Photo: Market gardens, Auckland. (Source: ARC).

4.2

State of the environment and biodiversity – Land

Contents 4.2

4.2

Land

Introduction

The land resource includes landforms, parent material and soil types. All of these vary in the Auckland region.

The west coast is dominated by huge dunes that form the peninsulas at Awhitu and South Kaipara Head: much of this sandy land contains brown soils, and is unstable and prone to erosion. In the north, the land consists of layers of sandstone and mudstone (the Waitemata formation). This area is dominated by highly weathered clay soils on rolling and hilly slopes, with some steeper slopes that are unstable and prone to erosion. The Waitakere Ranges in the west were formed by lava from volcanic eruptions and are covered mostly in native forest. The low undulating land of the Auckland isthmus is scattered with numerous small volcanic cones consisting of volcanic ash and lava (see Volcanic eruptions in Chapter 5.1). The volcanic eruptions covered a wide area and resulted in well-structured and productive granular soils in the west and south. Alluvium (older volcanic material re-deposited by water) is found south of the Manukau Harbour. To the east the soils are a mixture of brown soils from alluvium, and clayey soils from Waitemata formation. The Hunua Ranges in the south-east are characterised by steep slopes formed by greywacke and argillite. The central Franklin District is covered by airfall volcanic ash from local basaltic volcanoes and from much older rhyolitic eruptions from the central North Island volcanoes, producing well-structured and productive granular soils.

The land in the Auckland region is an important and valuable resource. It supports the growing population by providing food, a place to live and work, recreational and tourism opportunities, and it also has cultural significance.

Use of the land, changes in land use and intensification have a wide range of short and long-term implications for the environment. The conflict between continued agricultural production and urban expansion resulting from the increasing population in the Auckland region is putting the soil resource under pressure, and the productive potential of the soil is being lost or reduced by the increased development and non-economic rural residential blocks at the urban fringes (see Pressure: Land use, pg 37).

Inappropriate land use practices can lead to:

→ accelerated erosion
→ loss of soil structure
→ nutrient loss
→ reduction in organic matter
→ loss of soil biology
→ elevated levels of trace elements.

It takes thousands of years for soil to form, so for all practical purposes it is a non-renewable resource that must be well managed. Therefore it is vital to understand the condition of the land resources in the Auckland region, monitor changes, understand any long-term trends and develop policies to prevent further degradation of the soil resource. Our land monitoring programmes are predominantly concerned with the rural land in the Auckland region. Different rural land uses have different characteristics and different resource requirements. Other monitoring programmes look at the effects of urban land use.

Land stability, soil disturbance and bare soil

Key findings

→ Stable surfaces cover 30.1 per cent of the Auckland region. Unstable surfaces cover 51.2 per cent and include erosion-prone (35.7 per cent), eroded but re-vegetated (8.0 per cent) and eroding surfaces (7.4 per cent). The remainder of the Auckland region is extensively modified (17.8 per cent) or was not covered in the photographic survey (0.9 per cent).

→ Between 1999 and 2007 there was no change in the amount of stable surfaces. The amount of erosion-prone surfaces decreased and eroded surfaces increased. The amount of active erosion also increased, as shown by an increase in eroding surfaces (1.9 per cent).

→ The soil was intact at 53.9 per cent of the 2007 sample areas and showed no soil disturbance. Of the 45.2 per cent of soil that was disturbed:

  → 7.4 per cent was caused by natural erosion

  → 34 per cent was disturbed due to land use activities

  → 3.8 per cent consists of natural features that are extensively disturbed.

→ Bare soil accounts for 3.29 per cent (16,524 hectares) of the Auckland region. The 2007 survey indicated a relatively low level of natural erosion that produced bare soil on only 1.18 per cent of the land, although land use activities added another 2.11 per cent of bare soil.

→ The amount of bare soil exposed by natural processes remained constant (at 0.55 per cent of the Auckland region) between 1999 to 2007. There was an increase in the amount of soil disturbance in rural areas as a result of land use activities, from 0.72 per cent in 1999 to 1.07 per cent in 2007. This equates to 0.35 per cent or 1758 hectares.

Introduction

It is important to understand how well the land resource is remaining in place so that it continues to be available for urban use, farming, forestry and conservation across the Auckland region. Measuring the stability of the land gives the ARC an understanding of how much land is stable, unstable and affected by natural erosion processes.

Soil disturbance can occur through natural erosion processes (e.g. streambank erosion and landslides) and also through human-induced processes related to land use activities that disturb the land (e.g. creating tracks and cultivation).

The amount of bare soil that is associated with soil disturbance is important. When soil is lost, the productive capacity of land is reduced. Although vegetation returns within a few years on an eroded site, this new growth is generally less productive because the underlying soil is thinner and holds fewer nutrients. When bare soil is exposed, the potential generation and discharge of sediment is increased. Increased levels of sediment have adverse effects on both the freshwater and marine environments.

Changes over time in the land stability, amount of soil disturbance and bare soil indicate whether these are improving or getting worse. Understanding what types of natural and human land use result in soil disturbance can help to improve land management decisions and shape land management policies.

Land stability, soil disturbance and the bare soil monitoring programme

In order to monitor the land stability, and amounts of soil disturbance and bare soil, the ARC takes point samples from 5277 different one hectare sample areas. These point sample areas are spaced at one km intervals across the Auckland region. They are visually inspected using aerial photographs by someone who has landform and erosion knowledge and skills in photographic interpretation. Although the one km grid is not spatially random, it does provide a random sample because the underlying landforms, soils and land uses are distributed irregularly across the region. In addition, the 1 by 1km spacing provides sufficient sample areas to represent the whole of the region.

Within each sample area, the land stability and any soil disturbance as a result of land use or natural processes, are recorded. Soil disturbance is measured by interpreting the one hectare sample area and recording any sign of disturbance. Wherever soil disturbance was recorded within a sample area, a cluster analysis is used to record the percentage of bare ground within each of those sample areas. This determines the percentage of soil bare in the one hectare sample area and provides information on the proportion of soil within the Auckland region that is bare at the time of the survey.

This type of survey was completed for the first time in 1999. It captures the land stability status, and the amount of soil disturbance and bare soil, and is repeated every time there is new aerial photographic coverage of the Auckland region. New aerial photography was taken over the summer of 2006/07 so the survey was repeated in 2007. This also examined the extent of changes that had occurred since the 1999 survey.

Indicator 1: Land stability

It is important to understand how much land in the Auckland region is stable. Stable land can be used for a wide range of production purposes. Stable surfaces show no signs of past natural erosion, have a smooth appearance and are completely vegetated (unless the topsoil is disturbed by land use). Stable land surfaces make up 30.1 per cent of the Auckland region (Figure 1).

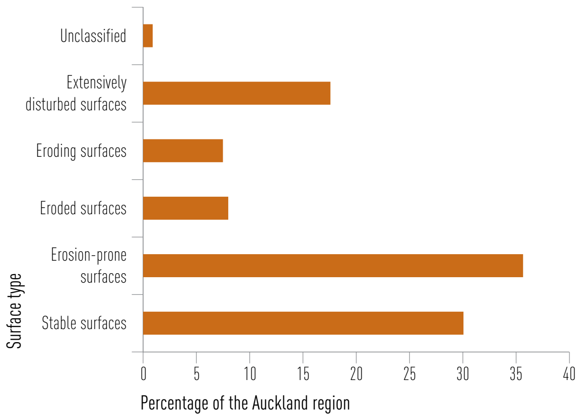

FIGURE 1 Land stability by surface type. (Source: ARC).

Unstable land is prone to natural erosion due to topography and geology, and needs to be managed carefully if used for production purposes so that erosion is not accelerated. Unstable surfaces may not always have active erosion but have been subject to natural erosion in the past. Unstable surfaces make up 51.2 percent of the Auckland region and are split into three categories:

→ Erosion-prone surfaces: these show signs of past erosion but are not eroding at present, erosion scars have healed and are well vegetated. Past erosion usually occurred at least a decade prior to the aerial photography. More than one third (35.7 per cent) of the land is erosion-prone and has already undergone some form of erosion.

- Eroded surfaces: these are erosion scars that are partially vegetated but still rough. Erosion has usually occurred within the decade before the aerial photography. 8 per cent of the Auckland region is naturally eroded, meaning that it has been disturbed in recent years but is now revegetating.
- Eroding surfaces: these are active erosion scars with no vegetation. Erosion has usually occurred in the year before the aerial photography and 7.4 per cent of the land in the Auckland region is currently eroding through natural processes.

Extensively disturbed surfaces are those where the soil has been partly or completely removed, re-contoured, or covered by buildings and pavements. They cover 17.8 per cent of the Auckland region, with 3.0 per cent partly covered by rural buildings, yards and major rural roads, another 11.0 per cent covered by urban land use (residential buildings and gardens, commercial buildings and yards, urban roads, railways and airfields, and open spaces with vegetation) and 3.8 per cent consisting of rock platforms, beaches, tidal creeks, and estuarine sandflats or mudflats.

Unclassifiable surfaces account for 0.9 per cent of the Auckland region. These are areas that had no aerial photographic coverage at the time of the survey.

Changes in land stability

The Auckland region has a large proportion of unstable surfaces that have eroded in the past or are currently eroding. It is important to monitor the percentages of different surface types to determine if these are changing, and whether land management practices are working and if more resources are required to help manage soil erosion.

There was no overall change in the amount of stable surfaces between 1999 and 2007. Erosion-prone but inactive land surfaces declined from 37.6 per cent in 1999 to 33.8 per cent in 2007, indicating that there was some active erosion on these surfaces. This can be seen by the increase in both eroded surfaces that were active in 1999 but have now been re-vegetated (up by 2.2 per cent from 1999), and eroding surfaces (up by 1.9 per cent from 1999).

Indicator 2: Soil disturbance

Natural erosion and land use activities can disturb the soil. The soil can be removed by water or wind as part of natural erosion processes and then deposited elsewhere, e.g. streambank erosion, landslides and sandblows (Table 1). Soil can also be disturbed by humans for land use activities, e.g. cutting a track for stock movement, cultivating a paddock for vegetable growing, and roading and urban development (Table 2).

In 2007, the soil was intact at 53.9 per cent of the sample areas. Of the 45.2 per cent of soil that was disturbed:

- 7.4 per cent was caused by natural erosion processes
- 3.8 per cent consisted of natural features that were extensively disturbed (rock platforms, beaches, tidal creeks, and estuarine sandflats or mudflats)
- 34 per cent was disturbed due to land use activities.

Note that 0.9 per cent of the Auckland region had no aerial photography coverage and was excluded from the analysis.

TABLE 1 Percentages of soil disturbance by natural processes. (Source: ARC).

Natural process	Percentage
Landslide	1.8
Debris avalanche	0.2
Slump or earthflow	0.7
Tunnel gully	0.2
Gully	0.4
Streambank scour	0.9
Streambank deposit	1.2
Sandblow	0.7
Sheetwash	0.3
Rockfall or bare rock	1.0
Total disturbance by natural processes	**7.4**

Soil disturbance by natural erosion

The assessment of soil disturbance by natural erosion that was undertaken in 2007 indicated that landslides generated the most soil disturbance (see Natural Hazzards: Landslides, pg 263); followed by streambank erosion (scour) and deposition (Table 1). When combined, scour and deposition accounted for most of the soil disturbance.

TABLE 2 Percentages of soil disturbance by land use activities. (Source: ARC).

Land use activity	Percentage
Grazing pressure	3.9
Cultivation	1.6
Harvest	1.5
Spraying	0.6
Drains	0.9
Tracks	8.6
Earthworks	1.5
Roads	1.3
Rural buildings	3.1
Urban areas	11
Total disturbance by land use activities	**34**

Soil disturbance by land use activity

Table 2 shows the type of land use activities that cause soil disturbance. Urban land use placed the most pressure on the soil, accounting for almost one third of the total land use disturbance in the Auckland region. Tracks on land that is used for production contributed a substantial amount of soil disturbance. Grazing pressure was another major land use activity causing soil disturbance.

Soil disturbance by land use type

To assess the effects of land use on soil disturbance, the survey assigned each sample area to a land use type, based on the predominant land use at that sample area.

Figure 2 shows that within the extensively disturbed category (rural buildings, major rural roads, residential buildings and gardens, commercial buildings, urban roads, railways, airfields, rock platforms, beaches, tidal creeks) most land use disturbance was human induced. This contrasts with sample areas covered by native vegetation, which had the lowest amount of human induced disturbance (this was often associated with access tracks). On land that is used for production, sheep-beef farming resulted in most of the human-induced disturbance and natural disturbance.

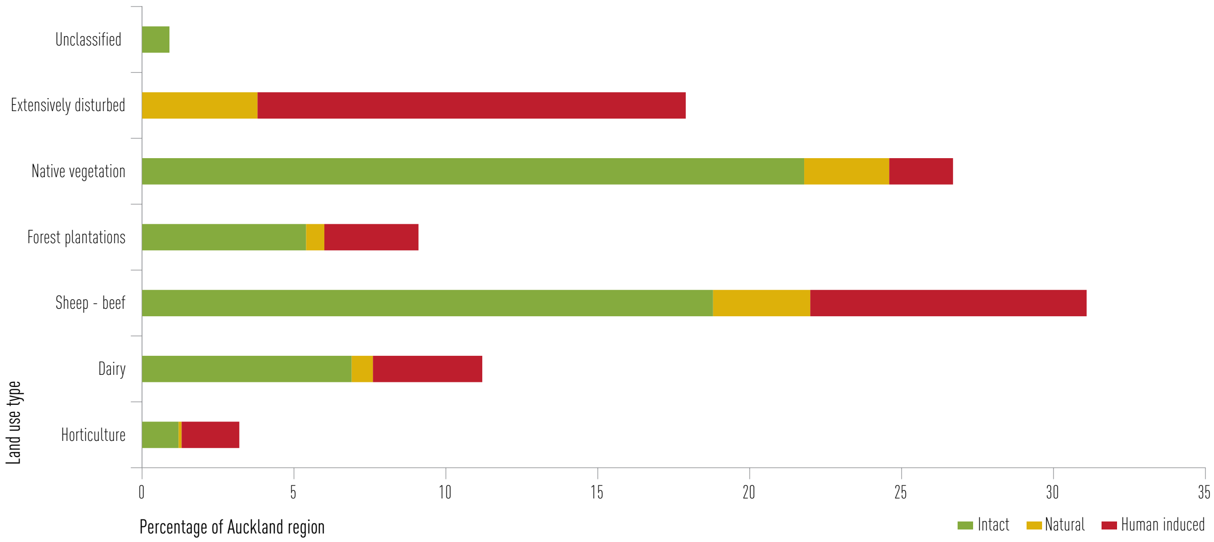

FIGURE 2 Soil disturbance, by land use type. (Source: ARC).

Land

Indicator 3: Bare soil

Natural erosion and land use activities both disturb the soil and have the potential to generate sediment.

If a sample area is recorded as disturbed, this does not necessarily mean that the entire sample area is bare soil, e.g. a farm track might be partially covered by vegetation with only some bare soil.

The 2007 survey showed that 3.29 per cent of the land within the Auckland region was bare through natural processes or human-induced land use disturbance. This equates to 16,525 hectares (equivalent to about twelve Rangitoto Islands in area).

Bare soil from natural processes

Bare soil exposed through disturbance from natural processes covers 1.18 per cent (5927 hectares) of the region. Figure 3 identifies the main types of erosion that are occurring in the region and their contribution to the total amount of bare soil.

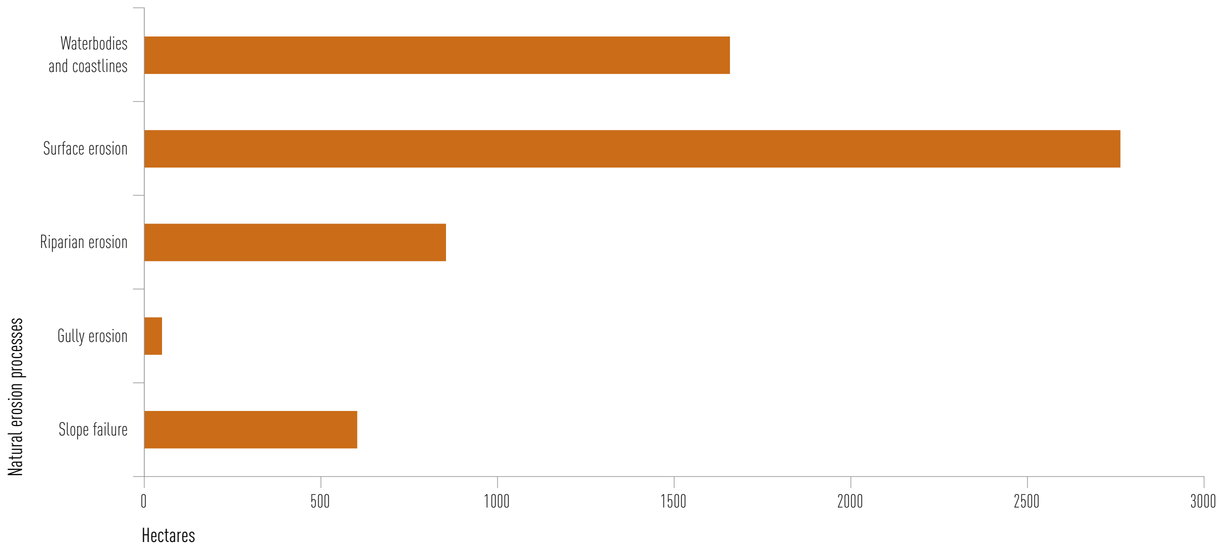

FIGURE 3 Hectares of soil bared by natural erosion processes. (Source: ARC).

Surface erosion produced the most bare soil in total, as a result of sheetwash, rock outcrops and sandblows. Deposits of sand, silt and gravel along the edges of rivers, together with streambank scour and collapse produced smaller amounts of bare soil, followed by slope failures (e.g. landslides and slips) with even smaller amounts resulting from gully erosion, tunnel gullies (under-runners) and open gullies. Other natural erosion processes around the coastline exposed bare soil, sediment, rock, estuarine flats, beaches and rock platforms.

Changes in the amount of bare soil from natural erosion processes

Some bare and eroding surfaces that were visible in 1999 were now revegetating, while some vegetated but inactive surfaces had been eroded since 1999 and now had bare soil. However, there was no overall change in the amount of bare soil from natural erosion processes in the Auckland region.

There were some changes in the types of erosion occurring between 1999 and 2007:

- slope failures (landslides, debris avalanches, slumps and earthflows), under-runners and gullies decreased
- sheetwash and sandblows showed little change
- streambank scour and deposits increased.

Bare soil by land use activities

Land use disturbance exposed 2.11 per cent (10,598 hectares) of the bare soil in the Auckland region. Figure 4 shows the types of land use activities that were exposing bare soil in 2007.

Cultivation was responsible for the most widespread soil disturbance that resulted in bare soil although this is to be expected, given the nature of this land use activity. Farm and forest tracks accounted for a substantial amount of bare soil, while rural yards and urban areas (including earthworks in urban areas) were also major contributors.

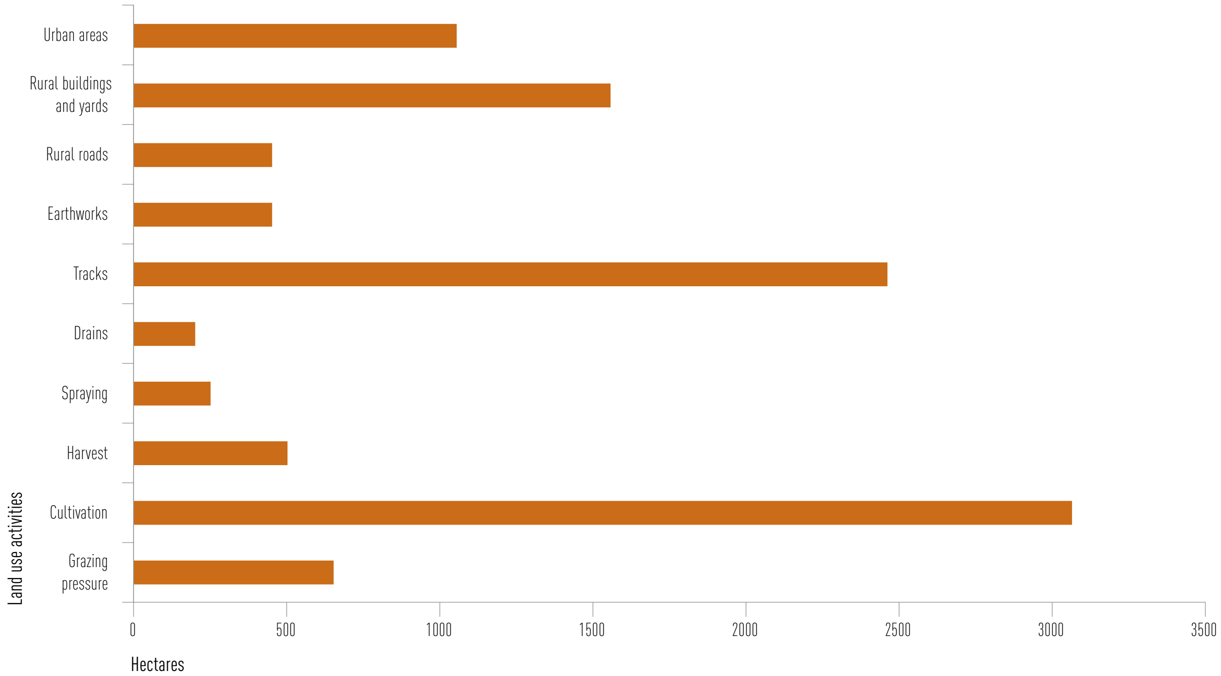

FIGURE 4 Hectares of soil bared by land use disturbance from human activities, 2007. (Source: ARC).

Changes in the amount of bare soil from rural land use activities

A comparison of sample areas measured at both dates showed an increase in the land use related disturbance of soils in rural areas of the Auckland region, from 0.72 per cent in 1999 to 1.07 per cent in 2007. This 0.35 per cent increase equates to 1758 hectares.

There has been a slight increase in the amount of bare soil generated from all rural land use activities (grazing pressure, cultivation, harvesting, spraying, drains, tracks and earthworks).

Bare soil by land use type

This measure looks at the amount of bare soil (hectares) that is associated with each broad land use type in the Auckland region. It indicates the level of pressure placed on the soil resource. Figure 5 shows the proportions of bare soil (from disturbances by natural processes and/or land use activities) by land use type.

In 2007, the greatest area of bare soil was associated with horticultural land use (as would be expected). This is often a temporary state before crops are grown but, as the survey is only snapshot in time, it cannot give a full picture of the amount of bare soil over a complete season or year.

Substantial areas of bare soil were measured in sheep-beef and dairy pasture as a result of grazing pressure. Rural buildings and yards, and urban areas also exposed sizeable areas of bare soil. Lower but measurable areas of bare soil were found in forest plantations due to topsoil exposure from logging and associated tracking. There was only a slight amount of bare soil under native vegetation and that was often due to tracks.

Natural processes often disturb subsoil as well as topsoil. In 2007, disturbance from natural processes was slight on land under dairy pasture and forest plantations. Most disturbance occurred in sheep-beef pasture and, predominantly, under native vegetation (native forest, natural scrub and coastal grasses). These land use activities and land cover types are more prone to erosion as they are often found on land that is steep and unstable. Natural erosion processes along waterbodies and coastlines tend to result in both erosion and deposition.

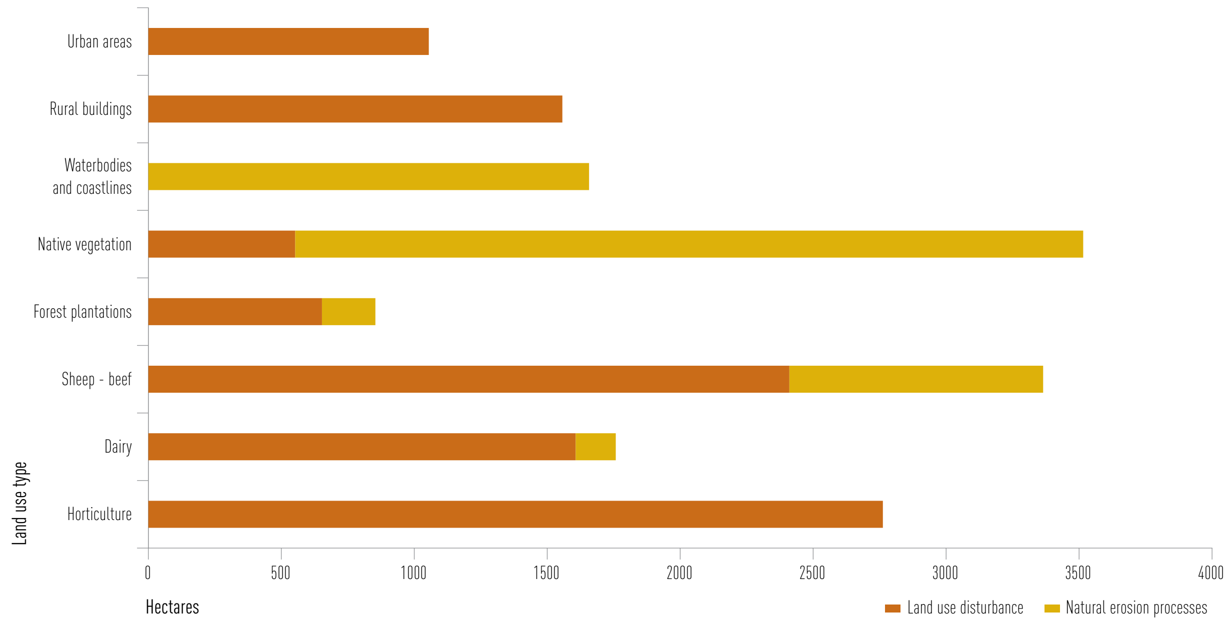

FIGURE 5 Hectares of bare soil and the proportions contributed by natural erosion and land use disturbance, by land use type. (Source: ARC).

Changes in the amount of bare soil by land use type

Between 1999 and 2007 there was:

- no change in the amount of bare soil on land under horticulture; none was noted on either date.
- an increase (from 0.19 to 0.31 per cent) in the amount of bare soil under dairy pasture, due to land use disturbance. There was also an increase (from 0.36 to 0.48 per cent) in the amount of bare soil under sheep-beef pasture and an increase (from 0.06 to 0.13 per cent) in the amount of bare soil due to land use disturbance in forest plantations.
- little or no change in the amount of bare soil under native vegetation due to land use disturbance.
- little or no change due to natural disturbance under all other rural land uses (dairy, sheep-beef, forestry and native vegetation).

No land use disturbance under waterbodies and coastline, including coastal grass and scrub was recorded on either date. Although it does occur (e.g. from grazing pressure) it is swiftly transformed into moving sandblows which are recorded as natural disturbance.

Implications of soil disturbance and bare soil

Although natural erosion processes can expose bare soil and generate sediment, human activities have altered the natural land cover and changed the original land use by disturbing the land through the removal of vegetation, cultivation, intensive grazing and earthworks.

As a result of land use activities and associated disturbances the amount of bare soil has increased and erosion has accelerated. Both natural and accelerated erosion can lead to:

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

It is hard to quantify the economic effects of erosion but one study suggests that surface erosion of bare topsoil can reduce crop yield and pasture growth by at least 20 per cent and, in extreme cases, more than 60 per cent.

Mass movements of subsoil by slumps, earthflows, earth slips and soil slips can initially reduce pasture growth by 40 to 80 per cent. After the surfaces have re-vegetated, production often remains depressed by 10 to 40 per cent, with a subsequent economic cost to the land owner. Table 3 shows the estimated costs in dollars.

TABLE 3 Estimated economic costs of lost productivity due to soil erosion. (Source: Landcare Research 2001).

Erosion type	Cost ($/hectare)
Mass movement	1,385.00
Surface erosion – arable cropping	750.00
Surface erosion – pasture	2.10

Table 4 shows the variable costs of farm repairs resulting from the cumulative impact of mass movement, gully creation and streambank erosion.

TABLE 4 Damage repair costs, 1988-92, averaged over farm area. (Source: Environment Waikato).

Type of repair	Minimum cost ($/hectare)	Maximum cost ($/hectare)
Fences	6	44
Tracks	1	26
Buildings	1	11
Pasture re-sowing	1	13
General clean-up	3	4

Soil quality

Key findings

- → The data from 88 sites that were assessed by seven soil quality parameters for rural land use categories (dairy, sheep-beef, horticulture, forestry and native vegetation) indicated that 38 per cent of the monitored land area met all the soil quality targets and was classified as excellent, 55 per cent was fair and 7 per cent was poor.
- → Dairy and horticulture had the lowest number of sites that met all seven soil quality parameters, and native vegetation had the highest number.
- → The two soil quality parameters that are of most concern for rural land in the Auckland region are low macroporosity indicating widespread soil compaction, and high Olsen P levels indicating high chemical fertility.

Introduction

Soil quality is often defined as the capacity of a soil to sustain biological production, maintain environmental quality, and promote plant and animal health. It is assessed using seven soil quality parameters that measure physical, chemical and biological functions of the soil. Changes in soil quality can be both positive and negative.

Soil quality monitoring programme

Soil quality monitoring is used to monitor status and trends, and to identify the long-term effects of production land uses on soil quality. The objective is to make sure that soil productivity is retained and that soils are protected from permanent loss and degradation, as current land management practices may not be sustainable for some combinations of soil and land use.

Soil quality monitoring helps to identify which soil parameters are of greatest concern and enables an appropriate management response to be determined, e.g. targeted education on the effects of soil compaction and the economic benefits of managing soil quality. In the longer term, trends can be identified and it is possible to see whether land management practices are improving or whether soil quality is deteriorating.

The ARC was involved in two programmes: one ran from 1995 to 1998 to identify 'preferred soil quality parameters' with Landcare Research, the second was the 500 Soils Project that ran from 1999 to 2000 and was developed by the Ministry for the Environment (MfE) and Landcare Research.

The initial programme measured a range of chemical, biological and physical soil quality parameters at sites throughout New Zealand. The results enabled these parameters to be reduced to seven soil quality parameters (see Table 5) that help to identify whether current land use practices are having a beneficial, or an adverse, effect on the soil.

TABLE 5 The seven chemical, biological and physical soil parameters used to assess soil quality. (Source: ARC).

Indicator type	Soil parameter	Soil management issue
Chemical	Total carbon	Carbon depletion
Chemical	Total nitrogen	Nutrient depletion/saturation
Chemical	pH	pH changes (acidity)
Chemical	Olsen P	Nutrient depletion/saturation (fertility) – the amount of phosphate readily available to plants
Biological	Mineralisable nitrogen	Measure of soil organic matter
Physical	Bulk density	Measure of structural decline
Physical	Macroporosity	Measure of the amount of large pore spaces which allow oxygen and water to move through the soil

The target range levels for each soil quality parameter were assigned for various land use types and soil classes at a series of workshops in 1999. These target range levels represent critical levels where deterioration of soil function occurs.

Between 1995 and 2000, a total of 88 sites were sampled across rural land in the Auckland region. These sites were considered to be a representative cross-section of the major soil and land use types, as it is not possible to measure all combinations of land use and soil classes within the Auckland region. The five broad types of land use were: dairying, sheep-beef pasture (also known as drystock), forest plantations, horticulture and native vegetation.

The ARC re-sampled the horticultural sites in 2008 when the ARC re-established its soil quality monitoring programme. The ARC will re-sample the other land use types over the next three years. After then, the horticultural sites will be sampled every three years, dairy and sheep-beef sites will be sampled every five years, and forestry sites every ten years. Native vegetation will be re-sampled every 20 years.

Infrequently the ARC analyses soil quality samples for a range of trace elements (Box 1 page 133).

Indicator 4: Soil quality

Soil quality by site

Table 5 shows the seven parameters that were used to assess the soil quality of a site. The results were analysed for each site, in order to identify the number of sites that met the target range levels for all of the seven parameters. The results for the 88 sites sampled (Figure 6) showed that:

- 29 sites (33 per cent) met all targets for the seven soil quality parameters
- 38 sites (43 per cent) did not meet the targets for one parameter
- 14 sites (16 per cent) did not meet the targets for two parameters
- four sites (five per cent) did not meet the targets for three parameters
- three sites (three per cent) did not meet the targets for four parameters.

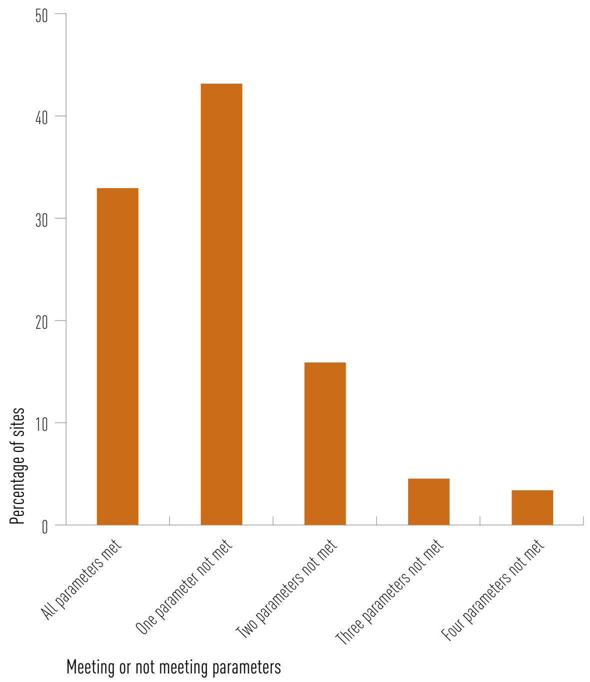

FIGURE 6 Percentage of sites meeting or not meeting the target range levels for soil quality parameters. (Source: ARC).

Soil quality by land use

To assess the effects of land use on soil quality, the 88 sites were split into broad land use types and assessed against the target range levels for all of the seven soil quality parameters. Of the 88 sites analysed, 21 were dairy pasture, 18 were sheep-beef pasture, 20 were horticulture, nine were forestry and 20 were native vegetation.

To get a better understanding of the soil quality data and how this related to the different types of rural land use, the data were categorised into the three groups and shown in hectares. Data from the land cover database (2002) which covers the period when samples were taken, and land use data from the Soil Intactness Survey (1999) were used to determine the area in hectares each land use type, excluding the categories of urban and other.

The data were classified into the following three categories:

- → Excellent: all soil quality parameter target levels were met
- → Fair: one or two parameters did not meet the target levels
- → Poor: three or four parameters did not meet the target levels.

Figure 7 shows the percentage of sites in each category. Native vegetation had the greatest number of sites classified as Excellent and no sites in the Poor category. Dairy and horticulture had the lowest number of sites in the Excellent category. Conversely, forestry recorded the highest proportion of sites categorised as Poor.

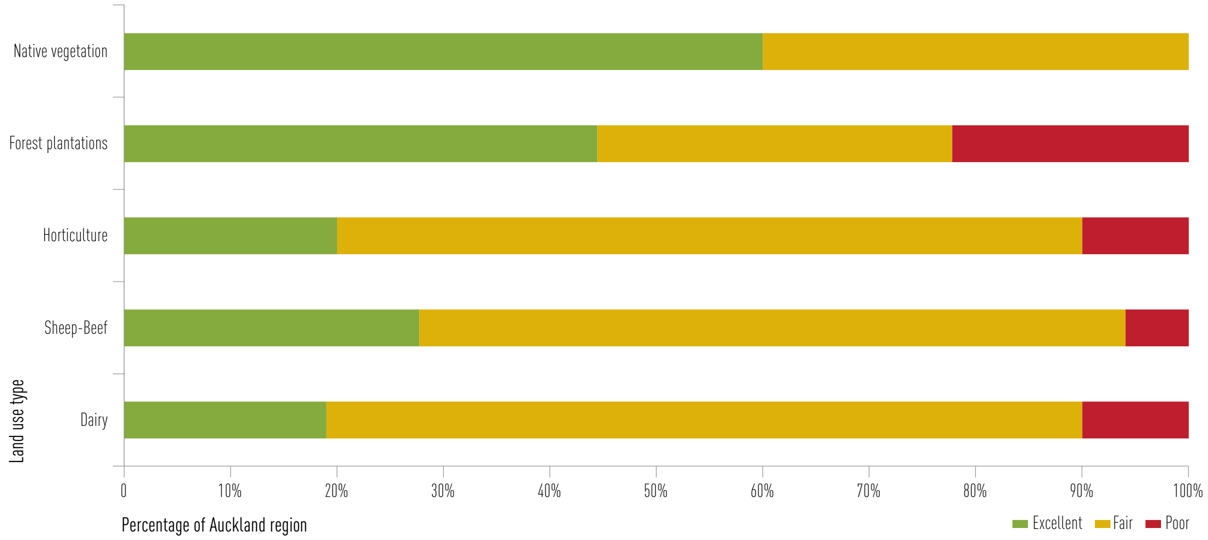

FIGURE 7 Percentage of sites categorised as Excellent, Fair or Poor soil quality according to five land use types. (Source: ARC).

Table 6 indicates that 38 per cent of the land area has Excellent soil quality, while 55 per cent has Fair soil quality and seven per cent has Poor soil quality. The three non-forested land uses (dairy, sheep-beef and horticulture) all have similar percentages in each of the Excellent, Fair and Poor soil quality categories.

Forestry has the highest percentage of Poor soil quality (22 per cent) covering an area of just under 12,000 hectares. Sheep-beef has the smallest amount of Poor soil quality by percentage but is substantial by area (just behind forestry).

TABLE 6 Rural land area (hectares) according to the three soil quality categories. (Source: ARC).

Land use	Area	Excellent (%)	Land area excellent	Fair (%)	Land area fair	Poor (%)	Land area poor
Dairy	63,811	19	12,124	71	45,306	10	6381
Sheep-beef	185,257	28	51,872	67	124,122	6	11,115
Horticulture	9281	20	1856	70	6497	10	928
Forest/Plantations	54,371	44	23,923	33	17,942	22	11,962
Native vegetation	135,856	60	81,513	40	54,342	0	0
Total	**448,576**		**171,289**		**248,210**		**30,386**
Percentage	**100**		**38**		**55**		**7**

Soil quality parameters by site

The percentage of sites not meeting targets for specific soil quality parameters identifies which of the seven soil quality parameters is of greater concern. Results from all 88 sites (Figure 8) show that the two major soil quality issues are:

- low macroporosity, which indicates widespread soil compaction (43 per cent of sites)
- high Olsen P levels, which indicates high chemical fertility (32 per cent of sites).

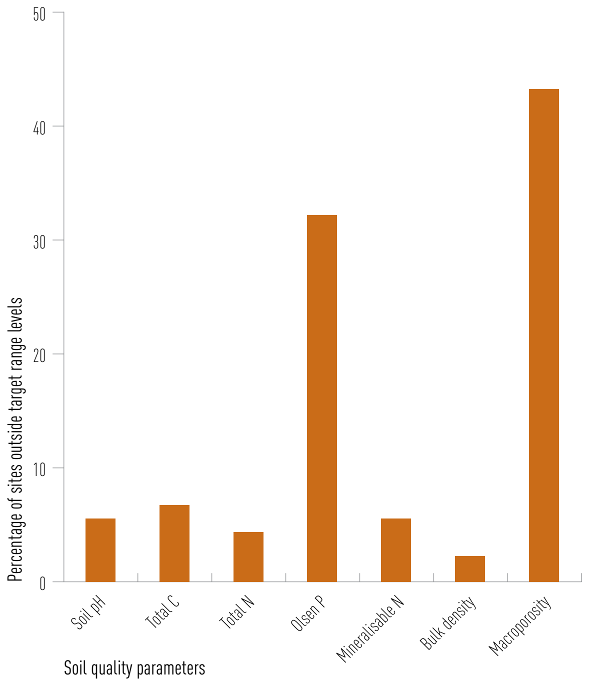

FIGURE 8 Percentage of sites not meeting soil quality targets for specific parameters. (Source: ARC).

Horticultural soil quality in 2008

Twenty horticultural sites (market gardens, vegetable producers, orchards and vineyards) that were sampled between 1995 and 2000 were sampled again in 2008. The soil quality parameters and target levels specific to soil type and land use were used to assess the soil quality at these horticultural sites. The ARC was unable to take samples from two of the original sites because they had since been built on).

In 2008:

- Four sites (22 per cent) met all the targets for the seven soil quality parameters
- Six sites (33 per cent) did not meet the targets for one parameter
- six sites (33 per cent) did not meet the targets for two parameters
- two sites (11 per cent) did not meet the targets for three parameters.

When the 20 horticultural sites were originally sampled between 1995 and 2000, only two sites met all the target levels for all soil quality parameters. The number of sites that met all the soil quality parameter target range levels has doubled but further monitoring is required to establish if this is a trend.

The status of each site in 2008 was compared with data from previous samples collected between 1995 and 2000. No consistent changes in soil quality were detected between the specific horticultural activity or soil class. The sites showed both positive and negative changes.

The percentage of horticultural sites not meeting targets for specific soil quality parameters identified which of the seven soil quality parameters are the biggest issues in 2008. The results from the horticultural sites (Figure 9) show that the soil quality parameters of greatest concern remain those identified between 1995 and 2000 for the Auckland region.

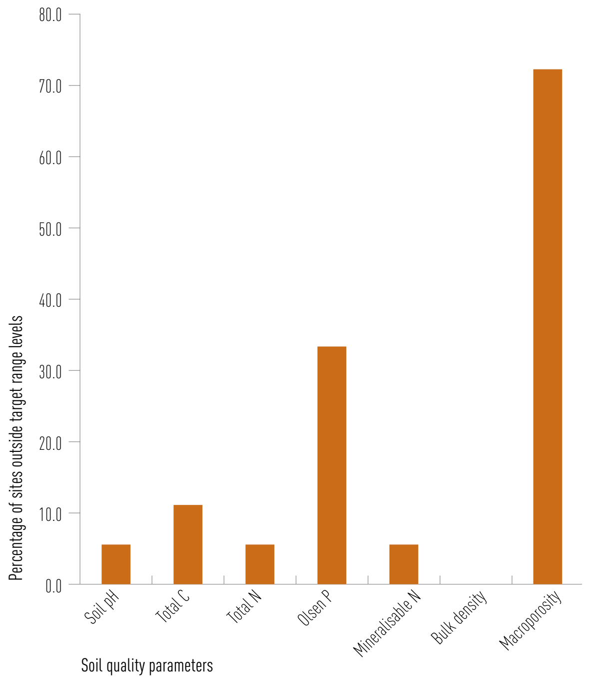

FIGURE 9 Percentage of horticultural sites not meeting soil quality targets for specific parameters. (Source: ARC).

Box 1 Trace elements in rural soil

Trace elements occur naturally in soils, mainly as a result of the natural weathering of rocks and minerals. These natural levels are often referred to as 'background concentrations' and can vary depending on the soil type, geology and climate. Trace elements can also be added to the soil as the result of agricultural and horticultural land use activities. Soils on land used for production can have different trace element profiles than soils with natural background levels.

In pastoral areas, the use of superphosphate fertiliser results in the gradual accumulation of several trace elements such as cadmium, fluorine and uranium. Arsenic based dips have also been used for sheep and beef cattle. Facial eczema remedies containing zinc sulphate are likely to account for zinc. Horticultural soils can receive high loads of pesticides and fungicides, some of which break down slowly.

Trace element concentrations that are higher than the background concentrations are usually referred to as 'elevated'. At present, there are no set national standards to assess trace elements for environmental or population health in soil, although guidelines exist that allow some comparison. For instance, the Guidelines for the Safe Application of Biosolids to Land in New Zealand (2003) have been used to assess the trace element results for arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.

Monitoring for trace elements in the Auckland region is part of the soil quality monitoring programme. Fifty-two archived soil quality samples from 1999 and 2000 were analysed for 39 trace elements. Across horticulture, dairying, sheep-beef, planted forestry and native vegetation land use types guidelines for chromium, lead, mercury, nickel and zinc were met. For cadmium, horticulture, dairying and drystock all had higher average concentrations in the soil compared to the background concentration for native vegetation. Dairying sites had the highest average concentration. For copper, dairying and horticulture concentrations were above native vegetation but within the range of concentrations for soils in the Auckland region.

Continued monitoring will give a better understanding of the accumulation of trace elements under various land uses in the Auckland region and help to identify emerging issues.

Implications of poor soil quality

Compaction

Large numbers of stock (high stocking rates) can cause immediate direct damage to pasture as stems, leaves and roots are crushed and plants are smothered under sediment. In the short-term, there is a drop in pasture productivity and in the amount of available feed for stock. In the long-term, high stocking rates can lead to structural breakdown of the soil as pore spaces are lost or reduced by compaction. Heavy machinery and repeat cultivation using heavy machinery, can also lead to compaction in soils under intensive cultivation. Wet conditions can exacerbate the effects of these land management practices. The structural decline of the soil from compaction limits subsequent pasture growth. Annual yield losses ranging between 15 and 30 per cent have been reported from severely compacted soils in the Manawatu, coastal Otago and Southland, Northland and the Waikato.

The implications of increased structural breakdown of soils under cultivation include:

- → increased fertiliser and irrigation requirements
- → poor seed germination and emergence
- → poor plant growth and vigour
- → delays in sowing and in harvesting
- → re-sowing of poorly performing paddocks and subsequent uneven ripening of crops
- → increased susceptibility to root diseases and pest attack
- → reduced crop yields and grain quality.

Soil compaction is also an issue for farmers when water drainage deteriorates due to the loss of pore spaces in the soil, as this can lead to ponding of water and surface runoff. Ponding can create anaerobic conditions that can restrict plant root growth. Surface runoff can lead to valuable nutrients and topsoil being lost and this, in turn, reduces pastoral or horticultural growth.

Increasing phosphate levels

The phosphate levels on land under intensive use often exceed the plant uptake level and the excess may be lost through leaching and/or surface erosion. This loss has a direct economic cost to the farmer and the potential to degrade water quality (see River water quality programme and Lake water quality programme in Chapter 4.3). For example, a study in 2002 estimated that the value of nutrients in Pukekohe vegetable-growing topsoils was between $8000 and $26,000 per hectare. Assuming a net rate of soil loss between seven and 30 tonnes per hectare per year, the loss of excess nutrients would be worth $35 to $570 per hectare per year.

Phosphate fertilisers also contain cadmium (Box 1). The Cadmium Working Group has reported a steady increase in the amount of phosphate fertiliser used in New Zealand, to a high of over two million tonnes in 2002/03. Cadmium levels will be investigated as part of the soil quality monitoring programme, as there are possible future implications if cadmium levels continue to rise:

- Toxicity of soil to organisms, plants and animals may occur.
- Cadmium in soil may rise to levels that could restrict the growth of certain types of produce if these levels exceed New Zealand and international food standards.
- The ability to subdivide land for residential purposes could be restricted if cadmium accumulates to a level where the land is classified as contaminated.
- The flexibility to change land use might be limited, as crops or vegetables sensitive to the uptake of trace elements would be restricted.

Sediment

Key findings

- The variation in specific sediment yield was mainly due to catchment rainfall, mean slope and land use.
- A regression model indicated that for a given rainfall and slope, the yields from forested areas were 66 per cent lower than pasture, while the yields from urban areas were 25 per cent lower than pasture.

Introduction

Sediment is any solid material mineral and organic that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice and has been deposited on the Earth's surface above or below water.' (Auckland Regional Council Technical Publication 90.)

The generation of sediment is a natural process driven by rainfall, geology, topography and land cover. It has been accelerated by human-induced land use change and intensification. Studies indicate that native forest catchments yield less sediment than pasture and exotic forest catchments. Changes in land use, e.g. forest harvesting and urban development, can cause major increases in sediment yields but these are often temporary.

Not all of the sediment generated in a catchment area will be flushed into the rivers, as some will be trapped near its source. However, some suspended sediment will drop out of suspension and be deposited on the riverbeds, and some will be carried out into the marine environment (see Pressures: Indicator 27, pg 62). Sediment can have many adverse impacts on the habitats and health of freshwater and marine ecological communities. Therefore, some freshwater and marine monitoring programmes measure the amount of sediment in the water (see river and lake monitoring programmes in Chapter 4.3, pages 143 and 161, coastal water quality monitoring programme and benthic ecology monitoring in Chapter 4.4, pages 183 and 189).

Sediment yield monitoring

Sediment yields in the Auckland region are monitored on a project basis as there is no regionally representative programme in place. It is impractical to continuously monitor sediment yields in every catchment across the region so, by developing an understanding of how sediment yields vary (according to land use and the hydrological and physical characteristics of catchments), sediment yields across the region can be estimated.

The information provided in Indicator 5 (below) is a measure of sediment yield from different land uses. The ARC will be developing this further to strengthen its regional application and address current limitations.

Indicator 5: Sediment yield

Sediment yields during storms at nine catchment areas within Waitemata Formation were analysed. The sediment yields from storm events and the mean annual sediment yields were determined. The catchment areas were under various land uses and ranged in size from 0.2 to 48.8km^2. The mean annual sediment yields from specific catchments were investigated using three approaches to compensate for the limited flow record for most of the study sites (Table 7).

The relationships between sediment yield and catchment characteristics were examined by comparing plots of sediment yield against land use. Figure 10 shows that the highest sediment yields are linked with forest harvesting (Redwood Forest) and the lowest occur in urban catchments (Lower Awaruku and Barwick). Between these extremes, there appears to be a trend for sediment yield to increase as the percentage of pasture increases and forest decreases. The exceptions are Redwood Forest during the pre-harvesting phase, and the Okura catchment, which both show higher than expected sediment yields. However, the high sediment yield at Redwood Forest may be due to its steep slopes and relatively high rainfall. The figures for the largely-forested Okura catchment may be higher than the long-term average due to the short recording period.

TABLE 7 Catchment-specific annual average sediment yields (t/km²/yr). (Source: ARC)

Catchment and area (km²)	Land use	Sediment yield	Years of flow data
Redwood Forest (0.6)	Exotic forest post-logging	241 +/- 35	11 months
Wylie Road (1.05)	Pastoral	200 +/- 2	1 year, 4 months
Redwood Forest (0.6)	Exotic forest pre-logging	172 +/- 19	2 years, 8 months
Lower Vaughan (2.17)	Pastoral	98 +/- 18	6 years, 1 month
Mangemangeroa (4.44)	Pastoral	89 +/- 7	8 years, 1 month
Mahurangi College (48.83)	Pastoral	88 +/- 19	26 years, 4 months
Okura at Weiti* (1.70)	Exotic vegetation	82 +/- 13	6 months
Awanohi – Okura (5.27)	Native vegetation	74 +/- 12	6 years, 4 months
Lower Awaruku (2.66)	Urban	40 +/- 11	3 years, 4 months
Barwick* (0.24)	Urban	13	6 months

*Results for Barwick and Okura at Weiti should be viewed with caution due to the short (six month) recording period, but all the remaining sediment yields are within the range of previous estimates for the Auckland region.

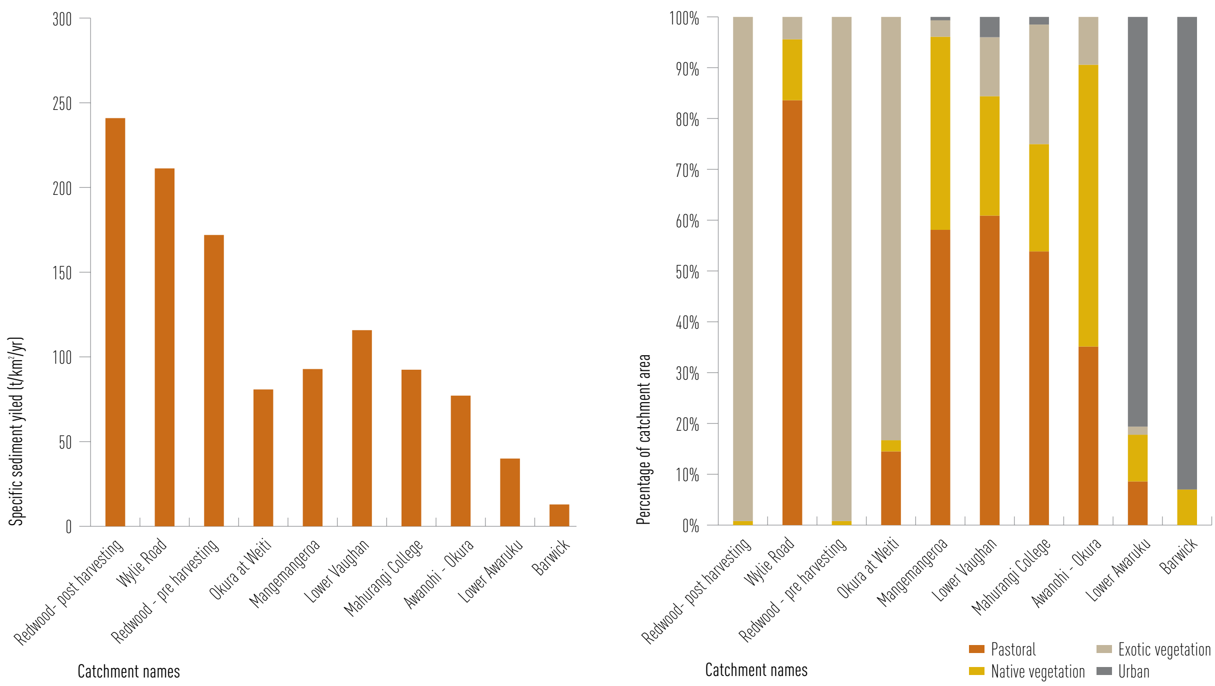

FIGURE 10 Specific sediment yield and land use type for each catchment. (Source: ARC).

Land

Sediment yields among the Lower Vaughan, Mangemangeroa, Mahurangi College, Okura-Weiti and Awanohi-Okura catchments range from 74 to 98 t/km^2/yr and, even allowing for the estimated uncertainty, there is little difference between them. Therefore, among these catchments at least, any influence from the type of land use does not appear to be strong.

The relationship between sediment yields and catchment characteristics was developed through another analysis. It indicated that variations in the annual average sediment yields are due mainly to catchment rainfall, the mean angle of the slope and the type of land use. For a given rainfall x slope product, sediment yields from forested areas are two thirds of those from pasture areas, while sediment yields from urbanised areas are one quarter of those from pasture areas.

Further monitoring of sediment yields at key sites is required to validate the relationship developed above. The programme will also need to monitor the other broad geologies to develop the picture for sediment yields across the Auckland region. In the long-term the ARC needs to understand the trends and evaluate the effectiveness of land management measures.

Implications of sediment

Sediment that is deposited on the land can smother pasture and crops, decreasing the productive capability of the land and reducing individual profit margins. It can also adversely affect other types of land cover and result in habitat loss. In the rivers and marine environment, suspended sediment can degrade the water quality by reducing the water clarity. Sediment can also silt up channels and accumulate in receiving environments such as lakes and harbours, adversely affecting natural habitats and ecosystems and leading to physical changes such as increasing the area of tidal flats.

Sediment also has a direct economic cost to the community when it damages infrastructure, e.g. siltation of reservoirs, and blocked roadside drains and stormwater networks. Excessive levels of sediment (and other debris such as sand, rocks and trees) that are washed into the rivers can cause further erosion, instability and ecological damage. Erosion control measures on the banks of unstable rivers can be very expensive and are often beyond the resources of individual landowners.

Conclusions on the state of the land

The ARC measures the effects that different land use types have on the land and soil. It does this by measuring soil stability, soil disturbance, bare soil, soil quality and sediment generation. Results show that the land and soil across the Auckland region are losing their ability to sustain their maximum productivity levels, because of soil degradation caused by land use activities.

In 2007, just under one third of the land in the region had stable land surfaces. Most land has been disturbed at some time in the past but has been re-vegetated. Natural processes have disturbed 7.4 per cent of the land and 17.8 per cent was extensively modified, largely due to urbanisation. Between the two surveys in 1999 and 2007 (and allowing for changes in survey methods) there was no change in the amount of stable surfaces but there was an increase in eroding surfaces due to the pressure of human-induced land disturbance, shown by an increased 0.35 per cent (1,758 hectares) of bare soil. Land use disturbance can be somewhat controlled, in comparison to natural erosion, through the use of best management practices and regulatory processes. Findings from these surveys will help to form policy decisions and target education within the region.

There were 16,525 hectares of bare soil (3.29 per cent of the region) with the potential to generate sediment. Bare soil and some land use activities including logging, pastoral land use and earthworks generate a greater proportion of bare soil than under natural land cover. Although sediment can impact the land, it is of greater concern when it enters freshwater and marine receiving environments because it can degrade the water quality and adversely effect existing ecosystems.

The most significant pressures leading to soil loss are agricultural practices that increase the exposure and vulnerability of soils. These include the removal of protective vegetation through the cultivation of soil for intensive uses, and the creation of farm and forestry tracks. At the time of the survey, natural processes had less impact than land use practices.

Of the 88 sites assessed by the seven soil quality parameters for rural land use categories (dairy, sheep-beef, horticulture, forestry and native vegetation), 38 per cent of the monitored land area met all the suggested soil quality targets.

The physical condition of the soil had decreased when land was under horticultural, dairy and sheep-beef pasture, as represented by low macroporosity indicating soil compaction. Repeat cultivation or the use of heavy machinery at certain times of the year when soil moisture conditions are not optimal are likely to be causing compaction in soils under horticultural use.

There was also a decrease in the chemical condition of the soil resulting from the addition of excessive nutrients (phosphate fertiliser) on land under horticultural use. The high use of chemical fertiliser on market gardens is of concern, as shown by the number of horticultural sites that had high Olsen P levels that exceeded the target range levels. The same concerns (low macroporosity and increased Olsen P levels) identified in the first sample of horticultural soils were identified again in the repeat sampling in 2008. Further sampling is required to determine if this is a real long-term trend.

Deterioration of one soil quality indicator may not necessarily cause an immediate loss of soil quality, but may have a synergistic effect that leads to a gradual reduction in soil quality.

Degradation or depletion of the land and soil resource has major economic, environmental and aesthetic implications for the region that can impact both the individual and the community. Soil quality can degrade quickly, but restoring the quality of a degraded soil tends to be a slow and costly process. Therefore, maintaining the soil quality is essential for sustainable land use that will continue to benefit the region's economy and maintain its water quality.

References and further reading

Auckland Regional Council, 1999. *Erosion and sediment control – guidelines for land disturbing activities in the Auckland region*. Auckland Regional Council Technical Publication 90.

Auckland Regional Council, 2001. *Background concentrations of inorganic elements in soils from the Auckland region.* Auckland Regional Council Technical Publication 153.

Basher, L. R. and Ross, C. W., 2002. *Soil erosion rates under intensive vegetable production on clay loam, strongly structured soils at Pukekohe, New Zealand. Australian Journal of Soil Research*. 40 (6), 947–961.

Cadmium Working Group, 2008. *Report one: cadmium in New Zealand agriculture*. Available from http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/land-management/cadmium-in-nz/report-one/

Environment Waikato, 2008. *The condition of rural water and soil in the Waikato region – risks and opportunities*.

Hicks, D. L. and Thompson, A. J., 2009. *Changes in soil state and disturbance from 1999-2007*. Prepared for Auckland Regional Council. Auckland Regional Council Technical Report 2009/012.

Hicks, D. L. and Thompson, A. J., 2009. *Soil state in the Auckland region 2007*. Prepared for Auckland Regional Council. Auckland Regional Council Technical Report 2009/016.

Hicks, D. L. and Thompson, A. J., 2009. *Methods used to survey soil state in the Auckland region 2007*. Prepared for Auckland Regional Council. Auckland Regional Council Technical Report 2009/018.

Hicks, D.M., Hoyle, J. and Roulston, H., 2009. *Analysis of sediment yields within Auckland region*. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Auckland Regional Council Technical Report 2009/064.

Hill, R. and Blair, I., 2005. *Middle Waikato pilot project: a review of soil conservation research and catchment environmental monitoring*. Environment Waikato Technical Report 2005/16.

Krausse, M., Eastwood, C. and Alexander, R., 2001. *Muddied waters. Estimating the national economic cost of soil erosion and sedimentation in New Zealand*. Landcare Research.

Lilburne, L. R., Hewitt, A. E., Sparling, G. P. and Selvarajah, N., 2002. *Soil quality in New Zealand – policy and the science response. Journal of Environmental Quality* 31:1768-1773.

New Zealand Water and Wastes Association, 2003. *Guidelines for the safe application of biosolids to land in New Zealand*. Produced by Water New Zealand in conjunction with the Ministry for the Environment.

Sparling, G., Lilburne, L. and Vojvodic-Vucovic, M., 2003. *Provisional targets for soil quality indicators in New Zealand*. Landcare Research.

Sparling, G., 2008. *An overview of soil quality in the Auckland region using data from the 500 Soils Project 1995–2001*. Prepared by Landcare Research for Auckland Regional Council. Auckland Regional Council Technical Report 2009/007.

Sparling, G., 2009. *Soil quality of horticultural sites in the Auckland region in 2008: changes since 1995-2000*. Prepared by Landcare Research for Auckland Regional Council. Auckland Regional Council Technical Report 2009/008.

Taylor M., Gibb, R., Willoughby, J., Hewitt, A. and Arnold, G., 2007. *Soil maps of cadmium in New Zealand*. Landcare Research.