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Soil stability in the Waikato Region - 2012

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- Doug Hicks (consulting soil scientist) who provided assistance to Tony Thompson during the analysis and completed an independent peer review of the photo interpretation work.

- Both Doug and Tony have provided valuable assistance by answering questions and providing data from the 2007 survey and reports, to help inform this report.

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Executive summary

Background

This report summarises and discusses results from a survey of soil stability and disturbance for the Waikato Region using aerial photography taken in 2012. The survey has been carried out in accordance with the National Land Monitoring Forum's procedure for assessing soil stability (Burton et al., 2009). Previous surveys were conducted for the Waikato region using aerial photography taken in 2002 and 2007. All three surveys have been undertaken to provide information about soil stability, soil disturbance and bare soil for state of environment reporting.

The monitoring was defined by the boundaries of the area that WRC 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 ortho-rectified aerial photos taken for WRC in 2012-13. Observations were collected from a 1 ha square centred on each sample point. At each sample information recorded included; landform, land use, associated vegetation, soil stability, and if present nature of soil disturbance (due to either land use or natural processes) and area of bare soil.

Soil stability

Of all sample points 51.3% contained land surfaces that were stable, 22.6% were erosion-prone but inactive and 18.8% had signs of recent (but re-vegetating) or fresh erosion. The remaining 7.3% of the regions sample points were extensively disturbed, where soil had been removed in whole or part, due to either the presence of rural buildings and yards, urban areas and water bodies.

Soil disturbance

Soil disturbance is a measure of those sample points which contained disturbed soil due to natural processes or land use-related activities, these disturbances, if recent, resulted in bare soil. Of all sample points 23.2% had soil disturbed by land use-related activities (e.g. tracks, cropping etc.), most of this was on dairy pasture (10.3%), dry stock pasture (6.8%) and forestry (3.4%). 9.1% had soil freshly disturbed by natural processes (e.g. mass movement etc.), about half of this was on dry stock pasture (4.8%).

60.4% of the regions sample points contained surfaces with undisturbed soil and were therefore protected by vegetation.

7.3% of samples that were extensively disturbed included; urban areas (1.1%) where much of the soil was covered by buildings and paved surfaces, rural buildings and yards (2.7%) where some of the soil was covered, and shorelines and waterbodies (3.6%) where soil was either stripped or submerged.

Bare soil by natural processes or land use

The measure of soil disturbance identified those sample points which contained either natural or land use related disturbance, however using a cluster sample approach the area of bare soil due to each of these disturbance processes could be estimated. Therefore; soil, sediment or rock exposed by all forms of disturbance amounted to 1.93% of the regions area.

On stable and erosion-prone surfaces bare soil due to land use related-activities represented 1.31% of the regions area, and this was dominated by farm or forest tracks which were 0.89% of the regions area. Combined cultivation and harvest exposed bare soil on 0.25% of the regions area and bare soil due to rural roads was 0.07%. Bare soil due to other land use related disturbances (e.g. earthworks, drain excavations and grazing pressure) individually covered less than or equal to 0.05% of the sampled area (Table 1).

Sample points with eroding surfaces exposed bare soil on 0.38% of the regions area due to natural processes, this is less than that observed due to land use-related activities. This comprised, 0.20% due to surface erosion processes which included; sheetwash, sandblow, geothermal activity and rockfalls. 0.08% was due to slope failures which included; landsides and debris avalanche. 0.06% and 0.05% weredue to riparian erosion and deposition and gully erosion respectively (Table 2).

Table 1: Area of bare soil due to land use-related activities

Disturbance type	% of the regions area	% of the regions area
Farm or forest tracks	0.89	0.89
Cultivation	0.16	0.16
Harvest	0.09	0.09
Grazing pressure	0.05	0.05
Earthworks	0.03	0.03
Rural roads	0.07	0.07
Drain excavation	0.02	0.02

Table 2: Area of bare soil due to natural processes.

Disturbance type	% of the regions area
Landslide	0.06
Debris avalanches	0.02
Sheetwash	0.05
Sandblow	0.03
Geothermal	0.01
Stream bank scour	0.02
Stream bank deposition	0.04
Tunnel gully	0.02
Gullies	0.03

On extensively disturbed land surfaces, land use related disturbance exposed bare soil, sediment and rock associated with: Rural buildings and yards, quarries and mines on 0.06% of the regions area, urban earthworks etc. on 0.01%, and natural disturbance exposed bare soil, sediment and rock associated with shoreline processes on 0.09% of the regions area.

Bare soil by land use group

Rural land uses

Rural land uses included dairy and dry stock pasture, horticulture and cropping and forestry. 64.8% of the observed sample points were on rural land uses, and land use activities associated with these exposed bare soil on 1.24% of the regions area. About half (0.64%) of this bare soil was on dairy pasture, with 0.28% and 0.22% on dry stock pasture and forestry respectively. On these three rural land use this bare soil mostly due to tracks. The remaining 0.10% of bare soil was on land associated with horticulture and cropping. On rural land uses bare soil due to natural processes occurred on 0.19% of the regions area, the majority of this (0.14%) was on dry stock pasture where over half was due to either landslides, rock fall or bare rock.

Conservation land uses.

Conservation land use included natural forest and scrub, exotic scrub, wetland and coastal areas and mountains. 27.9% of observed sample points were on conservation land uses. Bare soil on conservation land uses represented 0.20% of the regions area. Of this, 0.07% was due to land use-related activities, which was mostly on natural and exotic scrub (0.06%), and 0.13% was due to natural processes, which was mostly in mountain areas (0.09%).

Land in other uses (extensively disturbed)

7.3% of Waikato's land was under other uses (urban areas, rural buildings and yards, shorelines or waterbodies) and considered extensively disturbed. Here land use-related activities exposed bare soil, sediment or rock on 0.15% of the regions area, much of this was under rural buildings and yards (0.14%). Natural processes of erosion and deposition exposed bare soil, sediment or rock on an additional 0.09% of the regions area, most of this was along shorelines and waterbodies.

Bare soil as a percentage of land use area

When bare soil was expressed as a percentage of the land area for each land use, horticulture and cropping and rural buildings had about 5.2% of their land use area exposed as bare soil. Dairy and drystock pasture had around 2.5 and 1.8% respectively. Exotic scrub and urban areas had around 1% of their land use exposed as bare soil and all other land uses were less than 0.5%.

1 Introduction

Erosion is a natural process but people can greatly accelerate the rate of erosion by removing vegetation or through inappropriate land management practices. Erosion, and subsequent sedimentation, can lead to a variety is issues including:

- loss of the soil's productive capability,
- increased instability of the surrounding land surfaces,
- more sediment being generated and potentially washed into freshwater and marine environments,
- deterioration of surface and subsurface drainage,
- damage to infrastructure, fences, farm tracks, roads and houses,
- destruction or damage to native flora or habitats, and
- adverse effects on the aesthetic and cultural values associated with land.

By assessing soil stability and disturbance we can understand if soil surfaces are changing for better or worse, how much of the bare soil is related to natural processes and how much is generated through land use-related activities.

Determining the extent of soil stability and disturbance is challenging due to the large area that must be examined. The method Waikato Regional Council (WRC) selected used aerial photography and a point sample technique. The survey was carried out in accordance with the Land Monitoring Forum's procedure for point sampling (Burton et al., 2009) and has been used by many other Regional Councils (see for example; Hicks & Thompson, 2009; Marlborough District Council, 2010; Sorenson, 2012).

This report presents data and discusses results from a survey of soil stability and disturbance undertaken for Waikato Regional Council (WRC) in 2015. The survey was based on data collected from aerial photography flown in the summer of 2012/2013. Previous surveys have been conducted for the Waikato region based on aerial photography from 2002 and 2007 and reported in 2003 (Hicks, 2004) and 2009 (Thompson, 2009a) respectively. A change report between 2002 and 2007 has been completed as well (Thompson, 2009b). A change comparison, including data from this and previous surveys, will be presented as a separate report (Hicks in prep).

This survey has been undertaken primarily to provide information about soil stability and disturbance for state of the environment reporting. WRC has a statutory responsibility to collect information about state of the region's environment (Section 35, Resource Management Act

1991). By monitoring state of the region's environment, it helps WRC decide whether policies and plans are needed to protect the region's natural resources. Most importantly, it enables the region's resource users to see whether they are sustainably managing those resources.

Survey data are also expected to be useful for other purposes, such as providing detail about the region's land use and vegetation cover; assessing the extent of vegetative soil conservation measures; and as a source of facts and figures for the Council's policy documents and publications.

2 Methods

2.1 Background

A soil stability monitoring program should be technically sound, statistically robust, provide easily understandable data, within a short space of time, and at an acceptable cost.

The Regional Councils' Land Monitoring Forum (LMF) evaluated several pilot studies and prototype surveys carried out for its members between 1996 and 2003 (see for example; references). One of the trials was undertaken for WRC in 2003, by Dr Doug Hicks of Ecological Research Associates. For that particular trial, WRC requested point sampling of rural land from aerial photographs of the region taken in summer 2002-2003. The trial survey's methods, data analyses and findings were documented in Hicks, (2004).

Point sampling from aerial photography was found to be a suitable technique, and from 2004 to 2015 several surveys have been carried out in the Waikato and other regions using a standard format recommended by LMF. The survey procedure has been documented as; Chapter 4 – Assessing soil stability, in 'Land and Soil Monitoring, A Guide for SoE and Regional Council Reporting 2009' (see; Burton et al., 2009). This guideline document, commissioned and published by the Land Monitoring Forum (LMF), was a collaborative effort by a group of experts, comprising Regional Council scientists, practitioners, and researchers (Thompson, 2015).

In 2015 WRC commissioned Mr Tony Thompson of Thelton Environmental Ltd to undertake a new point sample from region-wide orthorectified aerial photographs taken in 2012 - 2013, and stored on the Council's geographic information system (GIS).

One of the Council's GIS specialists, Mr Dan Borman, set up the aerial photography and sample grid layers in the GIS package Geomedia for Mr Thompson to use. Photo-interpretation was undertaken by Mr Thompson in May and June 2015. Dr Hicks assisted Mr Thompson throughout with procedural tests and quality control checks. Following this data analysis and draft report preparation was completed by WRC, using an improved data analysis spreadsheet commissioned by WRC from Dr Mark Kimberly a statistician at SCION Ltd.

2.2 Survey concepts and definitions

Burton et al., (2009) provides definitions of some key concepts that underpin the measurement of soil stability for environmental reporting. The guide interprets soil erosion or accumulation using the broader framework of soil stability and disturbance.

Soil stability

Identifies whether points are on stable or unstable surfaces. Unstable surfaces include; erosion prone, recently eroded or freshly eroded surfaces.

Soil disturbance

Identifies the exposure of bare soil and therefore potential for movement. Where disturbance is observed these are then classified by types of either land use-related activities (e.g. cultivation, harvest) or natural processes (e.g. landslide, slump).

Burton et al., (2009) defines these and other terms used in the reports, these include; stable and unstable, erosion-prone, eroded and eroding, extensively disturbed, types of land use-related disturbances and natural disturbances, intact soil, disturbed soil, vegetated soil, bare soil, rural land use, and non-rural land use.

2.3 Description of survey methods

WRCs 2015 survey of soil stability and disturbance followed the standard procedure documented in Burton et al., (2009) in almost all respects, so readers are referred there for a detailed description. Any variations were minor, and relate to locally applicable data recording codes. The survey method is briefly outlined below.

2.3.1 Monitoring area

The extent of monitoring was defined by the boundaries of the area that WRC has statutory responsibility for. Within this area, soil stability was assessed at 6122 sample points, distributed at 2 kilometre intervals on the NZTM map grid. A sample point was centred on the grid intersection and the area of observation for recording soil stability and disturbance information was delineated by a one hectare square centred on each sample point (Figure 1). Although spatially regular, this sample design was random with respect to land use and other factors which are unrelated to the map grid (Burton et al., 2009). Sample points used in this survey are the same as those used for previous survey's, which assessed aerial photography taken during 2002 and 2007.

Figure 1: Topographic map sheet grid with 1 hectare sample points (white squares) centred on each 2 km intersection overlaying an orhtophoto (image and description from Burton et al., 2009).

2.3.2 Sampling procedure

Monitoring was performed using digital orthorectified aerial photographs taken for WRC in the summer of 2012-2013. Photo interpretation was by on-screen viewing through GIS software, with direct entry of data to a GIS-linked database.

Each grid/data point was linked to an attribute layer, so the interpreter was able to click on the one hectare sample 'point' and the attribute information from the previous survey would appear as a 'pop-up' window. For each 'point', each of the attributes was re-assessed and changes made where necessary. When the interpreter was satisfied that the information was correct, the 'checked' code was changed from '0' to '1', thereby signalling in the database that the point had been visited. The colour of the 'point' on screen would then change from red to green so that the interpreter could visually keep track of which points had been visited and assessed (Thompson, 2015).

Viewing was carried out at a scale of 1:5000, zooming to smaller scales to inspect detail at points when necessary, and to larger scales to view points in the context of surrounding terrain.

2.3.3 Data recording

Data recorded in 2015 were; soil stability, soil disturbance type and area of freshly disturbed soil, land use and secondary vegetation. Items which had not changed since the previous survey

(notably landform) were not re-recorded. Standard LMF codes, as found in Burton et al., (2009), were used when recording data.

However, for the benefit of the reader Figure 2 illustrates the categorisation of observations at each sample point when using the method of Burton et al., (2009) and make further notes about interpretation. Land stability (Stable, erosion prone, eroded and eroding) was classified on the basis of existing and historical erosion at the time of the survey. Disturbance due to land-use related activities was only recorded on stable and erosion prone surfaces and natural disturbance was only recorded on eroded and eroding surfaces (Figure 2).

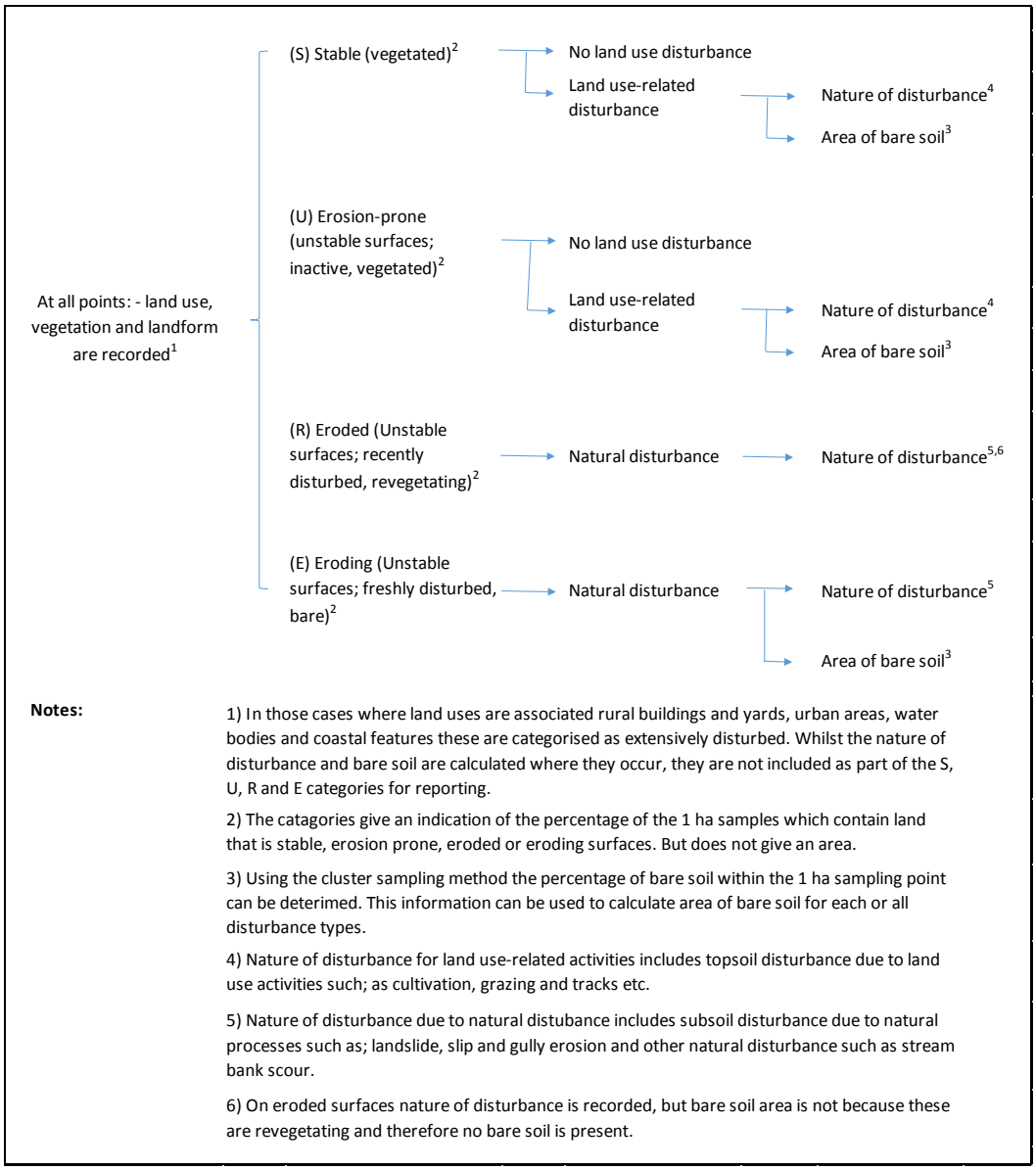

Figure 2: description and selection methods for the categories used in the point sample method of Burton et al., (2009).

2.3.4 Cluster sampling for bare soil

When bare soil was observed within the 1 ha square centred on each sample point, cluster sampling was used to estimate the area and calculate percentages of bare soil. The percentage

of bare-ground was estimated by applying a 100 dot grid within each one-hectare sample square (Figure 3). Where bare soil falls directly under a dot this was counted as 1% bare soil. The total number of dots on bare soil were then summed to determine the total percentage of bare soil within the 1 ha sample square.

Figure 3: 100 cluster sample points on a 10 x 10 grid within the 1 ha sample square (image and description from Burton et al., 2009).

Measurement for cluster sampling was carried out at a viewing scale of 1:5,000. Where necessary, the measurement grid was applied to each point by means of a GIS layer.

Considering the quantitative nature of the cluster sample approach values derived using this method could be considered as an estimate of bare soil for the Waikato region, the description of results will therefore reflect this. This approach also allowed the regional area of bare soil to be estimated for each disturbance type.

2.3.5 Data storage

Sample point locations, one-hectare squares, and cluster measuring grids were stored as Geomedia map layers. Sample point locations were cross-referenced to a Geomedia database, which contained their map grid references and raw data for all points. The database was exported as an Excel spreadsheet.

2.3.6 Photo-interpretation error

Photo-interpretation error was ascertained by randomly selecting 100 points and having them checked by an independent photo-interpreter. Data about each point was recorded and is discussed in more detail in section 3.2.

2.3.7 Analysis procedure

The point analysis procedure involved spreadsheet sorts, followed by point counts and conversion of totals to percentages of regional area, and area in each land use. Cluster analysis of bare soil was carried out for aggregated points in each category (soil stability and disturbance) region wide and by land use type. A review of methods (discussed in section 4) used to calculate statistics in the point sample was completed by Dr Mark Kimberly of Scion Ltd. Dr Kimberly developed a spreadsheet with formulae linked to filters to reduce the number of point counts and sorts required.

3 Attribute changes and interpretation accuracy

3.1 Attribute changes

Information about attribute changes made during the 2012 survey were provided by Mr Tony Thompson of Thelton Environmental Ltd (Thompson, 2015) these are given in sections 3.1.1 to 3.1.4 below.

3.1.1 Soil Stability

Soil stability codes were generally not changed. Where a change was made, this was for one of two possible reasons:

1) where the interpreter determined that there had been a clear miscoding in the previous survey; or
2) where the interpreter genuinely perceived a change in stability since the previous survey.

In the case of (1) There were two instances where the soil stability code was changed from erosion prone ('U') to stable ('S') due to previous miscoding coding. There was one case where the code was changed from eroded surfaces with revegetating soil ('R') to eroding ('E') due to fresh erosion being obvious on a previously re-vegetating area. There were two cases where the code was changed from 'R' to 'S' due to there being no visible evidence of prior erosion and subsequently re-vegetating areas. There were six instances where the code was changed from 'R' to 'U' due to there being little visible evidence of re-vegetating areas. There was one case where the code was changed from 'S' to 'R' due to erosion re-vegetating areas being detected. There were 17 instances where the code was changed from 'S' to 'U' due to there being underlying instability due to a combination of terrain and proximity of disturbance. There were 85 instances where the code was changed from 'U' to 'S' due to there being no proximal or contextual evidence of instability.

In the case of (2), there were numerous instances where the stability code was changed from 'E' to 'R' or 'R' to 'U' due to the area re-vegetating; and from 'U' to 'E' due to the area eroding. These were genuine changes between 2007 and 2012 surveys.

3.1.2 Nature of Disturbance

The nature of disturbance code employed depended on whether disturbance was natural or anthropogenic. Disturbance from human activity was the most difficult matter for interpretation, for example, distinguishing between cultivation versus harvest or between

spraying versus grazing. Sometimes it was difficult to determine the type of natural disturbance given the resolution of the photography, e.g. distinguishing between a landslide versus debris-avalanche or between bank-scour versus bank deposition. This is outlined further in the photo interpretation accuracy assessment (Section 3.2)

3.1.3 Land Use

Land-use codes were changed where there was a genuine change in primary land-use from the previous survey. There were 22 instances where primary land-use was changed from dairying to drystock (improved pasture). This was a mixture of genuine land-use change and miscoding from the previous surveys. There were another 70 instances where primary land-use was changed from drystock (improved pasture) to dairying, mostly due to miscoding from the previous survey but also in-part due to genuine change.

3.1.4 Landform

The landform code was generally not changed unless the interpreter determined that it had definitely been miscoded in the previous survey(s). There were 13 instances where the code was changed.

3.2 Photo interpretation accuracy

The following section has been provided by Dr Douglas Hicks who completed an independent peer review of the photo interpretation work (Thompson, 2015). Therefore, the sections 3.2.1 to 3.2.7 below present checks at 100 randomly selected points. They indicate reliability of photo-interpreted data stored for 6122 points in the sample.

3.2.1 Land use

Correct at 94 points. Photo-interpretation errors were:

- sparse dairy pasture (sprayed for renewal) recorded as harvested grain crop,
- improved drystock pasture recorded as unimproved,
- sparse exotic scrub (regrowth after forest harvest) recorded as rank grass,
- sparse exotic scrub (sprayed) recorded as closed-canopy, and
- closed-canopy natural scrub recorded as exotic (2 points).

3.2.2 Associated secondary vegetation

Correct at 87 points. Photo-interpretation errors were:

- secondary vegetation was omitted (scattered coniferous trees),

- secondary vegetation was absent (recorded as clumped natural scrub),
- the suffix (pattern of vegetation) changed (hedgerow recorded as broadleaved shelterbelt (2 points), sparse drystock pasture recorded as dense), and
- secondary vegetation was incorrectly recorded (clumped natural scrub as broadleaved trees (2 points), clumped exotic scrub as broadleaved trees (2 points), scattered broadleaved trees as coniferous, clumped natural trees as broadleaved, clumped exotic scrub as natural, emergent exotic scrub as rank grass).

3.2.3 Landforms

Correct at 97 points. Photo-interpretation errors were:

- hillslope recorded as steepland,
- plateau (undulating ridge) recorded as downland, and
- small alluvial channel recorded as hillslope.

3.2.4 Soil stability

Correct at 91 points. Photo-interpretation errors were:

- re-vegetating surfaces recorded as eroding (2),
- unstable (revegetated) surfaces recorded as revegetating (2),
- unstable surface recorded as eroding, and
- unstable surfaces recorded as stable (4).

3.2.5 Disturbance type

Correct at 90 points. Photo-interpretation errors were:

- disturbance was omitted (farm track),
- disturbance was absent (recorded as landslides or debris avalanches) (3),
- natural disturbance was mis-recorded (bare rock or bare sand confused, or recorded as landslides (3), debris avalanche as landslide), and
- land use-related disturbance was mis-recorded (grazing pressure as landslides) (2).

3.2.6 Bare soil

Percentage of bare soil was correctly recorded at 94 points. Photo-interpretation errors were:

- bare soil measured but under-recorded,
- bare soil measured but over-recorded (sealed tracks misinterpreted as bare (2),
- bare soil present but not measured, and
- bare soil measured but absent (re-vegetating ground misinterpreted as bare soil (2).

3.2.7 Overall comments on photo-interpretation accuracy

The land use error rate at 6%, comprised 3% minor differences (improved pasture as unimproved etc.) and 3% mis-identifications. The latter appear too few to have much impact on region-wide analysis of land use.

Secondary vegetation error rate at 13%, comprised 2% omission or absence errors, 3% minor differences (sparse to dense etc.), and 8% mis-identifications. The latter may affect any subsequent analysis of vegetative conservation cover's effect on soil stability. Most mis-identifications are scrub recorded as broadleaved trees i.e. soil conservation plantings, or vice versa.

The low error for landform codes at 3%, contrasts with the 2009 survey which had a high error rate (11-20%). The reason is that digital orthophotos cannot be viewed stereoscopically when interpreting them on a computer screen. Subtle changes in relief - where downlands are close to footslopes, terrace edges and stream floodways - are hard to detect. For example, during the survey in 2009, the original 2003 landform codes were re-examined with reference to a 20 metre contour overlay and changed where necessary. This considerably improved their accuracy.

Soil stability error rate at 9%, comprised 4% errors inherited from previous surveys (unstable surfaces recorded as stable). The other 5% are surfaces where stability class 'E' or 'R' (as recorded at date of previous survey) was retained despite bare ground declining close to 0% at the 2012 survey.

Disturbance type error rate at 10%, comprised 4% omission or absence errors. Most are points where disturbance type (as recorded at date of previous survey) was retained despite complete revegetation of the scar meanwhile. 6% are mis-identifications. The latter suggest that region-wide incidence of landslides may be somewhat over-estimated by including small patches of bare rock, bare sand or stock rubs.

Overall, photo-interpretation accuracy exceeds 90% except for secondary vegetation (87%). Accuracy for each parameter was at least as good as, and in some instances better than, other point sample surveys recently carried out for regional councils' state of environment monitoring, which are typically in the 85% to 95% range (Thompson, 2015). Few types of error were repeated more than once in the course of a hundred points, so it is unlikely that they will cause problems for any future analysis of the 2012 point sample. There is no need to correct data for errors which affect accuracy by one percent - indeed it would be impossible to make consistent corrections without visiting every sample point.

Changes subsequent to photography are not a problem. The sample is intended to provide a snapshot of the region in 2012, the year of photography. There is no need to adjust data for subsequent changes, which should be detected by a further survey at a later date.

4 Review of statistical methods

The purpose of the statistical methods review undertaken by Dr Mark Kimberly was to examine the analysis methods used during the 2002 and 2007 soil stability surveys and in the analysis of change between 2002 and 2007 (see; Kimberly 2016). In summary the methods used in 2002 and 2007 appeared to be applied correctly. However, the reports could have been made more readable by presenting key information graphically, and including more discussion. A streamlined method for performing the required calculations (using a master spreadsheet) was recommended, tested and supplied.

The following sections present the key points from the statistical methods review by Kimberly (2016), these build on those already presented in Burton et al., (2009). Furthermore, the approaches described here were used for the statistical analysis of data collected during this photo-interpretation survey.

4.1 Analysis of soil stability at one point in time

Point counts have been expressed as percentages of the sample or sub-sample being assessed. The analysis largely consisted of estimation of % areas within various subgroups, e.g., the % area with stable, erosion-prone, eroded, or extensively disturbed surfaces. These estimates were based on the percentage of grid points within each subgroup. Precision was expressed using 95% confidence intervals obtained using normal approximations for a percentage derived from a binomial variate,

$$95\%CI(P) = 1.96 \times \sqrt{P(100-P)/N}, \quad (1)$$

where P is the % of grid points in the subgroup, and N is the total number of points in the survey (Kimberly, 2016).

4.2 Analysis of bare soil at one point in time

The area of bare soil within a subgroup expressed as a percentage of total area within the region was calculated using:

$$\%Bare = b \times N_1/\mathrm{N}, \quad (2)$$

where *b* is the % of dots with bare soil in the cluster plots within the subgroup, N_1 is the number of grid points in the subgroup, and *N* is the total number of grid points.

To estimate the precision of *%Bare*, the standard error of *b* was calculated using:

$$se(b) = sd/\sqrt{N_1}, \quad (3)$$

where *sd* is the standard deviation of *b*. Next the standard error of N_1/N using a method similar that described above for *P* was calculated,

$$se(N_1/N) = \sqrt{[N_1/N\,(1 - N_1/N)]/N} \quad (4)$$

Because *%Bare* is a product of *b* and N_1/N, its standard error was calculated using the standard formula for a standard error of a product. This was converted into a 95% confidence interval using an assumption of normality,

$$95\%CI(\%Bare) = t \times \sqrt{b^2 se(N_1/N)^2 + (N_1/N)^2 se(b)^2}, \quad (5)$$

where *t* is a tabulated *t* value with N_1-1 degrees of freedom (for large subgroups *t* can be approximated by 1.96) (Kimberly, 2016).

Further suggestions were made in Kimberly (2016) with regard to statistically analysing change over time, however, these recommendations will be outlined in the change comparison report.

5 Results & discussion

The following sub-sections present and discuss the 2012 survey results for soil stability, soil disturbance and land use. Each is described at the time of the 2012 survey as is their contribution to bare soil in the region.

Information presented in these subsections follows the general structure:

- Overall (region-wide) status.
- Status for each land use.

The full data tables of soil stability and disturbance for each land use are presented in Appendix A. They summarise to what extent Waikato's soil is protected or disturbed under various rural land uses, together with the land uses' respective contributions to bare soil, region-wide.

5.1 Soil stability

Soil stability is a measure of how well the region's soil is being kept in place as a resource for farming, forestry and conservation.

5.1.1 Stable surfaces (S) – no erosion

Half (51.3%) of the regions sample points contained only stable surfaces (Figure 4). As per the definition in Burton et al., (2009), stable surfaces showed no signs of past natural erosion, had a smooth appearance and were completely vegetated (unless the topsoil was disturbed by land use related activities, such as cultivation). Stable surfaces were also protected floodplains, drained wetlands, elevated terraces, rolling down lands, parts of hill country and ranges that showed no sign of past erosion, and old coastal dunes with weathered soils.

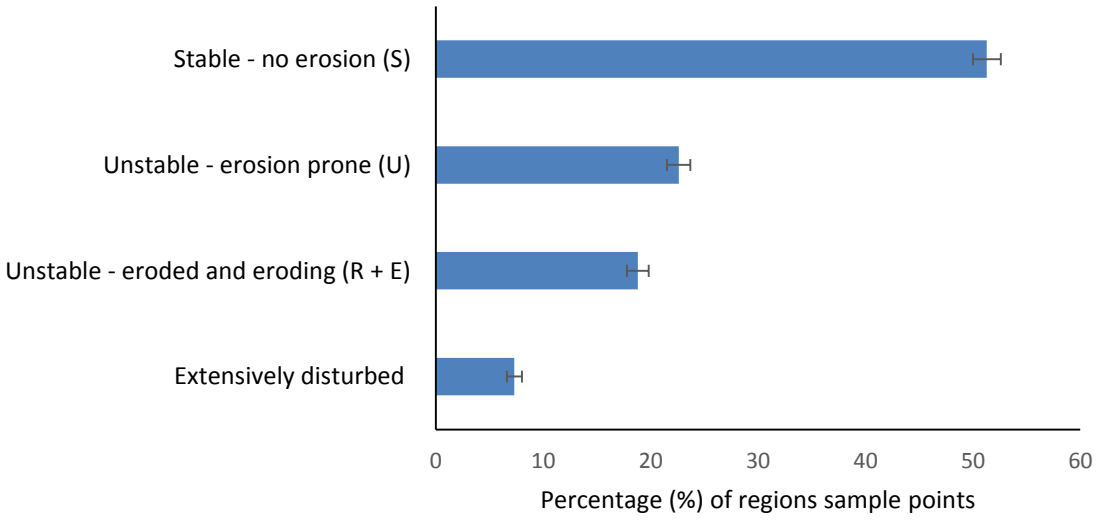

Figure 4: Percentage of sample points that contained stable, unstable and extensively disturbed

land surfaces across the Waikato region in 2012. Error bars represent the 95% confidence interval.

5.1.2 Unstable surfaces (U) – erosion prone

22.6% of the regions sample points contained unstable surfaces that showed signs of past erosion but these were inactive (Figure 4). These erosion-prone surfaces were unprotected floodplains, undrained or semi-drained wetlands, drainage hollows through terraces and downlands, parts of hill country and ranges that showed signs of past erosion but were currently not eroding, and intermediate-age coastal dunes that were protected by vegetation.

5.1.3 Unstable surfaces (R+E) – eroded and eroding

18.8% of the regions sample points contained eroded (erosion scars that were partially vegetated but still rough) and eroding (active erosion scars with no vegetation) surfaces (Figure 4). Eroded and eroding surfaces included - river and stream banks; wetland margins; under-runners or gullies through terraces and downlands; parts of hill country and ranges that were subject to mass movement erosion (slope failure) or to scour and deposition of sediment along valley bottoms; and young coastal dunes subject to sandblow.

5.1.4 Extensively disturbed surfaces

Extensively disturbed surfaces were areas of land where soil had been removed in whole or part, re-contoured, or covered by buildings, pavements or water. 7.4% of the observed sample points were extensively disturbed (Figure 4). As shown by further detail in Table 3 extensively disturbed surfaces were represented by:

- 2.7% was land in rural non-agricultural use, where some of the soil was covered by buildings and yards; industrial premises and quarries; or roads, railways and airfields.
- 1.1% was land in urban use, where much of the soil was covered by buildings and paved surfaces. Some was still vegetated, particularly urban open spaces and residential gardens. The covered and vegetated areas now have little soil disturbance.
- 3.6% of the region's sample points were water bodies or coastal features, extensively disturbed by natural processes in the absence of any land use.

Table 3: Percentage of regions sample points by surface type across the Waikato region in 2012. This table adds further detail to the categories presented in Figure 1. Error values represent the 95% confidence interval.

Regional Summary 2012	Points	Points as % of sample[1]	95% c.i.[3]	Bare soil as % of area[2]	95% c.i.[3]
Stable surfaces (S)					
S (i) with intact soil	2103	34.4	1.2		
S (ii) with soil disturbed by land use-related activities	1038	17.0	0.9	1.00	0.09
Erosion-prone surfaces (U)					
U (i) with intact soil	1001	16.4	0.9		
U (ii) with soil disturbed by land use-related activities	381	6.2	0.6	0.31	0.05
Eroded and eroding surfaces (R + E)					
R (i) with re-vegetating soil	595	9.7	0.7		
E (ii) with soil disturbed by natural processes	556	9.1	0.7	0.38	0.07
Extensively disturbed surfaces					
Rural buildings and yards	164	2.7	0.4	0.14	0.06
Urban areas and urban-rural fringe	66	1.1	0.3	0.01	0.01
Water bodies and coastal features	218	3.6	0.5	0.09	0.06
All regions sample points	6122	100.0	0.0	1.93	0.15

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: Confidence limits are not additive.

5.2 Soil disturbance

Soil disturbance is a measure of the regions sample points which had soil disturbed due to either natural processes of erosion or deposition, or land use-related activities. Those categories in Table 3 with bare soil were considered to be disturbed.

60.4% of regions sample points had no soil disturbance due to both land use and natural disturbance. This was comprised of, 34.3% on stable surfaces (Si), 16.4% on erosion-prone surfaces (Ui). 9.7% were previously eroded due to natural processes but were observed to have vegetative cover, and the soil is now protected by vegetation (Ri) (Table 3).

23.2% of the regions sample points were disturbed by land-use related activities. Of this, 17.0% and 6.2% were on stable (Sii) and erosion prone (Uii) surfaces respectively (Table 3).

9.1% of the regions sample points were disturbed by the natural processes of erosion and deposition (Eii) (Table 3). Soil here has the ability to recover over time, unless it is disturbed again.

As already outlined in section 5.1.4, 7.4% of sample points were extensively disturbed by rural buildings and yards, urban areas, water bodies and coastal features (Table 3). Of this 3.8% is due to extensive land use disturbance and 3.6% was due to extensive natural disturbance (Table 3). Soil here is permanently disturbed and unlikely to recover.

5.3 Bare soil

Using the cluster sample approach, as described in Section 2.3.4 the amount of bare soil on disturbed surfaces due to either land use-related activities or natural processes equated to 1.93% of the total area of all 6122 sample points (Table 3). Considering the nature of sample collection, these results can be considered an estimate of bare soil as a percentage of the regions area.

On stable surfaces (S) bare soil accounted for 1.0% of the region's area. Bare soil on erosion-prone surfaces (U) amounted to 0.31% of the region's area. Bare soil in both categories were due to land use-related activities (Table 3).

Bare soil on eroded and eroding surfaces (E) amounted to 0.38% of the region's area. This was due to natural processes (Table 3).

Bare soil on extensively disturbed surfaces was 0.24% of the regions area and, as shown in Table 3, was represented by the following;

- Rural - bare soil amounted to 0.14% of the region's area, much of was quarry or mine excavation, though some had other causes (e.g. construction earthworks, unsealed yards or tracks).
- Urban - bare soil amounted to 0.01% of the region's area, mostly subdivision earthworks or new roading.
- Shorelines - bare ground amounted to 0.09% of the region's area, all of it natural including, bare rock, soil sheetwash, landslides on cliffs; sandblows amongst dunes; sediment deposits along beaches, and tidal creeks.

5.4 Disturbance by land use-related activities

Information in Table 3 shows that disturbance due to land-use related activities was observed on 23.2% of the regions sample points and bare soil represented 1.31% of the regions area.

These values were found by summing Sii and Uii in Table 3. The following section adds further detail to these values by providing information on soil disturbance and bare soil by individual land use-related activities, this information is also presented in Figure 5 and Table 4.

- Farm or forest tracks were the most widespread disturbance by land use, present on 16.2% of the region's sample points. Bare track surfaces equated to 0.88% of the region's area or about 22 250 hectares.

- Livestock grazing pressure was present on 2.5% of the region's sample points, and exposed bare soil on 0.05% of the region's area or about 1 250 hectares.

- Cultivation and harvest activities (includes forest harvest) were collectively present on 2.2% of the region's sample points, and responsible for bare soil on 0.16%, and 0.09% of the region's area respectively and equated to about 6 250 hectares of bare soil.

- Unsealed rural roads were observed on 0.9% the region's sample points, and associated bare soil was 0.07% of the region's area or about 1 750 hectares.

- Drain excavation or cleaning was present on 0.8% of region's sample points, and exposed soil on 0.02% of the region's area or about 500 hectares.

- Earthworks for farm buildings or forest harvest sites occupied 0.5% of the region's sample points, and accounted for bare soil on 0.03% of the region's area or about 750 hectares.

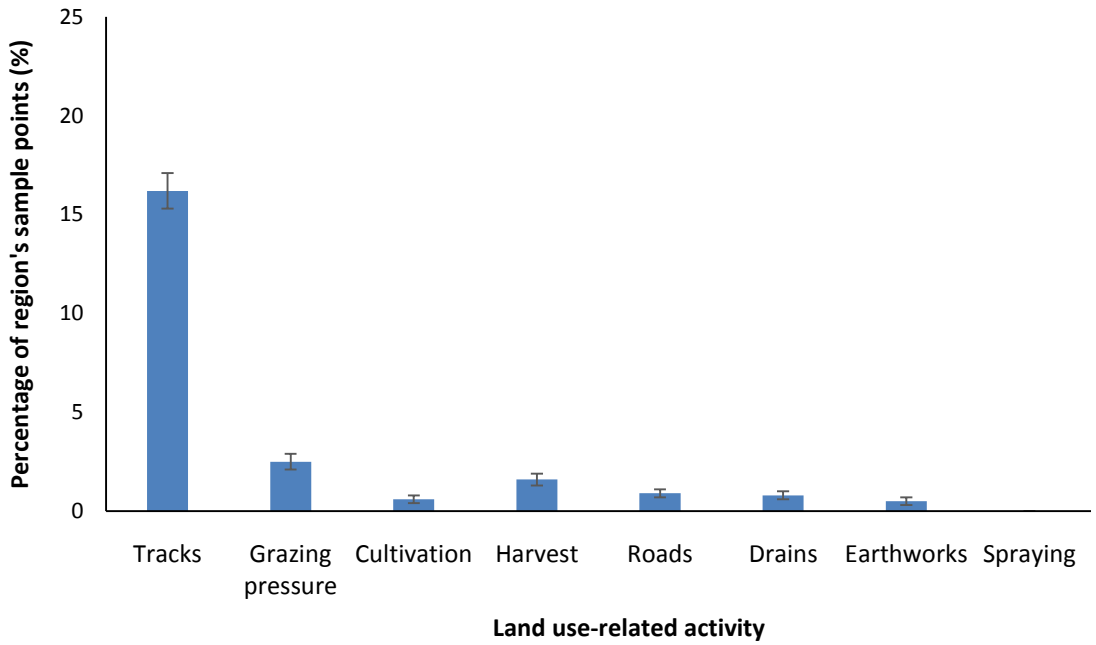

Figure 5: Percentage of the region's sample points that were disturbed by individual land use-related activities in 2012. Error bars represent the 95% confidence interval.

Table 4: Bare soil as a % of the region's area, using the cluster sample approach, due to land use-related activities in 2012. Error values represent the 95% confidence interval.

Soil disturbance 2012	**Bare soil as % of region's area[1]**	**95% c.i.[2]**	**Bare soil as hectares (ha)**
Land use-related activity			
Tracks	0.89	0.06	22250
Grazing pressure	0.05	0.01	1250
Cultivation	0.16	0.07	4000
Harvest	0.09	0.03	2250
Roads	0.07	0.02	1750
Drains	0.02	0.01	500
Earthworks	0.03	0.02	750
Spraying	0.00	0.00	0
Total	**1.31**	**0.1**	**32750**
Note 1: % of area sub totals/totals may differ by 0.01% due to rounding Note 2: Confidence limits are not additive.			

5.5 Disturbance by natural processes

Information in Table 1 shows that disturbance due to natural processes was observed on 9.1% of the region's sample points (Eii) and bare soil represented 0.38% of the region's area or about 9 500 hectares. The following section adds further detail to these values by providing information on soil disturbance and bare soil for individual natural processes of erosion and deposition, this information is also presented in Figure 6 and Table 5.

- Slope failures were the most widespread natural disturbance. Landslides and debris avalanches, slumps and earthflows, were collectively present on 3.0% of the region's sample points. They caused bare soil on 0.08% of the region's area or about 2 000 hectares.

- Tunnel gullies (under-runners) and open gullies were somewhat less widespread, present on 2.2% of the region's sample points. The area of bare soil they caused was 0.05% of the region's area or about 1 250 hectares.

- Riparian (streambank) scour and deposition were present on 1.6% of the region's sample points, but deposits of sand, silt or gravel along watercourses together with bank scour and collapse, accounted for bare soil, on just 0.06% of the region's area or about 1 500 hectares.

- Surface erosion (sheetwash, rockfall or bare rock and sandblow) although not as widespread as slope failure, accounted for the greatest area of bare soil exposed through natural processes. Sheetwash (0.5%), rockfall or rock outcrops (1.7%), and sandblow (0.1%) make up 2.3% of the region's land and collectively give rise to bare soil on 0.19% of the region's area or about 5 000 hectares.

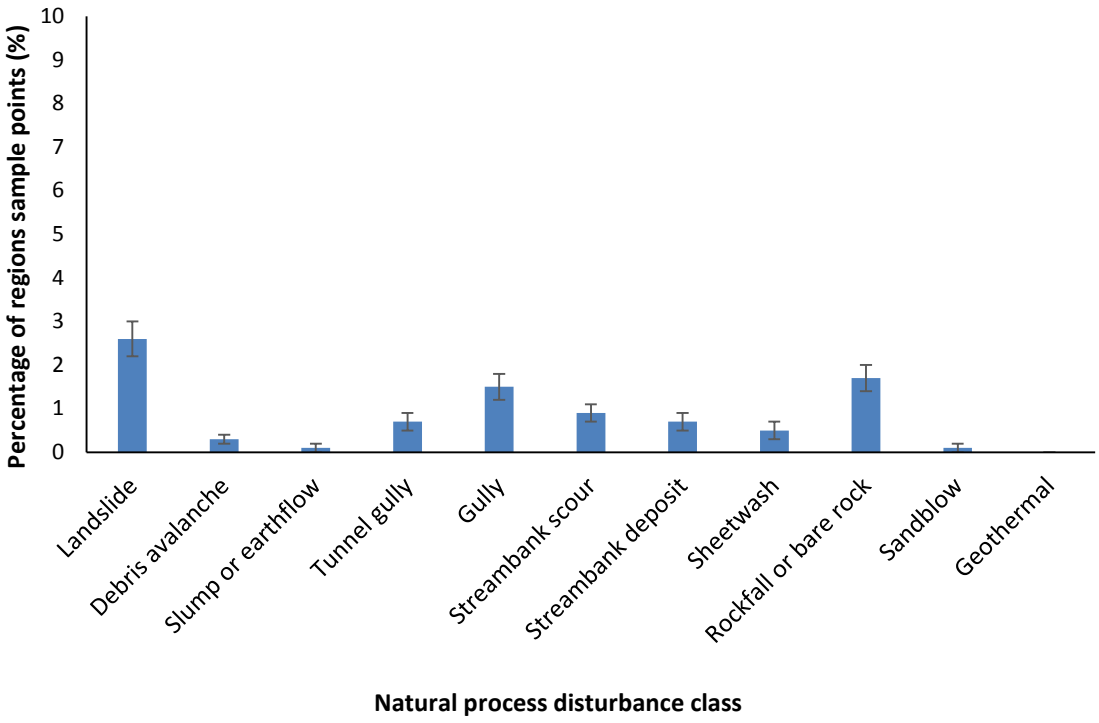

Figure 6: Percentage of regions sample points that were disturbed by natural processes by category across the Waikato region in 2012. Error bars represent the 95% confidence interval.

Table 5: Bare soil as a % of the region's area, using the cluster sample approach, due to natural processes in 2012. Error values represent the 95% confidence interval.

Soil disturbance 2012	**Bare soil as % of region's area[1]**	**95% c.i.[2]**	**Bare soil as hectares (ha)**
Natural process of erosion or deposition			
Landslide	0.06	0.01	1500
Debris avalanche	0.02	0.01	500
Slump or earthflow	0.00	0.00	0
Tunnel gully	0.02	0.01	500
Gully	0.03	0.01	750
Streambank scour	0.02	0.01	500
Streambank deposit	0.04	0.02	1000
Sheetwash	0.05	0.02	1250
Rockfall or bare rock	0.11	0.05	2750
Sandblow	0.03	0.03	750
Geothermal	0.01	0.01	250
Total	**0.38**	**0.07**	**9500**
Note 1: % of area sub totals/totals may differ by 0.01% due to rounding Note 2: confidence limits are not additive.			

5.6 Soil disturbance and bare soil for land uses in the Waikato

The point sample approach enables us to see how soil stability, disturbance and bare soil are distributed amongst the various land uses which are practised throughout the Waikato Region. This information is presented in the following sections.

5.6.1 Land uses in the Waikato Region

The point sample method estimated that the agricultural industries of; horticulture and cropping, dairy pasture, drystock pasture and forestry (in teal in Figure 7) covered 64.8% of the region. Conservation uses of; natural forest, natural scrub, exotic scrub, wetland and coastal scrub (in green in Figure 7) covered 27.9% of the region. Extensively disturbed surfaces (rural buildings, urban areas and shorelines (in orange in Figure 7) covered 7.3% of the region.

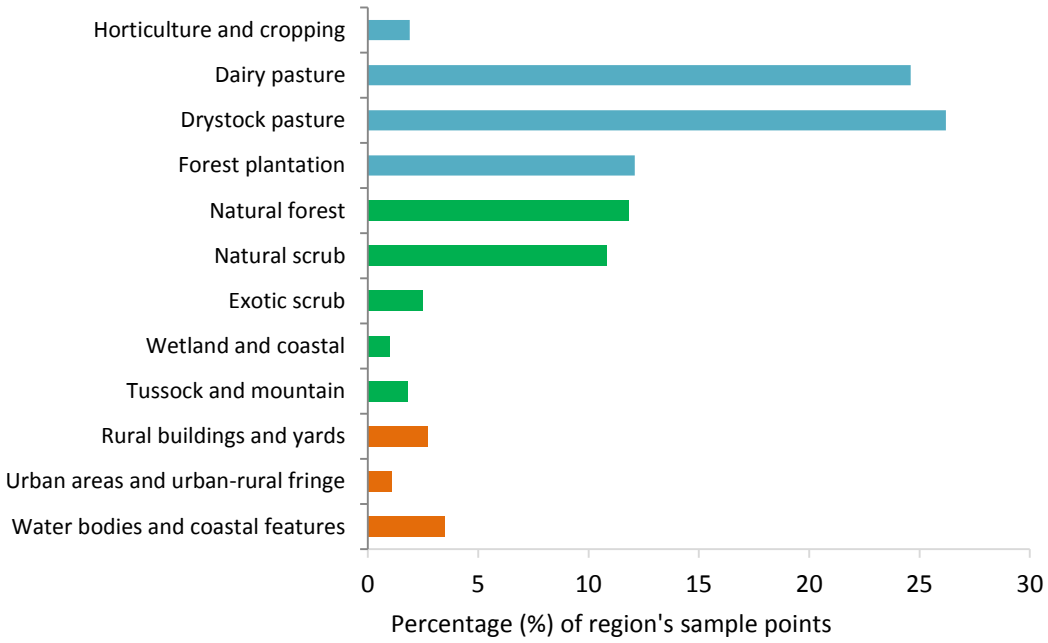

Figure 7: Percentage of region's sample points that are in each land use category as observed in this survey during 2012.

Table 6 adds further detail to that in Figure 7 by presenting sub-categories for each land use. For example, the estimated regional area estimated by horticulture and cropping is made up of; grain crops, green feed crops, vegetable crops, orchards and vineyards (Table 6).

Table 6 : Percentage of regions sample points by sub-land use category in 2012. This table adds land use sub-categories to those presented in Figure 7. The error value represents the 95% confidence interval.

Land use	Composition	Points	% of region's sample points[1]	95% c.i.[2]
Horticulture and cropping	grain crops	41	0.7	0.2
	greenfeed crops	42	0.7	0.2
	vegetable crops	20	0.3	0.1
	orchards incl. avocado	8	0.1	0.1
	vineyards incl. kiwifruit	5	0.1	0.1
Dairy pasture	dairy pasture	1505	24.6	1.1
Drystock pasture	improved drystock pasture	1467	24.0	1.1
	unimproved pasture or rank grass	137	2.2	0.4
Forest plantations	broadleaf trees	28	0.5	0.2
	pine trees	714	11.7	0.8
Natural forest	native trees - closed canopy	720	11.8	0.8
Natural Scrub	native woody scrub	663	10.8	0.8
Exotic scrub	exotic woody scrub	151	2.5	0.4
Tussock and mountain	tussock grass	20	0.3	0.1
	alpine	41	0.7	0.2
	sub-alpine scrub	52	0.8	0.2
Wetland and coastal	freshwater wetland vegetation	52	0.8	0.2
	saline wetland vegetation	1	0.0	0.0
	coastal scrub and grass	7	0.1	0.1
Other (Extensively disturbed)	Rural buildings	164	2.7	0.4
	Urban areas	66	1.1	0.3
	Shorelines	218	3.5	0.5
All Region	**total**	**6122**	**100.0**	

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

Note 2: confidence limits are not additive.

5.6.2 Soil stability by land use category

Drystock and dairy pasture were observed under a similar number of sample points (Figure 7), but drystock pasture had a greater number of points with land that was identified as unstable (U, R and E in Figure 8), at about 50% of the observed sample points. This is likely to be due to dairy pasture typically occupying flatter land and dry stock being associated with hill country.

Natural forest, forest plantations and natural scrub occupied a similar number of sample points but forest plantations had more sample points recorded as stable (Figure 8). Exotic scrub covered a much smaller area than native scrub but both had similar proportions of each stability type, relative to the number of sample points they were observed on.

Horticultural and cropping land had no points recorded as being eroded-unstable or eroding-unstable (Figure 8).

Wetland and coastal vegetation (Figure 7) was observed on the least number of sample points, and sample points were mostly recorded as unstable land use types. Tussock and Mountain vegetation also had the majority of sample points on unstable land (Figure 7).

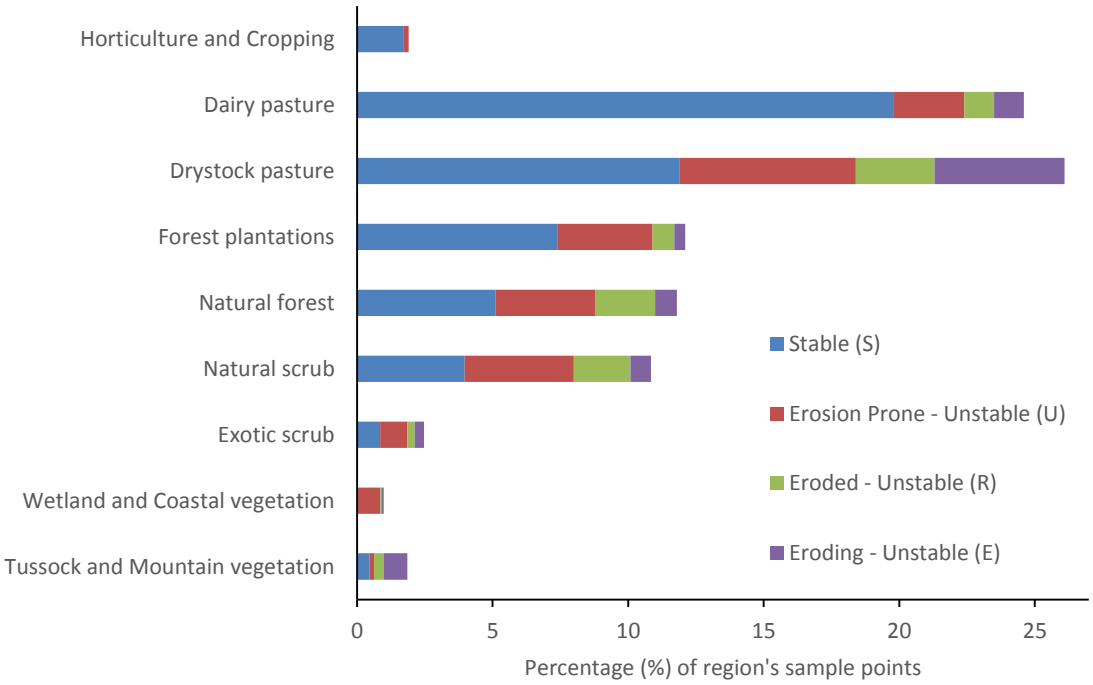

Figure 8: Percentage of region's sample points that contained stable (S), erosion prone (U), eroded (R) and eroding land surface by land use. Error values, representing the 95% confidence interval, can be found in Appendix A and range between 0.1 and 0.8%.

5.6.3 Soil disturbance and bare soil by land use category

The area of land with soil disturbance and the area of bare soil, as a percentage of the region, due to either land use-related activities or natural process for each land use type is presented in Table 5 and summarised in the following section. Further details are presented in Appendix A.

Horticulture and cropping

Horticulture and cropping was observed on 1.9% of the region's sample points (Figure 7), of this 1.1% were free from soil disturbance and 0.9% were disturbed due to land-use related activities. Bare soil amounted to 0.10% of the region's area (Table 7). Over half (0.6%) of the bare soil observed was due to cultivation.

Dairy pasture

Dairy pasture was observed on 24.6% of the region's sample points (Figure 7). This included 13.3% which was free from soil disturbance and 11.4% which was affected by soil disturbance. Of the land with soil disturbance 10.3% was due to land use-related activities, while 1.1% was caused by natural processes of erosion or deposition. Bare soil amounted to 0.66% of the entire region's area, of which 0.63% was attributed to land use-related activities and 0.03% to natural processes (Table 7). Most (0.51%) of the bare soil was due to tracks.

Drystock pasture

Drystock pasture was observed on 26.2% of the region's sample points (Figure 7). Of this, 14.6% was free from soil disturbance and 11.6% was impacted by soil disturbance. Where soil disturbance was observed 6.8% was due to land use-related activities, while 4.8% was caused by the natural processes of erosion or deposition. Bare soil amounted to 0.42% of the entire region's area, of which 0.27% was attributable to land use-related activities and 0.14% to natural processes (Table 7). The majority of the bare soil related to land use-activities was due to tracks (0.17%).

Forest plantations

Forest plantations were observed on 12.1% of the regions sample points (Figure 7). This included 8.3% which was free from soil disturbance and 3.8% which was affected by soil disturbance. Of the land with soil disturbance, 3.4% was due to land-use related activities while 0.4% was caused by natural processes of erosion or deposition. Bare soil amounted to 0.24% of the region's area, of which 0.22% was attributed to land use-related activities and 0.02% to natural processes (Table 7). Bare soil due to land use-related activities was mostly due to either harvest (0.07%) or tracking (0.12%).

Natural forest

Natural forest was observed on 11.8% of the region's sample points (Figure 7), of this 10.7% was free from soil disturbance and 1.1% was impacted by soil disturbance. Of the land with soil disturbance 0.3% was due to land use-related activities, while 0.8% was caused by natural processes of erosion or deposition. Bare soil amounted to 0.04% of the region's area, of which 0.01% was attributed to land use-related activities and 0.03% to natural processes (Table 7).

Natural scrub

Natural scrub was observed on 10.8% of the region's sample points (Figure 7), this included 9.2% which was free from soil disturbance and 1.6% which was impacted by soil disturbance. Of the land with soil disturbance 0.9% was due to land use-related activities, while 0.8% was caused by natural processes of erosion or deposition. Bare soil amounted to 0.06% of the region's area, of which 0.03% is attributable to land use-related activities and 0.03% to natural processes (Table 7).

Exotic scrub

Exotic scrub was observed on 2.5% of the region's sample points (Figure 7), this included 1.6% which was free from soil disturbance and 0.9% which was impacted by soil disturbance. Of the land with soil disturbance 0.6% was due to land use-related activities, while 0.3% was caused by natural processes of erosion or deposition. Bare soil amounted to 0.05% of the entire region's area, of which 0.03% was attributable to land use-related activities, and 0.02% to natural processes (Table 7).

Wetland and coastal vegetation

Wetland and coastal areas were observed on 1.0% of the region's sample points (Figure 7), of this 0.9% was free from soil disturbance and 0.1% was impacted by soil disturbance. Of the land with soil disturbance the majority of disturbance was by natural means (sandblow), however a small amount was land due to use-related activities; being a mix of cultivation and access tracks in partly drained wetlands. Bare soil (or bare sand) amounts to 0.03% of the region's area (Table 7).

Tussock and mountain vegetation

Tussock and mountain areas were observed on 1.8% of the region's sample points (Figure 7), of this 0.9% was disturbed and this was mostly all due to natural processes of erosion and deposition. Bare soil or rock in the mountains amounted to 0.09% of the entire region's area (Table 7).

Table 7: Soil disturbance and bare soil due to various land uses and natural processes in the Waikato region in 2012. The error value represents the 95% confidence interval.

		Impacts of land use on soil disturbance and bare soil			Impacts of natural processes on soil disturbance and bare soil		
	Area of land free from any disturbance	**Points**	**Area of land disturbed by use as % of region's sample points[1]**	**Bare soil within disturbed area as % of region's area[2]**	**Points**	**Area of land disturbed by use as % of region's sample points[1]**	**Bare soil within disturbed area as % of region's area[2]**
Rural uses							
Horticulture and cropping	1.1	52	0.9	0.10	0	0.0	0.00
Dairy pasture	13.3	628	10.3	0.63	67	1.1	0.03
Drystock pasture	14.6	419	6.8	0.27	292	4.8	0.14
Forest plantation	8.3	210	3.4	0.22	25	0.4	0.02
sub-total		**1309**	**21.4**	**1.22**	**384**	**6.3**	**0.19**
Conservation uses							
Natural forest	10.7	18	0.3	0.01	47	0.8	0.03
Natural scrub	9.2	53	0.9	0.03	46	0.8	0.03
Exotic scrub	1.6	35	0.6	0.03	21	0.3	0.02
Wetland and coastal	0.9	3	0.1	0.00	5	0.1	0.03
Tussock and mountain	0.9	1	0.0	0.00	53	0.9	0.09
sub-total		**110**	**1.8**	**0.07**	**172**	**2.8**	**0.20**
Other (Extensively disturbed)							
Rural buildings and yards	0.0	164	2.7	0.14	0	0.0	0.00
Urban areas and urban-rural fringe	0.0	66	1.1	0.01	0	0.0	0.00
Water bodies and coastal features	0.0	0	0.0	0.00	213	3.5	0.09
sub-total		**230**	**3.8**	**0.15**	**213**	**3.5**	**0.09**
Regional total	**60.5**	**1649**	**26.9**	**1.45**	**769**	**12.6**	**0.48**

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

Note 2: "% of area" sub-totals/totals may differ by 0.01% due to rounding.

5.7 Bare soil expressed as a percentage of land in each use.

Another way to assess soil disturbance by different land uses, is to express it as a percentage of the area in each use. Figure 9 shows that expressed this way land-use-related soil disturbance and associated bare ground were much higher than for horticulture and cropping also for rural buildings and yards than for other land uses.

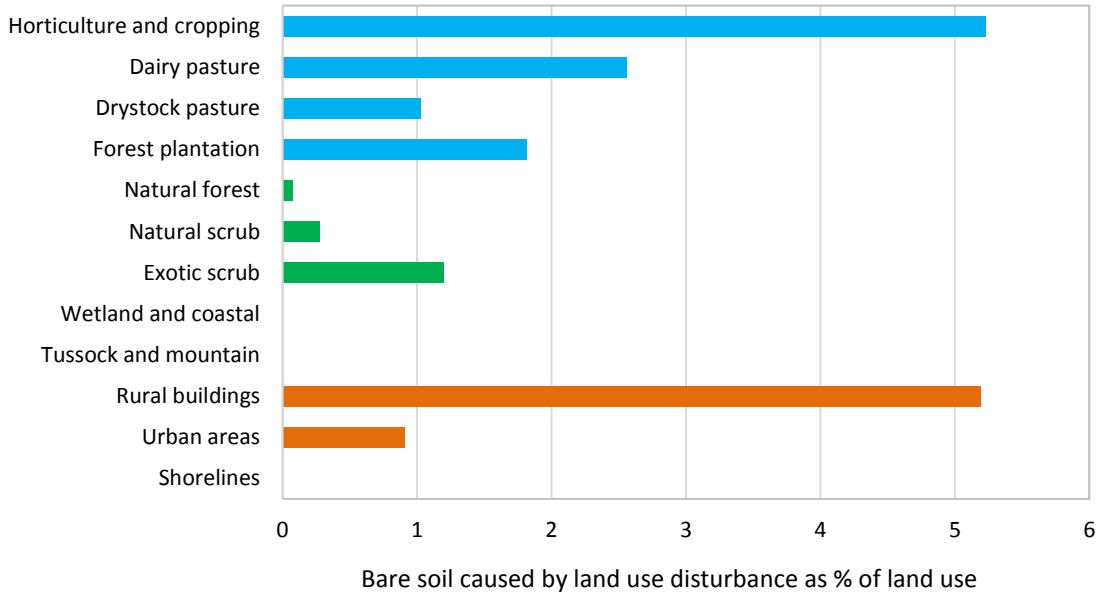

Figure 9. Bare soil disturbed by land use, expressed as percentage of land in each use, 2012.

Figure 10 shows that expressed the same way, natural soil disturbance and associated bare ground were higher for wetland and coastal vegetation (mainly coastal sand-blows), also tussock and mountain vegetation (mainly bare rock).

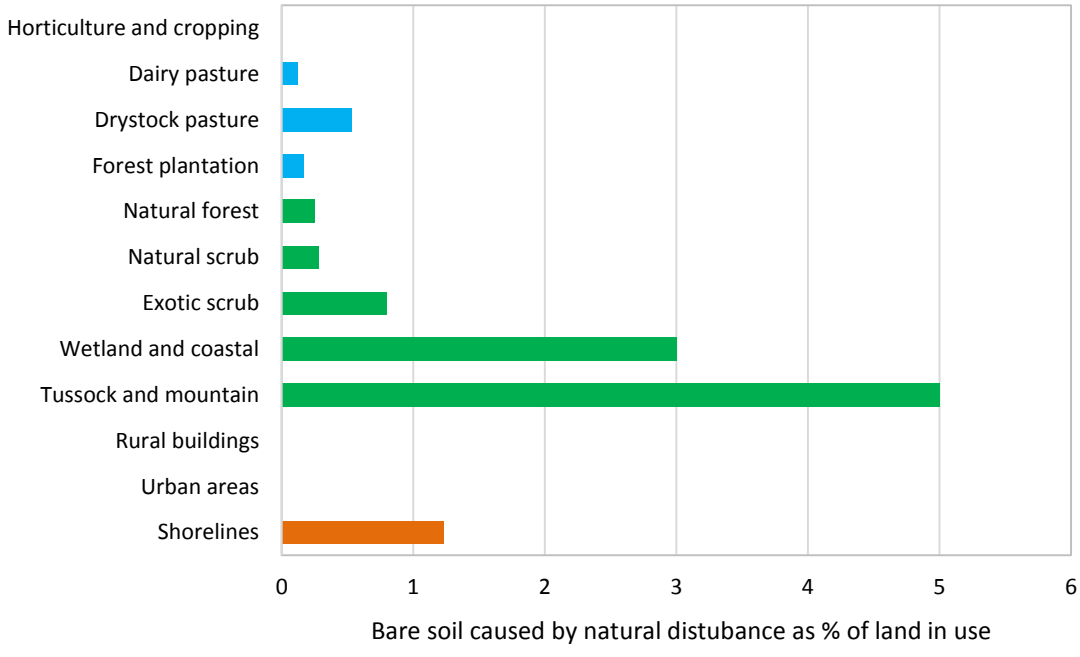

Figure 10. Bare soil disturbed by natural processes expressed as a % of land in each use, 2012.

6 Summary

6.1 State of soil stability, 2012

Stable surfaces made up 51% of the region's sample points. Stable surfaces showed no signs of past natural erosion and were completely vegetated except where the topsoil was disturbed by land use-related activities such as cultivation or tracking.

Unstable surfaces (comprising erosion prone, eroded and eroding surfaces) accounted for 41% of the region's sample points. Of this; 22% were erosion-prone surfaces which showed signs of past natural erosion, though these had completely revegetated and were inactive, and 19% were surfaces that had recently eroded, or were eroding. These unstable surfaces require careful management and erosion may limit the range of productive uses which can be sustained.

Extensively disturbed surfaces (where the soil has been partly or completely removed, re-contoured, or covered by buildings and pavements) were observed on 7.3% of the region's sample points These areas are unlikely to return to productive use though will remain sites for those activities which support it.

6.2 State of soil disturbance and bare soil, 2012

Soil disturbance exposes bare soil and can lead to land degradation and erosion. This is due to natural processes or as a result of land use-related activities.

60.4% of the Waikato region's sample points had no soil disturbance. Therefore these sites had good vegetative protection and no bare soil was observed. 32.3% of the region's point sample had disturbed soil of this, 23.2% was related to land use-related activities and 9.1% was due to natural processes. The remaining 7.3% of the regions sample points were observed to be extensively disturbed. Within these extensively disturbed surfaces disturbance was roughly equal between land use-related activities and natural processes with each being observed on 3.8% and 3.6% of the regions sample points respectively.

The main land use-related activities causing disturbance were farm tracks and logging roads, these were observed on 16.2% of the region's sample points, unsealed roads passing through land in rural use could be added to this, they were observed on another 0.9% of the region's sample points. All other disturbance related to land use activities were observed on a much smaller percentage of the region's sample points, these included; grazing pressure in pasture on

2.5%, harvest and spraying of cropland and pasture on 2.6%, drain or pond excavation on 0.8% and earthworks on 0.5%.

Bare soil exposed due to all land use-related activities covered an estimated 1.93% of the region's area or about 32,750 hectares. Farm tracks and logging roads contributed the greatest area of bare soil, covering an estimated 0.89% of the region's area or about 22,250 hectares. Bare soil associated with cultivation, harvest and roads covered an estimated 0.16%, 0.09% and 0.07% of the regions area respectively. All other categories with bare soil due to land use-related activities each covered < 0.05% of the region's area.

The main natural process causing soil disturbance was mass movement due to slope failure, these included; landslide, debris avalanche, slump and earthflow and were collectively observed on 3.0% of the region's sample points. Surface erosion processes, such as; sandblow, sheetwash, rockfall and rock outcrops, were observed on 2.3% of the region's sample points. Sediment deposition and bank scour along watercourses were observed on 1.6% of the region's sample points.

Bare soil exposed due to natural process covered an estimated 0.38% of the region's area or about 9 500 ha, therefore much less than bare soil due to land use related activities. Bare soil due to surface erosion processes due to surface erosion processes covered an estimated 0.19% of the regions area. All are considerably less than bare soil due to farm tracks and logging roads.

Bare soil on extensively disturbed surfaces covered 0.22% of the regions area, this was dominated by activities associated with rural buildings and rural roads which covered an estimated 0.14 and 0.07% of the region's area respectively. A very small percentage of bare soil was due urban land uses. Natural disturbance on extensively disturbed surfaces covered 0.1% of the region's area, which was dominated by shorelines and water bodies.

6.3 Pressure on soil - impacts of land use-related activities

6.3.1 On land in rural use

64.8% of the regions sample points were under rural land uses and 21.4% of the region's sample points under rural land uses were disturbed by land use-related activities.

- Bare soil due to rural land uses covered an estimated 1.22% of the region's area. All land uses contribute: orchards and cropland (cultivation and harvest), dairy farms (tracks, races and cultivation), dry stock pasture (grazing pressure, cultivation and tracks), forestry (harvest and logging tracks).

- When considering bare soil as a percentage of the area covered by a particular land use, horticulture and cropping was the most extensive with 5.3% of the land area in bare soil, dairy pasture had 2.6%, forest plantations had 1.8% and drystock pasture had 1.0%.

6.3.2 On land in conservation use

27.9% of the region's sample points were under conservation use, and 1.8% was disturbed by land use-related activities.

- Bare soil due to conservation land use covered an estimated 0.07% of the region's area. With the bulk of bare being observed in natural and exotic scrub in the form of unsealed roads, access tracks, earthworks and scrub clearance.
- As a percentage of land area covered by each conservation land use bare soil was observed on 1.2% of the land use area under exotic scrub, 0.28% under natural scrub and 0.08% under native forest. This bare soil was mainly due to access tracks.

6.3.3 On land in other use

On land which was observed to be extensively disturbed 3.6% of the region's sample points were disturbed due to rural buildings and yards, industrial sites, quarries and mines, or rural roads. In this category bare soil accounted for 0.14% of the regions area and is mainly due to unsealed yards, tracks and earthworks.

1.1% of the regions sample points were extensively disturbed by urbanisation. Here 0.01% of the region's soil was exposed to topsoil loss, mainly by housing subdivision and road construction.

6.4 Pressure on soil - impacts of natural processes

6.4.1 On land in rural use

6.3% of the regions sample points were disturbed by the natural processes of erosion or deposition under rural land uses.

- Bare soil accounts for 0.19% of the region's area. Most disturbance is in dry stock pasture (mass movement, gullying, streambank scour and deposition, sandblow, rock outcrops) though there is also measureable disturbance in dairy pasture (gullying, streambank scour and deposition, rock outcrops); and forest plantations (mass movement, gullying, rock outcrops).
- Bare subsoil as a percentage of the land area covered by each land use was 0.53% in drystock pasture, 0.17% in forest plantations and 0.12% in dairy pasture. The higher amount under

drystock pasture was due to a greater incidence of all disturbance types (particularly landslides gullies and rock outcrops).

6.4.2 On land in conservation use

2.8% of the region's sample points were freshly disturbed by natural processes on land in conservation use.

- Erosion or deposition accounts for 0.20% of the region's area. Almost half is bare soil in mountain areas (sheetwash, scree, rockfall). The rest is evenly distributed amongst other conservation uses though the causes vary; from forest (mass movement and streambank scour or deposition); through natural and exotic scrub (gullying, streambank scour or deposition, rock outcrops, geothermal disturbance); to wetland and coastal vegetation (sandblow).
- As a percentage of the area covered in each land use, bare soil was 0.25% and 0.28% of the area represented by natural forest and natural scrub respectively, and 0.80% of the area under exotic scrub. Amongst wetland and coastal vegetation, bare soil was 3.0% due to wind erosion of sand in coastal areas. Bare soil is highest at 5.00% of the area covered by mountains due to extensive sheetwash, scree slopes and rock bluffs.

6.4.3 On land in other use

Disturbance by natural processes is currently negligible for the regions sample points with rural buildings and within urban areas. Along shorelines and water bodies, 0.09% of the region's area is estimated to be currently exposed by natural processes through extensive disturbance by natural processes, with another 0.01% similarly exposed in geothermal areas.

7 References

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Appendix A - Soil stability and disturbance by land use

8 Horticulture and cropping - overview

1.9% of the regions sample points were under horticulture and cropping i.e. high-yielding food crops (Table 6). Grape vineyards or other vine crops (mainly kiwifruit) accounted for 0.1%, 0.1% were fruit orchards, 0.3% were vegetable crops, 0.7% were grain crops (mainly maize), and 0.7% were green feed crops (kale, turnips and similar).

8.1.1 Soil stability

Stable surfaces

Stable surfaces under horticulture and cropping were elevated terraces and rolling downlands, protected floodplains, or drained wetlands.

1.7% of the region's sample points were on stable surfaces under horticulture and cropping. Of these, 1.0% had intact soil, were well-vegetated (maturing crop, or tree and vine cover), and 0.7% had soil disturbed by land use. Within this category, bare soil amounted to 0.09% of the sampled area (Table 6).

Erosion prone surfaces

The erosion-prone surfaces were drainage hollows on terraces and downlands, or unprotected floodplains, or semi-drained/undrained wetland remnants.

0.2% of the region's sample points were on erosion-prone surfaces under horticulture and cropping. Of these, 0.1% had intact soil, were well-vegetated, and 0.1% had soil disturbed by land use. Within this category, bare soil amounts to 0.01% of the sample's area (Table 6).

Eroded and eroding surfaces

Eroded and eroding surfaces were where bank erosion or deposition occured along the streams that ran through terraces and downlands or across floodplains and wetlands. No points were recorded (Table 6).

Table 6. Soil stability and bare soil for horticulture and cropping in Waikato region, 2012. Error term represents the 95% confidence interval.

Horticulture and Cropping	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	59	1.0	0.2		
S (ii) with soil disturbed by land use	45	0.7	0.2	0.09	0.05
sub total	**104**	**1.7**	**0.3**		
Erosion prone surfaces (U)					
U (i) with intact soil	5	0.1	0.1		
U (ii) with soil disturbed by land use-related activities	7	0.1	0.1	0.01	<0.01
sub total	**12**	**0.2**	**0.1**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	-	-	-		
E (ii) with soil disturbed by natural processes	-	-	-	-	-
sub total	-	-	-		
All surface in land use total	**116**	**1.9**	**0.3**	**0.10**	**0.05**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

8.1.2 Soil disturbance by land use-related activities

The numbers in this section were obtained by adding and further investigating the percentages for S (ii) and U (ii) from Table 6. When stable and erosion-prone surfaces were combined, 0.8% of the regions sample points were disturbed by horticulture and cropping (Table 7). On most sites, growing crops, or fruit trees and vines with grass beneath, provided good ground cover. Nevertheless topsoil was exposed by (Table 7):

- cultivation on 0.06% of the region's area,
- harvest on 0.01%,
- drains on <0.01%,
- tracks on 0.03%
- earthworks on <0.01% and
- unsealed roads on <0.01%,

The above activities associated with horticulture and cropping land, collectively contributed 0.10% to the region's area of bare soil (Table 6 and 7).

8.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 6. No points were recorded (Tables 6 and 7).

Table 7. Soil disturbance amongst horticulture and cropping in Waikato region, 2012. Error term represents the 95% confidence interval.

Horticulture and Cropping	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	-	-	-		
cultivation	14	0.23	0.12	0.06	0.05
harvest	6	0.10	0.08	0.01	<0.01
spraying	-	-	-		
drains	1	0.02	0.03	<0.01	<0.01
tracks	29	0.47	0.17	0.03	0.01
earthworks	1	0.02	0.03	<0.01	<0.01
roads	1	0.02	0.03	<0.01	<0.01
sub total	**52**	**0.85**	**0.23**	**0.10**	**0.05**
By natural processes					
landslide	-	-	-		
debris avalanche	-	-	-		
slump or earthflow	-	-	-		
tunnel gully	-	-	-		
gully	-	-	-		
streambank scour	-	-	-		
streambank deposition	-	-	-		
sandblow	-	-	-		
sheetwash	-	-	-		
rockfall or bare rock	-	-	-		
geothermal	-	-	-		
sub total	**0**	**0.0**	**0.00**	**0.00**	**0.00**
Undisturbed sub total	**64**	**1.05**	**0.25**		
All in land use total	**116**	**1.9**	**0.30**	**0.10**	**0.05**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

9 Dairy farms - overview

24.6% of Waikato's sample points were occupied by dairy farms (Table 8). These were entirely composed of improved pasture.

9.1.1 Soil stability

Stable surfaces

Stable surfaces in dairy pasture were protected floodplains, well-drained wetlands, elevated terraces or rolling downlands, and easy hill country footslopes.

19.8% of the region's sample points were on stable surfaces under dairy pasture. Of these, 10.7% had intact soil, currently well-vegetated, and 9.1% had soil disturbed by land use. Bare soil amounted to 0.57% of the sampled area (Table 8).

Table 8: Soil stability and bare soil for dairy farms in the Waikato region, 2012. Error term represents the 95% confidence interval.

Dairy	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	654	10.7	0.8		
S (ii) with soil disturbed by land use	558	9.1	0.7	0.57	0.07
sub total	**1212**	**19.8**	**1.0**		
Erosion prone surfaces (U)					
U (i) with intact soil	89	1.5	0.3		
U (ii) with soil disturbed by land use-related activities	70	1.1	0.3	0.07	0.03
sub total	**159**	**2.6**	**0.4**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	67	1.1	0.3		
E (ii) with soil disturbed by natural processes	67	1.1	0.3	0.03	0.01
sub total	**134**	**2.2**	**0.4**		
All surface in land use total	**1505**	**24.6**	**1.1**	**0.67**	**0.07**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

Erosion prone surfaces

Erosion-prone surfaces were unprotected floodplains, poorly-drained wetlands, drainage hollows on terraces and downlands, or unstable footslopes.

2.6% of the region's sample points were on erosion-prone surfaces under dairy pasture. Of these, 1.5% had intact soil, were well-vegetated, and 1.1% had soil disturbed by land use. Here bare soil amounted to 0.07% of the sampled area (Table 8).

Eroded and eroding surfaces

Eroded and eroding surfaces were unprotected floodplains with streambank scour or deposition, drainage hollows on terraces and downlands, or unstable footslopes in rolling to hilly country with landslides, slumps, gullies and some rock outcrops.

2.2% of the regions sample points were on eroded and eroding surfaces under dairy pasture. Of these, 1.1% had soil recently disturbed by natural erosion processes, but revegetating, and 1.1% had soil freshly disturbed, with bare soil amounting to 0.03% of the sampled area.

9.1.2 Soil disturbance by land use-related activities

Numbers in this section were obtained by adding and further investigating the percentages for S(ii) and U(ii) from Table 8. When stable and erosion-prone surfaces were combined, 10.3% of regions sample points disturbed by dairy farming. The fairly high percentage was due to; farm tracks (7.97%), grazing pressure (0.96%), drain clearance (0.75%), seasonal cultivation for pasture renewal and summer green-feed (0.28%), and roads (0.21%) (Table 9).

The greatest cause of bare soil was tracking, this accounted for 0.51% of bare land under dairy farming from a total of 0.63% (Table 9). A high proportion of tracks on dairy farms are surfaced with race rock or similar, and also away from streams - factors which reduce off-site soil loss. Likewise, a high proportion of soil bared by seasonal cultivation is on flat land where any soil removed by runoff is likely to be trapped by adjacent dense pasture before reaching a watercourse (assuming appropriate buffers are in place).

9.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 8. 1.1% of the regions sampler points were disturbed by natural processes occurring under dairy pasture. The contributors were gullies (including tunnel gullies) and landslides, bank scour or deposits along watercourses and areas of bare rock (Table 9).

Soil bared by natural disturbance was minor, equating to 0.03% of the region's bare ground (Table 9), and so its contribution to region-wide bare soil (which was 1.93%, as shown in Table 3) was slight.

Table 9: Soil disturbance amongst dairy farms in Waikato region, 2012. Error term represents the 95% confidence interval.

Dairy	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	59	0.96	0.24	0.02	0.01
cultivation	17	0.28	0.13	0.07	0.05
harvest	-	-	-		
spraying	-	-	-		
drains	46	0.75	0.22	0.02	0.01
tracks	488	7.97	0.68	0.51	0.05
earthworks	5	0.08	0.07	<0.01	<0.01
roads	13	0.21	0.12	0.02	0.01
sub total	**628**	**10.3**	**0.8**	**0.63**	**0.07**
By natural processes					
landslide	17	0.28	0.13	<0.01	<0.01
debris avalanche	-	-	-		
slump or earthflow	-	-	-		
tunnel gully	8	0.13	0.09	<0.01	<0.01
gully	18	0.29	0.14	<0.01	<0.01
streambank scour	7	0.11	0.08	<0.01	<0.01
streambank deposit	7	0.11	0.08	<0.01	<0.01
sandblow	1	0.02	0.03	<0.01	<0.01
sheetwash	-	-	-		
rockfall or bare rock	9	0.15	0.1	0.01	<0.01
geothermal	-	-	-		
sub total	**67**	**1.09**	**0.3**	**0.03**	**0.01**
Other undisturbed sub total	**810**	**13.2**	**0.8**		
All in land use total	**1505**	**24.6**	**1.1**	**0.66**	**0.07**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

Drystock - overview

26.2% of the regions sample points (Table 10) were under drystock farms (beef cattle, deer, sheep and goats). At the time of photography (mid to late summer 2012) most of the farms had improved pasture, and just 2.2% had unimproved pasture (Table 4).

9.1.4 Soil stability

Stable surfaces

Stable surfaces under drystock pasture were elevated terraces, rolling downlands, easy hillslopes, and old coastal dunes with weathered soils.

11.9% of the region's sample points were on stable surfaces under drystock pasture. Of these 7.8% had intact soil, were well-vegetated, and 4.1% had soil currently disturbed by land use. Bare soil amounts to 0.17% of the sampled area (Table 10).

Erosion prone surfaces

Erosion-prone surfaces were drainage hollows on terraces and downlands (including healed under-runners and gullies); moderate hill slopes showing traces of past slope failure, now completely revegetated; and young or intermediate-age coastal dunes fixed by pasture.

6.6% of the region's sample points were on erosion-prone surfaces under drystock pasture. Of these, 3.8% had intact soil, were well-vegetated, and 2.7% had soil disturbed by land use. Bare soil amounted to 0.11% of the sampled area (Table 10).

Eroded and eroding surfaces

Eroded and eroding surfaces were landslides, slumps and earthflows on moderate hill country; under-runners and gullies or in drainage hollows on terraces and downlands; and streambank scour or deposition along watercourses. Sandblow on sparsely vegetated dunes, sheetwash on sparsely vegetated hill country spurs or ridges, and rockfall or rock outcrops on inland bluffs and coastal cliffs, were also present.

7.7% of the region's sample points were on eroded and eroding surfaces in drystock pasture. Of these, 2.9% had soil recently disturbed by natural erosion processes, but revegetating, and 4.8% had soil freshly disturbed, with bare soil amounting to 0.14% of the sampled area.

Table 10: Soil stability and bare soil for drystock farms in the Waikato region, 2012. Error term represents the 95% confidence interval.

Drystock	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	480	7.8	0.67		
S (ii) with soil disturbed by land use	251	4.1	0.50	0.17	0.04
sub total	**731**	**11.9**	**0.81**		
Erosion prone surfaces (U)					
U (i) with intact soil	235	3.8	0.48		
U (ii) with soil disturbed by land use-related activities	168	2.7	0.41	0.11	0.02
sub total	**403**	**6.6**	**0.62**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	178	2.9	0.42		
E (ii) with soil disturbed by natural processes	292	4.8	0.53	0.14	0.02
sub total	**470**	**7.7**	**0.67**		
All surface in land use total	**1604**	**26.2**	**1.10**	**0.42**	**0.05**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

9.1.5 Soil disturbance by land use-related activities

Numbers in this section are obtained by adding and further investigating the percentages for S(ii) and U(ii) from Table 10. When stable and erosion-prone surfaces were combined, 6.8% of the regions sample points were disturbed by drystock farming. The percentage is less than that under dairy farming, however causes of topsoil disturbance were similar, with the principal contributors being farm tracks (4.48%) and grazing pressure (1.75%). Other land-use-related disturbances are individually minor, though and cumulatively amounted to 0.62% of land (Table 11).

Bare soil equated to 0.27% of the region's area, which is about 14% of the region's land at risk of topsoil loss (of the 1.93% in total, as in Table 3). Tracks contribute the most to bare soil under drystock farms. Tracks on drystock farms are usually bare earth, many are on rolling to moderately steep ground, and some cross streams - factors which pre-dispose them to off-site soil loss. Grazing pressure and cultivation for pasture renewal contribute most of the balance (Table 11).

Table 11: Soil disturbance amongst drystock farms in Waikato region, 2012. Error term represents the 95% confidence interval.

Drystock	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	107	1.75	0.33	0.04	0.01
cultivation	5	0.08	0.07	0.03	0.03
harvest	-	-	-		
spraying	-	-	-		
drains	4	0.07	0.06	<0.01	<0.01
tracks	274	4.48	0.52	0.17	0.02
earthworks	16	0.26	0.13	0.02	0.02
roads	13	0.21	0.11	0.01	0.01
sub total	**419**	**6.85**	**0.63**	**0.27**	**0.04**
By natural processes					
landslide	99	1.62	0.32	0.04	0.01
debris avalanche	1	0.02	0.03	<0.01	<0.01
slump or earthflow	9	0.15	0.1	<0.01	<0.01
tunnel gully	30	0.49	0.17	0.01	<0.01
gully	58	0.95	0.24	0.02	0.01
streambank scour	17	0.28	0.13	<0.01	<0.01
streambank deposition	7	0.11	0.08	<0.01	<0.01
sandblow	2	0.03	0.05	<0.01	<0.01
sheetwash	3	0.05	0.06	<0.01	0.01
rockfall or bare rock	66	1.08	0.26	0.05	0.02
geothermal	-	-	-		
sub total	**292**	**4.8**	**0.53**	**0.14**	**0.02**
Other undisturbed sub total	**893**	**14.6**	**0.88**		
All in land use total	**1604**	**26.2**	**1.1**	**0.41**	**0.05**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

9.1.6 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 10. 4.8% of the regions sample points were disturbed by natural processes on land under drystock pasture. The disturbance was dominated by landslides, bare rock on steep faces and gully erosion (including tunnel gullies) in drainage hollows. Streambank scour or deposition along watercourses was also a contributor (Table 11).

Soil exposed by natural processes in drystock pasture equated to 0.14% of the region's area (Table 11), and accounted for 37% of the region's soil erosion by natural processes[1].

[1] Where 0.38% represents the total regional area of bare soil due to disturbance by natural processes, as presented in Table 1.

10 Forest plantations - overview

Forest plantations occupied 12.1% of the regions sample points (Table 12). These plantations were predominantly pine plantations, with a very small proportion of broadleaf trees (as represented by, 0.5% in Table 4).

10.1.1 Soil stability

Stable surfaces

Stable surfaces under forest plantation were elevated terraces, rolling downlands, easy hillslopes, and old coastal dunes with weathered soils.

7.4 % of the region's sample points were on stable surfaces under forest plantations. Of these, 5.1% had intact soil, were well-vegetated, and 2.3% had soil disturbed by land use-related activities. Bare soil amounted to 0.15% of the regional sample's area (Table 12).

Erosion- prone surfaces

Erosion-prone surfaces were mostly moderate hillslopes or steep rangelands showing traces of past slope failure, now completely revegetated. Some appeared on coastal dunes of young to intermediate age, now stabilised by pine trees. A small proportion were stream banks, drainage hollows on terraces and downlands, or unstable footslopes.

3.5% of the region's sample points were on erosion-prone surfaces under forest plantations. Of these, 2.4% had intact soil, currently well-vegetated, and 1.1% had soil disturbed by land use. Here bare soil amounted to 0.07% of the sample's area (Table 12).

Eroded and eroding surfaces

The eroded and eroding surfaces under forest plantation were streambank scour along watercourses; landslides or debris avalanches on hill faces and steep ranges; gully erosion in drainage hollows and incised steeper country; and rock outcrops on inland bluffs or ash-mantled ignimbrite plateaux.

1.2% of the region's sample points were on eroded and eroding surfaces under forest plantations. Of these, 0.8% had soil recently disturbed by natural erosion processes, but were revegetating, and 0.4% had freshly disturbed soil. Bare soil amounted to 0.02% of the sample's area (Table 12).

Table 12: Soil stability and bare soil for forest plantations in the Waikato region, 2012. Error term represents the 95% confidence interval.

Forest Plantations	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	313	5.1	0.55		
S (ii) with soil disturbed by land use	141	2.3	0.38	0.15	0.03
sub total	**454**	**7.4**	**0.66**		
Erosion prone surfaces (U)					
U (i) with intact soil	147	2.4	0.38		
U (ii) with soil disturbed by land use-related activities	69	1.1	0.26	0.07	0.03
sub total	**216**	**3.5**	**0.46**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	47	0.8	0.22		
E (ii) with soil disturbed by natural processes	25	0.4	0.16	0.02	0.02
sub total	**72**	**1.2**	**0.27**		
All surface in land use total	**742**	**12.1**	**0.82**	**0.24**	**0.04**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

10.1.2 Soil disturbance by land use-related activities

Numbers in this section are obtained by adding and further investigation the percentages for S (ii) and U (ii) from Table 12. When stable and erosion-prone surfaces were combined, 3.4% of regions sample points were disturbed. 2.0% of land use-related disturbance was due to tracking or forest roads - this included access tracks for planting and silviculture as well as roads for harvest. 1.0% was land where soil was exposed by harvest – this was concentrated along skidder tracks and hauler paths rather than disseminated throughout harvested compartments (Table 13).

Bare soil land use-related activities on forest plantations equated to 0.22% of the region's area (Table 13), and therefore amounts to 12% of the region's land at risk of topsoil loss[2]. Much of

[2] Where 1.31% represents the total regional area of bare soil due to disturbance by land use related activities, as presented in Table 1.

the exposed soil was on upper slopes close to landing stages, where it was unlikely to move towards watercourses. Where it was on lower slopes, off-site soil loss may be mitigated by forest management practices on adjacent ground - metalling of tracks, over-sowing of grasses and legumes on harvest sites, and avoidance of planting or harvest near streams.

Table 13: Soil disturbance amongst forest plantations in the Waikato region, 2012. Error term represents the 95% confidence interval.

Forestry	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	2	0.03	0.05	<0.01	<0.01
cultivation	-	-	-		
harvest	62	1.01	0.25	0.07	0.04
spraying	-	-	-		
drains	-	-	-		
tracks	125	2.04	0.35	0.12	0.03
earthworks	5	0.08	0.07	<0.01	<0.01
roads	16	0.26	0.13	0.02	0.01
sub total	**210**	**3.43**	**0.46**	**0.22**	**0.04**
By natural processes					
landslide	7	0.11	0.08	<0.01	<0.01
debris avalanche	2	0.03	0.05	<0.01	<0.01
slump or earthflow	-	-	-		
tunnel gully	1	0.02	0.03	<0.01	<0.01
gully	6	0.1	0.08	<0.01	<0.01
streambank scour	2	0.03	0.05	<0.01	<0.01
streambank deposition	2	0.03	0.05	<0.01	<0.01
sandblow	-	-	-		
sheetwash	1	0.02	0.03	0.01	0.02
rockfall or bare rock	4	0.07	0.06	<0.01	<0.01
geothermal	-	-	-		
sub total	**25**	**0.41**	**0.16**	**0.02**	**0.02**
Other undisturbed sub total	**507**	**8.28**	**0.69**		
All in land use total	**742**	**12.1**	**0.82**	**0.24**	**0.04**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

10.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 12. A further 0.4% of land in Waikato is disturbed by natural processes occurring on land in forest plantations. In forest plantations, soil bared by natural erosion or deposition amounts to 0.02% of the region's land; a small contribution to regional soil erosion by natural processes (which was 0.38%, as shown in Table 1). Given the area in forest plantation (12.1% of the region), proportionately it is much less than might be expected and indicates the stabilising effect of tree roots in soil whether under maturing forest, or beneath harvested and replanted trees.

11 Natural forest – overview

Natural forest is present at 11.8% of Waikato's sample points (Table 14). The forest areas were predominantly closed canopy, with small proportion of open canopy, plus small forest remnants near houses and buildings.

11.1.1 Soil stability

Stable surfaces

Stable surfaces in natural forest were moderate hillslopes, or spurs and ridges in the ranges; apart from a small proportion where forest remains on footslopes, terraces or downlands.

5.2% of the region's sample points were on stable surfaces under natural forest. Of these, 5.0% had intact soil, were well-vegetated, and 0.1% had soil currently disturbed by land use. Bare soil amounted to 0.01% of the sampled area (Table 14).

Erosion prone surfaces

Erosion-prone surfaces were moderate hillslopes showing traces of past slope failure (now completely revegetated), or steep slopes in the ranges with similar evidence. A small proportion were forest remnants adjacent to watercourses that run through footslopes, terraces or downlands.

3.7% of the region's sample points are on erosion-prone surfaces under natural forest. Of these, 3.5% had intact soil, currently well-vegetated, and 0.2% have soil currently disturbed by land use. Here bare soil amounts to <0.01% of the sample's area (Table 14).

Eroded and eroding surfaces

Eroded and eroding surfaces are landslides and debris avalanches in the hill country and ranges; and streambank scour or deposition along watercourses.

2.9% of the region's sample points are on eroded and eroding surfaces under natural forest. Of these 2.2% had soil recently disturbed by natural erosion processes, but revegetating, and 0.8% have soil freshly disturbed, with bare soil amounting to 0.03% of the sample's area (Table 14).

Table 14: Soil stability and bare soil for natural forest in the Waikato region, 2012. Error term represents the 95% confidence interval.

Natural forest	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	307	5.0	0.55		
S (ii) with soil disturbed by land use	8	0.1	0.09	0.01	<0.01
sub total	**315**	**5.2**	**0.55**		
Erosion prone surfaces (U)					
U (i) with intact soil	215	3.5	0.46		
U (ii) with soil disturbed by land use-related activities	10	0.2	0.10	<0.01	<0.01
sub total	**225**	**3.7**	**0.47**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	133	2.2	0.37		
E (ii) with soil disturbed by natural processes	47	0.8	0.22	0.03	0.01
sub total	**180**	**2.9**	**0.42**		
All surface in land use total	**720**	**11.8**	**0.81**	**0.04**	**0.01**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

11.1.2 Soil disturbance by land use-related activities

Numbers in this section were obtained by adding and further investigating the percentages for S(ii) and U(ii) from Table 14. When stable and erosion-prone surfaces were combined, just 0.29% of Waikato's land is disturbed by land use-related activities within natural forest. These were almost entirely access tracks or unsealed rural roads (earthwork disturbance and harvest was recorded at just one sample point each). Equating to 0.01% (Table 15) of the region's bare soil the contribution of land use-related activities in natural forest to land with a risk of topsoil loss is negligible.

Table 15: Soil disturbance amongst forest plantations in the Waikato region, 2012. Error term represents the 95% confidence interval.

Natural forest	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	-	-	-		
cultivation	-	-	-		
harvest	1	0.02	0.03	<0.01	<0.01
spraying	-	-	-		
drains	-	-	-		
tracks	14	0.23	0.12	0.01	0.01
earthworks	1	0.02	0.03	<0.01	<0.01
roads	2	0.03	0.05	<0.01	<0.01
sub total	**18**	**0.29**	**0.14**	**0.01**	**0.01**
By natural processes					
landslide	13	0.21	0.12	<0.01	<0.01
debris avalanche	9	0.15	0.10	<0.01	<0.01
slump or earthflow	-	-	-		
tunnel gully	-	-	-		
gully	-	-	-		
streambank scour	11	0.18	0.11	<0.01	<0.01
streambank deposition	9	0.15	0.10	0.02	0.01
sandblow	-	-	-		
sheetwash	-	-	-		
rockfall or bare rock	5	0.08	0.07	<0.01	<0.01
geothermal	-	-	-		
sub total	**47**	**0.77**	**0.22**	**0.03**	**0.01**
Other undisturbed sub total	**655**	**10.7**	**0.77**		
All in land use total	**720**	**11.8**	**0.81**	**0.04**	**0.01**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

11.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 14. 0.8% of land in Waikato was disturbed by erosion or deposition within natural forest. Bare soil on disturbed surfaces (0.03%) was largely attributable to stream scour and deposition and was a very small contribution towards the region's total bare soil (which was 0.38%, as shown in Table 1.). Although the region's remaining forest is mainly on hill country or steep ranges subject to high rainfall, for the most part it is underlain by stable geology.

12 Natural scrub - overview

Natural scrub was present at 10.8% of Waikato's sample points (Table 16). There is a mixture of closed canopy scrub, scrub with emerging forest trees (such areas include forest long since cut-over, and long-abandoned farms) and scrub with grass, exotic scrub or exotic trees in canopy gaps; these are areas of recently abandoned or lightly grazed pasture.

12.1.1 Soil stability

Stable surfaces

Stable surfaces in natural scrub were moderate hillslopes, or spurs and ridges in the ranges; apart from a small proportion where scrub remained on footslopes, terraces or downlands.

4.0% of the region's sample points are on stable surfaces in natural scrub. Of these, 3.6% had intact soil, were well-vegetated, and 0.4% had soil disturbed by land use. Bare soil amounted to 0.01% of the sampled area (Table 16).

Erosion- prone surfaces

Erosion-prone surfaces were moderate hillslopes showing traces of past slope failure (now completely revegetated), or steep slopes in the ranges with similar evidence. A small proportion are scrub remnants adjacent to watercourses that run through footslopes, terraces or downlands.

4.0% of the region's sample points were on erosion-prone surfaces in natural scrub. Of these, 3.5% had intact soil, currently well-vegetated, and 0.5% had soil currently disturbed by land use. Here bare soil amounted to 0.02% of the sampled area (Table 16).

Eroded and eroding surfaces

The eroded and eroding surfaces were landslides and gullies on hill country; debris avalanches in the ranges; streambank scour or deposition along watercourses; and rock outcrops on inland bluffs.

2.8% of the region's sample points were on eroded and eroding surfaces in natural scrub. Of these, 2.1% had soil recently disturbed by natural erosion processes, but revegetating, and 0.8% have soil freshly disturbed, with bare soil amounting to 0.03% of the sampled area (Table 16).

Table 16: Soil stability and bare soil for natural scrub in the Waikato region, 2012. Error term represents the 95% confidence interval.

Natural Scrub	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	220	3.6	0.47		
S (ii) with soil disturbed by land use	23	0.4	0.15	0.01	0.01
sub total	**243**	**4.00**	**0.49**		
Erosion prone surfaces (U)					
U (i) with intact soil	216	3.5	0.46		
U (ii) with soil disturbed by land use-related activities	30	0.5	0.17	0.02	0.01
sub total	**246**	**4.00**	**0.49**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	128	2.1	0.36		
E (ii) with soil disturbed by natural processes	46	0.8	0.22	0.03	0.01
sub total	**174**	**2.9**	**0.42**		
All surface in land use total	**663**	**10.8**	**0.78**	**0.06**	**0.02**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding.

Note 3: confidence limits are not additive.

12.1.2 Soil disturbance by land use-related activities

Numbers in this section were obtained by adding and further investigating the percentages for S(ii) and U(ii) from Table 16. When stable and erosion-prone surfaces were combined, 0.9% of the regions sample points were disturbed by land use-related activities within natural scrub. Most disturbances were access tracks or rural roads remaining within areas formerly harvested for timber or formerly farmed (Table 17). Equating to 0.03% of bare soil by area, land use-related disturbance in natural scrub made a slightly larger contribution to the region's soil at risk of topsoil loss (which was 1.31%, as shown in Table 2) than is the case in natural forest. As shown in Table 17 components of the bare soil were:

- tracks at 0.02% of the region's area,
- unsealed roads at 0.01%,
- earthworks at <0.01%, and
- grazing pressure at <0.01%.

Table 17: Soil disturbance amongst natural scrub in the Waikato region, 2012. Error term represents the 95% confidence interval.

Natural Scrub	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	5	0.08	0.07	<0.01	<0.01
cultivation	-	-	-		
harvest	-	-	-		
spraying	-	-	-		
drains	-	-	-		
tracks	39	0.64	0.2	0.02	0.01
earthworks	1	0.02	0.03	<0.01	<0.01
roads	8	0.13	0.09	0.01	0.01
sub total	**53**	**0.87**	**0.23**	**0.03**	**0.01**
By natural processes					
landslide	14	0.23	0.12	0.01	<0.01
debris avalanche	1	0.02	0.03	<0.01	<0.01
slump or earthflow	-	-	-		
tunnel gully	-	-	-		
gully	2	0.03	0.05	<0.01	<0.01
streambank scour	8	0.13	0.09	<0.01	<0.01
streambank deposition	9	0.15	0.1	0.01	0.01
sandblow	-	-	-		
sheetwash	1	0.02	0.03	<0.01	<0.01
rockfall or bare rock	11	0.18	0.11	0.01	0.01
geothermal	-	-	-		
sub total	**46**	**0.75**	**0.22**	**0.03**	**0.01**
Other undisturbed sub total	**564**	**9.21**	**0.72**		
All in land use total	**663**	**10.8**	**0.78**	**0.06**	**0.02**

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

Note 2: % of area sub totals/totals may differ by 0.1% due to rounding

Note 3: confidence limits are not additive.

12.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 16. 0.8% of the regions sample points were was disturbed by erosion or deposition within natural scrub, and bare soil on disturbed surfaces was due to:

- slope failures on 0.01% of the region's area,
- stream scour and deposit on 0.01%, and
- bare rock on 0.01%

These equated to 0.03% of the region's area; or 9.6% of soil exposed by natural erosion region-wide (which was 0.31%, as shown in Table 3).

13 Exotic scrub – overview

Exotic scrub occupied 2.5% of regions sample points (Table 18). Exotic scrub consisted of closed-canopy stands; typically blackberry, broom or gorse, although other species e.g. tobacco weed, brush wattle, pampas, are locally present, mature exotic scrub stands intermingled with native scrub which successively replaces it and contain scrub in remnant pasture or exotic trees, on abandoned or reverting farmland.

13.1.1 Soil stability

Stable surfaces

Stable surfaces in exotic scrub ranged from infertile soils on terraces, downlands or footslopes, through spurs and ridges in hill country, to shallow soils on steep but stable faces in the ranges.

0.9% of the region's sample points were on stable surfaces in exotic scrub. Of these 0.7% had intact soil, were well-vegetated, and 0.2% had soil disturbed by land use. Bare soil amounted to 0.01% of the sampled area (Table 19).

Erosion- prone surfaces

The unstable surfaces were drainage hollows through terraces, downlands or footslopes, and moderate hillslopes or steep ranges showing traces of past slope failure, now completely revegetated.

1.0% of the region's sample points were on erosion-prone surfaces in exotic scrub. Of these, 0.6% had intact soil, were well-vegetated, and 0.4% had soil disturbed by land use. Here bare soil amounted to 0.02% of the sampled area (Table 19).

Eroded and eroding surfaces

The eroded and eroding surfaces are where mass movement, gully or surface erosion occurs on any of the unstable landforms listed above, and the scars are colonised by exotic scrub.

0.6% of the region's sample points were on eroded and eroding surfaces in exotic scrub. Of these, 0.3% had soil recently disturbed by natural erosion processes, but were revegetating, and 0.3% had soil freshly disturbed. Bare soil amounted to 0.02% of the sampled area (Table 19).

Table 18: Soil stability and bare soil for exotic scrub in the Waikato region, 2012. Error term represents the 95% confidence interval.

Exotic Scrub	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (s)					
S (i) with intact soil	40	0.7	0.2		
S (ii) with soil disturbed by land use	12	0.2	0.11	0.01	0.01
sub total	**52**	**0.9**	**0.23**		
Erosion prone surfaces (U)					
U (i) with intact soil	38	0.6	0.2		
U (ii) with soil disturbed by land use-related activities	23	0.4	0.15	0.02	0.01
sub total	**61**	**1.00**	**0.25**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	17	0.3	0.13		
E (ii) with soil disturbed by natural processes	21	0.3	0.15	0.02	0.01
sub total	**38**	**0.6**	**0.2**		
All surface in land use total	**151**	**2.5**	**0.39**	**0.05**	**0.02**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

13.1.2 Soil disturbance by land use-related activities

Numbers in this section were obtained by adding and further investigation the percentages for S(ii) and U(ii) from Table 18. When stable and erosion-prone surfaces were combined, 0.6% of the regions sample points were disturbed by land use-related activities within exotic scrub. As with natural scrub, most disturbance is access tracks and roads remaining within areas formerly farmed. The balance is scrub clearance, and earthworks (Table 19). Bare soil due to land use-related activities equated to 0.03% (Table 19) of the region's bare soil, therefore representing a small contribution (2%) to the region's exposed soil at risk of topsoil loss (which was 1.31%, as shown in Table 2).

13.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 18. 0.3% of land in Waikato is disturbed by erosion or deposition within exotic scrub. Bare soil on disturbed surfaces is due to a wide range of natural processes. These add to 0.02% of the region's area

(Table 29) and represent a small contribution to the region's total soil bare due natural disturbance (0.38%, Table 3). Exotic scrub's contribution is surprisingly low, given that it colonises abandoned or unstable sites following unsuccessful attempts at use, or after frequent natural disturbance. Such a low figure may be attributed to the very small area currently in exotic scrub (2.47% of the Waikato region).

Table 19: Soil disturbance amongst exotic scrub in the Waikato region, 2012. Error term represents the 95% confidence interval.

Exotic Scrub	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	-	-	-		
cultivation	-	-	-		
harvest	8	0.13	0.09	0.01	<0.01
spraying	-	-	-		
drains	-	-	-		
tracks	23	0.38	0.15	0.02	0.01
earthworks	1	0.02	0.03	<0.01	0.01
roads	3	0.05	0.06	<0.01	<0.01
sub total	**35**	**0.57**	**0.19**	**0.03**	**0.02**
By natural processes					
landslide	4	0.07	0.06	<0.01	<0.01
debris avalanche	2	0.03	0.05	<0.01	<0.01
slump or earthflow	-	-	-		
tunnel gully	1	0.02	0.03	<0.01	<0.01
gully	-	-	-		
streambank scour	3	0.05	0.06	<0.01	<0.01
streambank deposition	4	0.07	0.06	<0.01	0.01
sandblow	-	-	-		
sheetwash	1	0.02	0.03	<0.01	<0.01
rockfall or bare rock	3	0.05	0.06	<0.01	0.01
geothermal	3	0.05	0.06	0.01	0.01
sub total	**21**	**0.35**	**0.15**	**0.02**	**0.01**
Other undisturbed sub total	**95**	**1.55**	**0.31**		
All in land use total	**151**	**2.47**	**0.39**	**0.05**	**0.02**

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

Note 2: % of area sub totals/totals may differ by 0.1% due to rounding

Note 3: confidence limits are not additive.

14 Tussock and mountain vegetation - overview

Tussock and mountain vegetation occupied 1.8% of Waikato's sample points (Table 20). It comprises tussock on elevated plateaux, sub-alpine scrub (including exotic heather), alpine tussock and herb-field, and bare rock on mountain flanks and summits.

14.1.1 Soil stability

Stable surfaces

Stable surfaces in the mountains were generally confined to lower slopes, spurs and ridges. 0.5% of the region's sample points were stable surfaces on mountains, 0.5% had intact soil, were well-vegetated, and 0.0% had soil disturbed by land use, so there was no bare soil measured here.

Table 20: Soil stability and bare soil for tussock and mountain vegetation in the Waikato region, 2012. Error term represents the 95% confidence interval.

Tussock and mountain	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (S)					
S (i) with intact soil	28	0.5	0.17		
S (ii) with soil disturbed by land use	0	0.0	0.00		
sub total	**28**	**0.5**	**0.17**		
Erosion prone surfaces (U)					
U (i) with intact soil	9	0.2	0.10		
U (ii) with soil disturbed by land use-related activities	1	0.02	0.03	<0.01	<0.01
sub total	**10**	**0.2**	**0.10**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	22	0.4	0.15		
E (ii) with soil disturbed by natural processes	53	0.9	0.23	0.09	0.05
sub total	**75**	**1.2**	**0.28**		
All surface in land use total	**113**	**1.9**	**0.34**	**0.09**	**0.05**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

Erosion-prone surfaces

Erosion-prone surfaces in the mountains are steep upper slopes and inactive gullies. 0.2% of the region's sample points were erosion-prone surfaces on mountains, 0.2% had intact soil, that was well-vegetated. 0.02% (one sample point) had soil disturbed by land use (forest plantation), with bare soil on less than 0.01% of regions area.

Eroded and eroding surfaces

Eroded and eroding surfaces were mass movement scars on upper slopes, active gullies or streams, unvegetated or re-vegetating scree slopes, and old or fresh rock-falls on bluffs. 1.2% of the region's sample points were eroded and eroding surfaces on mountains, 0.4% were areas of surface and sub-surface erosion which were re-vegetating, 0.9% were freshly disturbed, with bare soil or rock amounting to 0.09% of the regions area.

Soil disturbance by land use-related activities

Numbers in this section were obtained by adding the percentages for S(ii) and U(ii) from Table 20. When stable and erosion-prone surfaces were combined, 0.02% (one single point) of Waikato's land was disturbed by land use-related activities on mountains (Table 21). This is due to the unproductive, isolated and steep nature of the land, generally precluding land use. Nonetheless, plantation forestry borders these areas, which accounts for a single point representing a vehicle track.

Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E(ii) in Table 20. Only 0.87% of Waikato's land is disturbed by natural erosion or deposition in mountains (Table 21). Bare soil and rock (0.09%) is caused by:

- slope failures, exposing 0.01% of the region's area,
- tunnel gullies and gullies, <0.01%
- streambank scour or deposition, <0.01%
- sheetwash, 0.03%
- bare rock, 0.04%

These contributes substantially (24%) to the region's area of bare soil due to natural disturbance (0.38%, Table 1). Proportionately it is very high relative to the small area of mountains (1.8% of the regions sample points).

Table 21: Soil disturbance amongst tussock and mountain vegetation in the Waikato region, 2012. Error term represents the 95% confidence interval.

Tussock and mountain	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	-	-	-		
cultivation	-	-	-		
harvest	-	-	-		
spraying	-	-	-		
drains	-	-	-		
tracks	1	0.02	0.03	<0.01	<0.01
earthworks	-	-	-		
roads	-	-	-		
sub total	**1**	**0.02**	**0.03**	**<0.01**	**<0.01**
By natural processes					
landslide	3	0.05	0.06	<0.01	<0.01
debris avalanche	5	0.08	0.07	0.01	0.01
slump or earthflow					
tunnel gully	3	0.05	0.06	<0.01	<0.01
gully	2	0.03	0.05	<0.01	<0.01
streambank scour	6	0.10	0.08	<0.01	<0.01
streambank deposition	2	0.03	0.05	<0.01	<0.01
sandblow					
sheetwash	23	0.38	0.15	0.03	0.02
rockfall or bare rock	9	0.15	0.1	0.04	0.05
geothermal					
sub total	**53**	**0.87**	**0.23**	**0.09**	**0.05**
Other undisturbed sub total	**59**	**0.97**	**0.24**		
All in land use total	**113**	**1.86**	**0.34**	**0.09**	**0.05**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

15 Wetland and coastal vegetation - overview

Wetland and coastal vegetation occupied 1.0% of Waikato's sample points (Table 22). The components were freshwater wetland (0.8%), mangrove and saltmarsh (<0.1%), and coastal grass or scrub (0.1%).

Soil stability

15.1.1 Stable surfaces

Stable surfaces (Table 22) in wetland and coastal vegetation were confined to drained wetlands that have been under productive use for some time. 0.3% of the region's sample points were on stable surfaces on wetlands, 0.3% had intact soil, currently well-vegetated, and 0.0% had soil currently disturbed by land use, so there is no bare soil measured here.

Table 22: Soil stability and bare soil for wetland and coastal vegetation in the Waikato region, 2012. Error term represents the 95% confidence interval.

Wetlands and coastal	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
Stable surfaces (S)					
S (i) with intact soil	2	0.03	0.05		
S (ii) with soil disturbed by land use	-	-	-		
sub total	**2**	**0.03**	**0.05**		
Erosion prone surfaces (U)					
U (i) with intact soil	47	0.8	0.22		
U (ii) with soil disturbed by land use-related activities	3	0.1	0.06	<0.01	<0.01
sub total	**50**	**0.8**	**0.23**		
Eroded (R) and eroding (E) surfaces					
R (i) with revegetating soil	3	0.1	0.06		
E (ii) with soil disturbed by natural processes	5	0.1	0.07	0.03	0.03
sub total	**8**	**0.1**	**0.09**		
All surface in land use total	**60**	**1.0**	**0.25**	**0.03**	**0.03**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.

Erosion-prone surfaces

The erosion-prone surfaces were mostly undrained or semi-drained swamps (on floodplains and coastal flats) but also include intact or partly reclaimed mangrove swamps (in estuaries), perched wetlands on terraces and downlands, and vegetated young sand dunes or coastal cliffs. 0.8% of the region's sample points were on erosion-prone surfaces under wetland or coastal vegetation, 0.8% had intact soil, currently well-vegetated, and 0.1% had soil disturbed by land-use-related activities, with exposed soil amounting to <0.01% of the region's area.

Eroded and eroding surfaces

Eroded and eroding surfaces comprised active sand blows and rockfalls on coastal cliffs, plus banks of watercourses flowing through wetlands or tidal creeks. 0.1% of the region's sample points were on eroded and eroding surfaces under wetland and coastal vegetation, 0.1% had soil recently disturbed by natural erosion processes but revegetating, and another 0.1% had soil freshly disturbed, with bare soil amounting to 0.03% of the regional sample's area.

15.1.2 Soil disturbance by land use-related activities

Numbers in this section were obtained by adding the percentages for S (ii) and U (ii) from Table 22. When stable and erosion-prone surfaces were combined, <0.1% of Waikato's land is currently disturbed by land use-related activities within wetland and coastal vegetation. Exposed soil is <0.01% of the region's area, a negligible contribution to the total bared by land use (1.31% region-wide, Table 1); and is accounted for by:

- Cultivation and grazing pressure <0.01% (3 sample points).

15.1.3 Soil disturbance by natural processes

Numbers in this section correspond with the percentages for E (ii) in Table 22. 0.08% of Waikato's land was disturbed by natural erosion or deposition within wetlands and coastal areas. Bare soil associated with these areas amounted to 0.03% of the region's area and was confined to:

- Wind erosion of young sand dunes, at 0.02%
- Gully erosion at <0.01% (Table 23).

This is a measureable contribution (7.9%) to the region's area of bare soil due to natural disturbance (total 0.38%, Table 1). Proportionately it is quite high relative to the area of land in wetland and coastal vegetation (1.0% of the region).

Table 23: Soil disturbance amongst tussock and mountain vegetation in the Waikato region, 2012. Error term represents the 95% confidence interval.

Wetlands and coastal	Points	Points as % of regional sample[1]	95 % c.i.[3]	Bare soil as % of regional area[2]	95 % c.i.[3]
By land use-related activities					
grazing pressure	1	0.02	0.03	<0.01	<0.01
cultivation	2	0.03	0.05	<0.01	<0.01
harvest	-	-	-		
spraying	-	-	-		
drains	-	-	-		
tracks	-	-	-		
earthworks	-	-	-		
roads	-	-	-		
sub total	**3**	**0.05**	**0.06**	**<0.01**	**<0.01**
By natural processes					
landslide	-	-	-		
debris avalanche	-	-	-		
slump or earthflow	-	-	-		
tunnel gully	-	-	-		
gully	1	0.02	0.03	<0.01	<0.01
streambank scour	-	-	-		
streambank deposition	-	-	-		
sandblow	4	0.07	0.06	0.02	0.03
sheetwash	-	-	-		
rockfall or bare rock	-	-	-		
geothermal	-	-	-		
sub total	**5**	**0.08**	**0.07**	**0.03**	**0.03**
Other undisturbed sub total	**52**	**0.85**	**0.23**		
All in land use total	**60**	**0.98**	**0.25**	**0.03**	**0.03**

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

Note 2: % of area sub totals/totals may differ by 0.01% due to rounding

Note 3: confidence limits are not additive.