil	**0.7**	**0.1**	***Y***
95% c.i.	*0.2*	*0.1*	
with soil disturbed by land use	**<0.1**	**<0.1**	*N*
95% c.i.	*<0.1*	*<0.1*	
Eroded and eroding surfaces			
with revegetating soil	**0.3**	**0.5**	*N*
95% c.i.	*0.1*	*0.2*	
with soil disturbed by natural processes	**0.4**	**0.9**	***Y***
95% c.i.	*0.2*	*0.2*	
All surfaces in land use			
as percentage of sample	**2.1**	**2.0**	*N*
95% c.i.	*0.4*	*0.4*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

Stable surfaces dropped from 0.8% to 0.6% of regional sample points, due to reclassification of 12 points as erosion-prone, eroded or eroding. There has been no significant change in surfaces with intact soil between 2002 and 2007. No surfaces were recorded as having soil disturbed by land use.

There has been a significant decrease in erosion-prone surfaces between 2002 and 2007, from 0.7% to 0.1% of regional sample points. This is entirely a decline in surfaces with intact soil, due to transfer of points into the 'eroded and eroding' category. Although statistically significant, it is an artefact of change in survey procedure because high-altitude points under snow were classed as erosion-prone in 2002 (see Methods report). There has been no significant change in soil disturbed by land use on erosion-prone surfaces (<0.1% at both dates; one point where a track was recorded).

On eroded and eroding surfaces, re-vegetating soil has increased from 0.3% to 0.5% of regional sample points, but the change is statistically insignificant. However, surfaces with bare soil disturbed by natural processes have increased significantly, from 0.4% to 0.8% between 2002 and 2007. This increase is not necessarily genuine as it may be influenced by high altitude points beneath snow cover in 2002, (assumed to be erosion-

prone), but where re-vegetating surfaces, sparsely vegetated surfaces with fresh disturbance, or bare rock were visible in 2007.

5.8.2 Soil disturbance amongst tussock and mountain vegetation

Table 19: Changes in soil disturbance amongst mountain vegetation, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	2007	
By land use:			
grazing pressure			
95% c.i.			
cultivation			
95% c.i.			
harvest			
95% c.i.			
spraying			
95% c.i.			
drains			
95% c.i.			
tracks	**<0.01%**	**<0.01**	*N*
95% c.i.	*<0.01%*	*<0.01%*	
earthworks			
95% c.i.			
roads			
95% c.i.			
all land use disturbance	**<0.01%**	**<0.01**	*N*
95% c.i.	*<0.01%*	*<0.01*	
By natural processes:			
landslide		**<0.01**	
95% c.i.		*<0.01*	
debris avalanche	**0.01**	**0.01**	*N*
95% c.i.	*0.02*	*0.01*	
slump or earthflow			
95% c.i.			
tunnel gully		**<0.01**	
95% c.i.		*<0.01*	
gully	**0.01**	**<0.01**	*N*
95% c.i.	*0.02*	*<0.01*	
streambank scour	**<0.01**	**<0.01**	*N*
95% c.i.	*0.01*	*<0.01*	
streambank deposit		**<0.01**	
95% c.i.		*0.01*	
sandblow			
95% c.i.			
sheetwash	**0.05**	**0.09**	*N*
95% c.i.	*0.04*	*0.05*	
rockfall or bare rock	**0.07**	**0.10**	*N*
95% c.i.	*0.06*	*0.07*	
geothermal	**0.02**	**0.02**	*N*
95% c.i.	*0.03*	*0.03*	
all natural disturbance	**0.16**	**0.23**	*N*
95% c.i.	*0.09*	*0.10*	
All disturbance:	**0.16**	**0.23**	*N*
95% c.i.	*0.09*	*0.10*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There has been an increase in soil disturbance under tussock and mountain vegetation, from 0.18% of regional area (3920 ha) to 0.23% (5635 ha) between 2002 and 2007, but the change is statistically insignificant.

Bare soil exposed by land use is minimal (<0.01% at both dates). It has been recorded at one point where a track is present.

Bare soil or rock is almost entirely due to natural disturbance. There has been no significant change in disturbance by landslides, debris avalanches, under-runners and tunnels, or stream-bank scour and deposition; all of which are minor. Most changes are sheet-wash of exposed soil (up from 0.05% to 0.09% of regional area), or rock-fall and scree (up from 0.07% to 0.10%), but neither change is individually significant, because error margins are wide. All types of natural disturbance, when combined, are up from 0.16% of regional area (3920 ha) to 0.23% (5635 ha), but the combined change remains statistically insignificant.

5.8.3 Contribution to regional change, 2002 - 2007

Tussock and mountain vegetation made no contribution to the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007.

None of the increase in bare soil caused by land use disturbance (up by 1.28% of regional area) is contributed by tussock and mountain vegetation.

Tussock and mountain vegetation contributed 0.5% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007, larger than expected given that tussock and mountain vegetation occupies 2.0% of the region's area.

Tussock and mountain vegetation contributed 0.07% to the 0.18% regional increase in bare soil caused by natural processes. Although a measurable contribution (1715 ha), it may not be a genuine increase, being more likely due to recording of bare surfaces in 2007 that were snow-covered in 2002.

5.9 Wetland and coastal vegetation changes

5.9.1 Soil stability amongst wetland and coastal vegetation

Table 20: Changes in soil stability amongst wetland and coastal vegetation, 2002 - 2007

	Points as % of sample:		Significant change:
	2002	2007	
Stable surfaces			
with intact soil	**0.0**	**<0.1**	*N*
95% c.i.	*0.0*	*<0.1*	
with soil disturbed by land use	**0.0**	**0.0**	*N*
95% c.i.	*0.0*	*0.0*	
Erosion-prone surfaces			
with intact soil	**1.0**	**0.8**	*N*
95% c.i.	*0.2*	*0.2*	
with soil disturbed by land use	**<0.1**	**<0.1**	*N*
95% c.i.	*<0.1*	*<0.1*	
Eroded and eroding surfaces			
with revegetating soil	**0.1**	**<0.1**	
95% c.i.	*0.1*	*<0.1*	*N*
with soil disturbed by natural processes	**<0.1**	**0.1**	*N*
95% c.i.	*<0.1*	*0.1*	
All surfaces in land use			
as percentage of sample	**1.1**	**1.0**	*N*
95% c.i.	*0.3*	*0.2*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

No stable surfaces were recorded under wetland and coastal vegetation in 2002. In 2007, one point under coastal vegetation was reclassified as stable, but this is not a significant change.

Erosion-prone surfaces dropped between 2002 and 2007, from 1.0% to 0.8% of the regional sample. The drop is partly due to transfer of a few points into the eroded and eroding category but also to a decline in area of wetland and coastal vegetation (from 1.1% to 1.0% of the region). The consequent decrease in surfaces with intact soil (1.0% to 0.8%) is statistically insignificant because so few points are involved.

There has also been no significant change in eroded and eroding surfaces under wetland and coastal vegetation between 2002 and 2007 (0.1% of the region at both dates). A decline in surfaces with re-vegetating soil has been counter-balanced by an increase in surfaces with bare soil disturbed by natural processes.

5.9.2 Soil disturbance amongst wetland and coastal vegetation

Table 21: Changes in soil disturbance amongst wetland and coastal vegetation, 2002 - 2007

	Bare soil as % of region:		Significant change:
	2002	**2007**	
By land use:			
grazing pressure			
95% c.i.			*N*
cultivation	0.01	0.01	
95% c.i.	*0.02*	*0.01*	
harvest			
95% c.i.			
spraying			
95% c.i.			
drains			
95% c.i.			
tracks		**<0.01**	
95% c.i.		*<0.01*	
earthworks			
95% c.i.			
roads			
95% c.i.			
all land use disturbance	**0.01**	**0.01**	*N*
95% c.i.	*0.02*	*0.01*	
By natural processes:			
landslide			
95% c.i.			
debris avalanche			
95% c.i.			
slump or earthflow			
95% c.i.			
tunnel gully			
95% c.i.			
gully			
95% c.i.			
streambank scour			
95% c.i.			
streambank deposit			
95% c.i.			
sandblow	**0.02**	**0.03**	*N*
95% c.i.	*0.03*	*0.04*	
sheetwash			
95% c.i.			
rockfall or bare rock			
95% c.i.			
geothermal			
95% c.i.			
all natural disturbance	**0.02**	**0.03**	*N*
95% c.i.	*0.03*	*0.04*	
All disturbance:	**0.03**	**0.03**	*N*
95% c.i.	*0.03*	*0.04*	

Note 1: % of sample sub-totals/totals may differ by 0.1% due to rounding
Note 2: confidence limits are not additive

There has been no significant change in soil disturbance under wetland and coastal vegetation between 2002 and 2007. It remains 0.03% (735 ha) of regional area at both dates.

Bare soil exposed by land use has been recorded due to cultivation of drained wetlands (one point at each date), plus track formation through coastal vegetation (just one point in 2007). Combined, they amount to 0.01% of regional area at both dates i.e. no significant change.

Bare soil exposed by natural disturbance has gone up slightly, from 0.02% (490 ha) of regional area in 2002 to 0.03% (735 ha) in 2007. The disturbance is entirely sand-blows amongst coastal vegetation. However, the change is statistically insignificant. When added to land use disturbance (0.01%), the increase disappears due to rounding, i.e. the combined total for bare soil amongst wetland and coastal vegetation remains 0.03% (735 ha).

5.9.3 Contribution to regional change, 2002 - 2007

Wetland and coastal vegetation made no contribution to the 16.3% jump in surfaces with soil disturbed by land use region-wide between 2002 and 2007 i.e. land use disturbance remained minimal at both dates.

Wetland and coastal vegetation made no contribution to the region-wide increase (1.28%) in bare soil exposed by land use disturbance. The small increase in bare soil associated with tracks was <0.01% of regional area.

Wetland and coastal vegetation contributed <0.1% of the 4.2% jump in surfaces with soil disturbed by natural processes region-wide between 2002 and 2007, about the level that would be expected, given these covers' small area (1.0% of the region).

Wetland and coastal vegetation contributed 0.01% to the 0.18% regional increase in bare soil caused by natural processes. Although this was a minimal contribution (245 ha), it reflects a real increase in incidence of coastal sand erosion.

6 Summary

6.1 Region-wide changes

Table 22: Changes in soil stability and disturbance region wide

		Points as % of sample 2002[1]	Points as % of sample 2007[1]
Stable	Intact	46.0	33.1
	disturbed by land use	4.9	16.7
Erosion-prone	Intact	31.2	16.3
	disturbed by land use	1.8	6.3
Eroded and eroding	revegetating	6.2	9.3
	disturbed by natural processes	3.3	7.5
Extensively disturbed	shorelines etc.	3.7	3.5
	rural buildings etc.	2.0	2.5
	urban areas etc.	0.8	1.0
Other	no photos or unclassified	0.2	3.9
Totals	**as % of region**	**100.0**	**100.0**

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.

6.1.1 Soil stability

Stable and erosion-prone surfaces have declined from 83.9% to 72.4% of the regional sample between 2002 and 2007 (Table 22). These are surfaces where soil is intact, apart from temporary disturbance by activities undertaken in the course of land use.

Of the decrease, 7.3% is caused by re-classification of surfaces as either recently eroded or freshly eroding. 0.5% is caused by re-classification of surfaces as extensively disturbed (urban subdivision, roadworks, quarries and mines). The balance (3.7%) is caused by inability to re-record surface stability at 241 sample points (3.9%) where there was no aerial photo cover in 2007, compared with 10 points (0.2%) in 2002.

Eroded and eroding surfaces have increased from 9.5% to 16.7% of the regional sample between 2002 and 2007, due to recent or fresh natural disturbance over the five years. These are surfaces where some (not all) soil is disturbed by natural processes of erosion or deposition.

Extensively disturbed surfaces have increased from 6.5% to 7.0% of the regional sample between 2002 and 2007. These are surfaces where soil has been re-contoured or removed.

6.1.2 Soil disturbance

On stable and erosion-prone surfaces, soil disturbance by land use has increased from 6.7% to 23.0% of the regional sample between 2002 and 2007 (Table 22). Most types of land use disturbance were recorded at a greater number of points in 2007 (Table 23), particularly tracking (up from 3.6% to 15.1% or 219 to 925 points).

The increases appear genuine (see Methods, Section 2), apart from tracks. There is a possibility that tracks were either under-recorded in 2002, or over-recorded in 2007. After cross-checking between 2002 and 2007 photos, we are confident that the increase is real on dairy farms (up from 113 to 448 points). It has two components: some are points where new tracks expose bare soil; but most are where existing dairy races have been improved or extended by re-surfacing. We are less confident about the apparent increase on drystock farms (up from 48 to 280 points). Here some of the points are new tracks, but many are tracks recorded as re-vegetating in 2002 despite presence of residual bare soil. Due to change in survey procedure, residual bare soil was measured in 2007, transferring them into the 'disturbed' category. The increased number of points with bare tracks in forest plantations (up from 33 to 103 points) is real, caused either by up-grade of vegetated tracks preparatory to logging, or construction of new ones.

On eroded and eroding surfaces, natural disturbance has increased from 3.3% to 7.5% of the regional sample between 2002 and 2007 (Table 22). Most types of natural disturbance were recorded at a greater number of points in 2007 (Table 23), particularly landslides (up from 0.6% to 1.9% or 34 to 117 points) and streambank scour or deposit (up from 0.4% to 1.5% or 27 to 91 points).

After cross-checking between 2002 and 2007 photos, we are confident that these increases are genuine (see Methods, Section 2), apart from rockfalls and rock outcrops. Some of the increase in this category is accounted for by high-altitude points, snow-covered in 2002, which were recorded as erosion-prone. In 2007 these points were either exposed or had patchy snow cover, so were transferred to either the eroded or eroding categories.

Extensively disturbed surfaces have increased from 6.5% to 7.0% of the regional sample between 2002 and 2007 (Table 22). Of the increase, 0.5% is caused by earthworks associated with rural buildings and roads (Table 23), and 0.2% by

earthworks in urban areas, offset by a 0.2% decline in points classified as shorelines (transferred to adjacent land uses in 2007).

Table 23: Changes in disturbance-type and bare soil region-wide

Disturbance cause:	Disturbance type:	Points as % of sample 2002[1]	Points as % of sample 2007[1]	Bare soil as % of area 2002	Bare soil as % of area 2007
Land use	grazing pressure	1.4	2.4	0.10	0.08
	cultivation	0.4	1.8	0.14	0.81
	harvest	0.6	1.2	0.15	0.15
	spraying	0.1	<0.1	0.02	<0.01
	drains	0.2	0.8	0.04	0.03
	tracks	3.6	15.1	0.40	0.89
	earthworks	0.4	0.7	0.10	0.07
	rural roads	Not rec in 2002	1.0	Not rec in 2002	0.08
	rural buildings etc	2.0	2.5	0.05	0.14
	urban areas etc.	0.8	1.0	Not rec in 2002	0.02
Land use sub total		**9.4**	**26.5**	**0.99**	**2.27**
Natural processes	landslide	0.6	1.9	0.04	0.06
	debris avalanche	0.2	0.6	0.03	0.03
	slump or earthflow	0.5	0.2	0.04	0.01
	tunnel gully	0.4	0.7	0.02	0.02
	gully	0.6	0.9	0.04	0.03
	streambank scour	0.3	1.0	0.02	0.03
	streambank deposit	0.1	0.5	0.02	0.03
	sandblow	0.1	0.2	0.03	0.05
	sheetwash	0.2	0.4	0.05	0.09
	rockfall or rock outcrop	0.4	1.1	0.09	0.15
	geothermal	<0.1	0.1	0.03	0.02
	shorelines etc.	3.7	3.4	Not rec in 2002	0.05
Natural processes sub total		**7.0**	**10.9**	**0.39**	**0.57**
Totals	**as % of region**	**16.4**	**37.4**	**1.37**	**2.85**

Note 1: "% of sample" sub-totals/totals may differ by 0.1% due to rounding.

6.1.3 Bare soil

Bare soil exposed by land use disturbance on rural land has increased from 0.99% to 2.12% of regional area between the two dates (Table 23). Even if all the increase in bare soil from tracking (+0.49%) and roading (+0.08%) were regarded as present in 2002, bare soil from other types of land use disturbance has increased by 0.56% of regional area.

Bare soil exposed by natural disturbance on rural land has increased from 0.39% to 0.57% of regional area between the two dates.

Bare soil, sediment or rock exposed by extensive disturbance has increased from 0.05% to 0.21% of regional area between the two dates. 0.09% of the increase is genuine (associated with rural buildings measured at both dates). The balance of 0.07% was probably present in urban areas and along shorelines in 2002, but un-measured.

6.2 Changes for each land use

Table 24: Changes in soil disturbance for each land use.

Land use	Points with land use disturbance as % of regional sample		Points with natural disturbance as % of regional sample	
	2002	2007	2002	2007
Horticulture and Cropping	0.2	1.2	0.0	<0.1
Dairy pasture	2.9	10.0	0.3	0.8
Dry-stock pasture	2.0	7.2	1.7	3.7
Forest Plantations	1.2	3.1	0.2	0.5
Natural Forest	0.1	0.3	0.2	0.5
Natural Scrub	0.1	0.7	0.2	0.8
Exotic Scrub	0.1	0.5	0.2	0.4
Wetland and Coastal vegetation	<0.1	<0.1	<0.1	0.1
Tussock and Mountain vegetation	<0.1	<0.1	0.4	0.9
Rural buildings etc	0.1	0.8	0.0	<0.1
Urban areas etc	not rec in 2002	0.2	not rec in 2002	<0.1
Shorelines etc	not rec in 2002	<0.1	not rec in 2002	0.3

Table 24 shows changes in soil disturbance for each land use, expressed as percentages of the regional sample.

On stable and erosion-prone surfaces, of the 16.3% increase in points disturbed by **land use** between 2002 and 2007:

- horticulture and cropping contributed 1.0% of the increase,
- dairy farms contributed 7.1%,
- drystock farms contributed 5.0%,
- forest plantations contributed 1.9%,
- natural forest contributed 0.3%,
- natural scrub contributed 0.6%,
- exotic scrub contributed 0.4%,
- wetland and coastal vegetation contributed 0%,
- tussock and mountain vegetation contributed 0%,

On eroded and eroding surfaces, of the 4.2% increase in points disturbed **by natural processes** between 2002 and 2007:

- horticulture and cropping contributed <0.1% of the increase,
- dairy farms contributed 0.5%,
- drystock farms contributed 2.0%,
- forest plantations contributed 0.3%,
- natural forest contributed 0.3%,

- natural scrub contributed 0.6%,
- exotic scrub contributed 0.2%,
- wetland and coastal vegetation contributed 0.1%,
- tussock and mountain vegetation contributed 0.5%,

On extensively disturbed surfaces, of the 0.9% increase in points disturbed by land use between 2002 and 2007 :

- rural buildings contributed 0.7% of the increase,
- urban areas contributed 0.2%,

but as disturbance associated with urban areas was not measured in 2002, the true increase may have been somewhat less.

Of the 0.3% increase in points disturbed by natural processes :

- shorelines and waterbodies contributed all 0.3%,

but as disturbance associated with these was not measured in 2002, it is likely that much of the disturbance was already present (beaches and cliffs), and that little of the increase is genuine.

Table 25: Changes in bare soil for each land use.

Land use	Bare soil from land use disturbance as % of regional area		Bare soil from natural disturbance as % of regional area	
	2002	2007	2002	2007
Horticulture and Cropping	0.06	0.52	0.00	<0.01
Dairy pasture	0.36	0.81	0.02	0.03
Dry-stock pasture	0.25	0.42	0.13	0.16
Forest Plantations	0.19	0.27	0.01	0.02
Natural Forest	0.01	0.01	0.01	0.02
Natural Scrub	0.02	0.03	0.02	0.03
Exotic Scrub	0.03	0.04	0.03	0.02
Wetland and Coastal vegetation	0.01	0.01	0.02	0.03
Tussock and Mountain vegetation	<0.01	<0.01	0.16	0.23
Rural buildings etc	0.05	0.14	0.0	<0.01
Urban areas etc	not rec in 2002	0.02	not rec in 2002	<0.01
Shorelines etc	not rec in 2002	<0.01	not rec in 2002	0.04

Table 25 shows changes in bare soil for each land use, expressed as percentages of the regional area.

On stable and erosion-prone surfaces, of the 1.28% increase in soil exposed by **land use** between 2002 and 2007:

- horticulture and cropping contributed 0.46% of the increase,
- dairy farms contributed 0.45%,
- drystock farms contributed 0.17%,
- forest plantations contributed 0.08%,
- natural forest contributed 0%,

- natural scrub contributed 0.01%,
- exotic scrub contributed 0.01%,
- wetland and coastal vegetation contributed 0%,
- tussock and mountain vegetation contributed 0%,

On eroded and eroding surfaces, of the 0.18% increase in soil exposed by **natural processes** between 2002 and 2007:

- horticulture and cropping contributed <0.01% of the increase,
- dairy farms contributed 0.02%,
- drystock farms contributed 0.03%,
- forest plantations contributed 0.01%,
- natural forest contributed 0.01%,
- natural scrub contributed 0.01%,
- exotic scrub contributed -0.01%,
- wetland and coastal vegetation contributed 0.01%, ,
- tussock and mountain vegetation contributed 0.07%,

On extensively disturbed surfaces, of the 1.28% increase in soil exposed by land use region-wide between 2002 and 2007 :

- rural buildings contributed 0.09%,
- urban areas contributed 0.02%,

As mentioned above, disturbance associated with urban areas was not measured in 2002, so the true increase in bare soil may have been somewhat less.

Of the 0.18% increase in soil, sediment or rock exposed by natural processes region-wide :

- shorelines and waterbodies contributed all 0.04%.

Also, as mentioned above, disturbance associated with these was not measured in 2002, so it is likely that much of the bare soil, sediment or rock was already present as beaches and cliffs.

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