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>> New Zealand's Environmental Reporting Series

Our land 2018

DATA TO 2017

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Contents

Message to our readers		5
Our land at a glance		6
Executive summary		7
Introduction		13
	How the report works	13
	Data sources and limitations	16
Fundamentals		18
	Why land matters	18
	How whenua matters	22
1	Physical processes	24
	Aotearoa New Zealand – land formation	24
	Why physical processes matter	27
	Data gaps for physical processes	29
2	Climate variability and change	30
	Natural climate variability	30
	Long-term climate change	31
	Data gaps for climate	32
3	How human activity affects the land	34
	Introduction	35
	Land cover	36
	Major land uses	41
	a. Conservation land	43
	b. Forestry	48
	c. Agriculture	51
	d. Urban land	57
	Extractive activities	60
	Waste	65
	Contaminated land	67
	Data gaps for human activities	70

4	The state of New Zealand soils	72
	Introduction	73
	Our precious and fragile soils	73
	Soil erosion	75
	Soil quality	79
	Soil biodiversity	83
	Environmental impacts of soil degradation	84
	Data gaps for soil	84
5	The state of New Zealand's biodiversity and ecosystems	86
	Introduction	87
	Habitat extent and diversity	88
	Habitat quality	90
	Species threat status	97
	Wetlands: a case study of combined effects of multiple pressures	101
	Data gaps for biodiversity and ecosystems	102
Appendix: Data sources and specific gaps		104
Glossary – te reo Māori		111
Acknowledgements		115
References		116

Message to our readers

Ko au te whenua,
ko te whenua, ko au

The land defines my quality of life.
I am the whenua, the whenua is me.

Land is our place to stand, our tūrangawaewae, and it is what makes Aotearoa New Zealand home. “People need nature, land and waters for life, purpose and humanity” (Te Urewera Board, 2017).

Our relationship with land can also be viewed through the benefits or ‘ecosystem services’ we derive from it. In Aotearoa New Zealand, soil is the foundation of our economy; and healthy soils are key to managing climate change and improving freshwater quality. Our rich biodiversity is the web of life that shapes and sustains our society – and is also a major drawcard for international tourists.

So intuitively you would think soil and biodiversity are among our most treasured assets.

But this report paints a different picture; it shows that in some areas soil and biodiversity are being seriously compromised by our actions. The evidence in the report highlights that the way we use our land is contributing directly to erosion, and soil and water degradation, and is reducing the health and diversity of our precious plants, animals, and habitats.

This is an important story and one well-founded on available information. However, there are parts of the story still missing. The report reveals significant and fundamental gaps in the data, especially integrated data at a national scale. This means, for example, that while we can talk generally about land use, we are not able to report in a detailed way on what happens where, how intensively the land is used, nor how that use is changing. Without better land use information we cannot fully understand the extent of pressures, the rate of change, or how emergent land use practices are likely to impact on our soil and biodiversity. Plugging this fundamental knowledge gap isn’t an easy task. It will require many different parties to work together to resolve data ownership issues and to target investment.

Similarly, our understanding of soil and ecosystem health is limited to specific aspects, habitats, or species. And we lack a systematic view of the environmental, social, cultural and economic impacts of changes in soil and biodiversity. Having a more balanced picture of what is important for soil and ecosystem health, and why it matters, will require better data coverage and consistency. It also requires us to dig deeper to understand the connections and interdependencies in our ecosystems. Without this knowledge, we risk letting slip the very things that underpin our well-being and prosperity.

This report provides an opportunity for us to recognise that soil and biodiversity are taonga, that our stewardship depends on us earnestly building our knowledge base, and that it is our responsibility to take action to restore the health of the whenua, for today and tomorrow’s generations.

Vicky Robertson
Secretary for the Environment

Liz MacPherson
Government Statistician

Our land at a glance

This is the first report focused solely on land in the environmental reporting series begun in 2015.

Our land 2018 reports on the state of the soil, and the state of indigenous biodiversity and ecosystems. The aim is to provide an overview of condition, and changes over time, to support decision-making at all levels of society.

This page presents a snapshot of the top-level findings. It is followed by an executive summary.

- **Land is fundamental to human life, and central to the environmental system we depend on.** The decisions we make and the actions we take affect not just the land, but also water, oceans, air and atmosphere, and the life they support.
- **There have been significant shifts in land use in the past two decades.** These include:
  - expansion in urban areas (a 10 percent increase between 1996 and 2012), and accompanying loss of some of our most versatile land
  - reduction in the area of land in agricultural production (7 percent decrease between 2002 and 2012)
  - increase in the proportion of farmland used for dairy (42 percent increase in area between 2002 and 2016), and a decrease in the area in sheep and beef (20 percent reduction between 2002 and 2016)
  - continued intensification of farming, including a shift in the past 15 years to higher stocking rates, especially for dairy.
- **The quantity and quality of soil are affected by erosion and intensification of agriculture**:
  - of the 192 million tonnes of soil estimated lost each year, 44 percent comes from exotic grassland
  - while five out of seven indicators of soil quality were largely within target range, two indicators present concern, as more than 48 percent of tested sites were outside target range for those properties
  - one indicator is for phosphorus content in soil, which when too high can have negative impacts on water quality; the second indicator is for macroporosity (which is part of the soil's physical status and when too low is an indicator of compaction), which can have negative impacts on water quality and production
  - sites under more intensive land uses, such as dairy, cropping and horticulture, and dry stock, were more frequently outside target range for these two soil quality indicators.
- **Indigenous biodiversity and ecosystems continue to be under threat**:
  - there was continued loss of indigenous land cover
  - coastal and lowland ecosystems continued to decline in extent
  - nearly 83 percent (285 of 344 taxa) of the land vertebrates classified in the threatened species system were either threatened or at risk of extinction, and the status of 11 species declined
  - predation and plant-eating by pests, as well as disease and weeds, continued to threaten indigenous biodiversity.
- **There is a bright spot for biodiversity – 20 bird species have improved conservation status.** The status improvement for more than half of these bird species was dependent on intensive conservation management.
- **There are significant gaps in the data that limit the analysis in this report.** Filling these gaps would support better decision-making. This is particularly important for our key economic asset – the soil, and the underlying environmental services that biodiversity and ecosystems provide.

Executive summary

What is at stake – why do soil and biodiversity and ecosystems matter?

The biodiversity and ecosystems above and below the ground sustain every aspect of life in Aotearoa New Zealand. They provide our life-support systems and the foundation of our economy and society.

Land underpins the country's top two export earners: primary production and tourism. In 2016, land-based primary production (agriculture, horticulture, and forestry) earned $35.4 billion (half of the country's total export earnings of $70.9 billion), while international tourism expenditure in New Zealand was $14.7 billion. In the same year, land-based primary production's share of total gross domestic product (GDP) was 3.7 percent, while tourism's share was 5.7 percent.

Land ecosystems are central to all human life: they provide air, water, and food for survival, and insulate us from natural forces such as flood and fire. The land is important for other aspects of being human too: it provides a connection to place and history, and a space we play and learn in. It is where we define culture, express spirituality, and anchor memory and identity.

These together make up the 'ecosystem services': benefits that people derive from the natural world. This is a dependency clearly expressed in te ao Māori: a world view "defined by relationships between people, land, water, flora, fauna, and inhabitants of the spiritual world – all bound together in a web of mutual responsibility" (Waitangi Tribunal, 2011). This has a central tenet, that human well-being is directly connected to the state of the land:

> Te toto o te tangata he kai, te oranga o te tangata he whenua.
> While food provides the blood in our veins, our health is drawn from the land.

Aotearoa New Zealand's biodiversity has particular significance. Many of our indigenous species, particularly our animals, come from old lineages. A large proportion of these indigenous species are endemic – they are internationally distinctive and important to global biodiversity. If these species are lost to the world, they cannot be replaced.

The most recent survey of our land cover shows that just under half of the land area is covered by natural cover types like indigenous forest, tussock grassland, scrub and shrubland, as well as water bodies, and bare ground. The other half is made up of modified land cover types such as exotic forests and grasslands, cropland, and urban areas. What is known about the condition of these areas, and how they have changed over time, is summarised in the next section.

The current state of biodiversity and ecosystems, and the soil

The findings of this report show that the state of our biodiversity and ecosystems and our soil resources is continuing to decline.[1]

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[1] The selection of the report's top findings was based on these criteria: spatial scale of impact to natural systems; magnitude of change; scale of impact on culture, recreation, health, and the economy; and irreversibility or long-lasting effects of change.

Indigenous biodiversity and ecosystems continue to be under threat

- There is continued loss of indigenous land cover. Between 1996 and 2012 there was a net loss of 31,000 hectares of tussock grassland, 24,000 hectares of indigenous shrubland, and around 16,000 hectares of indigenous forests, through clearance, conversion, and development. Although these areas represent a small proportion of each land cover type, the ongoing loss continues to threaten indigenous biodiversity.
- Coastal and lowland ecosystems that were once widespread (including wetlands) continue to decline in extent. Almost two-thirds of New Zealand's rare and 'naturally uncommon' ecosystems are threatened.
- Of the taxa that are assessed in New Zealand's threat classification system, nearly 83 percent (285 of 344 taxa) of indigenous land-based vertebrates are either threatened or at risk of extinction. This affects taonga species.
- The conservation status of seven bird species, three gecko species, and one species of ground wētā is worsening. The conservation status of 20 bird species is improving – more than half of them are dependent on intensive conservation management.
- Except for some offshore islands and fenced sanctuaries, exotic pests are found almost everywhere in New Zealand. Predation and plant-eating by pests, as well as disease and competition from weeds, continue to threaten indigenous biodiversity.

The quantity and quality of soils are affected by erosion and intensifying agriculture

- New Zealand has naturally high rates of erosion, due to a combination of steep terrain, rock and soil types, and climate. Erosion can be accelerated when tree cover is removed. Erosion models comparing soil loss to water with land cover types show 44 percent of the soil that enters our rivers each year comes from pasture (exotic grassland). This is equivalent to 84 million tonnes of soil out of the 192 million tonnes estimated lost each year.
- Soil monitoring programmes in 11 regions across the country between 2014 and 2017[2] show that results for 83 percent or more of tested sites were within target range for five of the seven indicators (pH, total carbon, total nitrogen, mineralisable nitrogen, bulk density). However, the remaining two indicators give reason for concern.
- More than 48 percent of tested sites were outside the target range for two indicators of soil quality: phosphorus content (an indicator of soil fertility) and macroporosity (a measure of how many pore spaces there are in the soil, which is an indicator of the soil's physical status).
- Of tested sites, 33 percent had soil phosphorus levels that were too high. Excess phosphorus can travel into waterways through erosion and run-off, where it can trigger growth of unwanted plants and reduce water quality.
- Of tested sites, 44 percent were below the target range for the macroporosity soil indicator (indicating soil compaction). Soil compaction makes soil less productive, and can reduce soil biodiversity and restrict plant growth. As compaction impedes drainage, it can also result in increased greenhouse gas emissions from urine on soils, and an increased amount of phosphorus and eroded soil reaching waterways.

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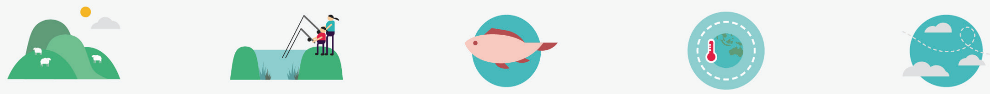
[2] These programmes are run by 12 of the 16 regional and unitary councils in New Zealand. In this reporting period only 11 councils provided data for analysis.

- Sites under more intensive land uses, such as dairy, cropping and horticulture, and dry stock, were more frequently outside the target range for these two soil quality indicators. In particular, 51 percent of tested dairy sites had excess soil phosphorus and 65 percent of tested dairy sites were below the target range for macroporosity. Some horticultural and cropping sites also had high phosphorus levels (37 percent) and low macroporosity levels (39 percent). Drystock sites also had low macroporosity levels (41 percent).

The state of the land is central to the wider environmental system

Changes to the state of the soil or biodiversity and ecosystems have major effects on other parts of the environmental system (figure 2). This is particularly the case 'downstream' in freshwater and marine environments, but also in air and atmosphere. The connections and interdependencies within indigenous ecosystems are central to the life-giving services they provide, and declines in biodiversity reach across all aspects of the physical environment. The close interrelationship between different environmental 'domains' is illustrated by the wider effects of changes in soil quantity and quality (figure 1).

Figure 1 Environmental impacts of soil degradation



Land	Fresh water	Marine	Atmosphere & climate	Air
Soil quality changes can put added pressure on indigenous plant species and raise opportunities for invasive species.	Water quality and the ecological health of rivers, streams, and lakes can be degraded when eroded sediment, contaminants, and nutrients enter waterways.	A reduction in survival rates of many species and the loss of important marine habitats occurs when eroded sediment reaches estuarine and coastal areas.	Soil is a major carbon sink. Land use change can cause the soil carbon stock to increase or decrease, especially if there is a disturbance of the topsoil as in agriculture and production forestry. When a land use change decreases the soil carbon stock, carbon dioxide, a greenhouse gas, is emitted to the atmosphere. When a land use change increases the soil carbon stock, carbon is removed from the atmosphere.	Dry, bare soil can be eroded by wind, suspending particles in the air and causing respiratory issues, dust nuisance, and loss of fertile soil.
Erosion damages infrastructure such as fencing and roads on farms, and when it occurs, can cause significant impacts to roads, housing, and infrastructure (such as water pipelines).	Compacted soils are often slow draining, which can lead to more sediment and nutrients moving off the land and affecting waterways.		Soil carbon is an indicator of soil organic matter, which is important in supplying and retaining nutrients for plants and farm production and reducing the amount of nutrients leached to water.	
Erosion reduces the amount and quality of soil, leading to reductions in plant and animal productivity.	Sediment that enters waterways can build up in river channels leading to an increased flooding hazard and risk to infrastructure such as bridges.		We have limited understanding of the relationship between erosion and the storage/release of carbon.	
Reductions in soil quality can limit plant growth leading to reductions in animal productivity.			Soils that are wet or compacted are likely to have increased emissions of nitrous oxide, a greenhouse gas.	

What is putting pressure on our land

Human use of land has always had an impact on the environment. What has changed in our lifetime is the extent and intensity of this impact as population increases and technology and society change.

This report presents a view of measurable change in the pressures that affect soil and biodiversity and ecosystems. The findings reflect the pressures of human activity in combination with the physical processes of geology and climate. In 2018, the accentuating effects of major earthquakes and climate change have particular relevance.

To gain a view of the overall pressures on land, and on the soil in particular, the report focuses on recent changes in land use (changes in extent, activity type, or intensity), across these major land use types: conservation, forestry, agriculture, and urban. It also reports on three pressures that can have concentrated effect at specific points: mineral extraction, waste, and contamination.

To understand the decline in indigenous biodiversity and ecosystems the report looks at the effects of human activities in terms of habitat loss, habitat degradation, and species loss. The focus is on changes in the extent and distribution of indigenous land cover and ecosystems; and the effects of habitat fragmentation; and pests, weeds, and disease.

These pressures on land can have a compounding effect, as in many wetland areas. Wetland ecosystems continue to decline in extent, after already declining to about 10 percent of their pre-human extent. This habitat loss can result in habitat degradation through fragmentation. Fragmentation can increase the proportion of vulnerable 'edge habitats' and can also result in species isolation, making populations more vulnerable to chance events.

Our human activities, accentuated by recent natural disasters and climate change, are putting pressure on soil and indigenous biodiversity and ecosystems

- While there has been little change in the total exotic grassland area between 2002 and 2012, there was a reduction in the total agricultural land in the same period. The total area recorded in the Agricultural Production Census dropped from approximately 13.4 million hectares in 2002 to about 12.6 million hectares in 2012, a decrease of 7 percent, mainly in pastoral farming land for sheep and beef.
- Overall, the main shifts in land cover between 1996 and 2012 were from exotic grassland and shrubland to exotic forest, some conversion in the opposite direction, and a 10 percent expansion of urban land. Cropland expanded in area between 1996 and 2002 and more so between 2002 and 2008.
- Agricultural intensification includes a shift in the past 15 years to higher stocking rates (especially for dairy).
- At the same time, land under dairy increased to 2.6 million hectares in 2016 (42 percent increase from 2002) and the area under sheep and beef farming decreased to 8.5 million hectares (a 20 percent drop). This shift from sheep and beef farming to dairy farming was most pronounced in Canterbury and Southland.
- Urban expansion is reducing the availability of some of our most versatile productive land. Studies based on changes in land cover indicate that between 1990 and 2008, 29 percent of new urban areas were on some of our most versatile land. Fragmentation can also be a pressure on urban fringes: in 2013, lifestyle blocks occupied 10 percent of New Zealand's most versatile land. This may block future options for agricultural production.
- Change in land cover, historic and recent, is a key pressure on our biodiversity and ecosystems. The remaining indigenous vegetation cover is mostly in hilly and mountainous areas, with only small fragments in lowland and coastal environments. This is not representative of the full range of indigenous ecosystems and habitats.
- Pressures from human activity and exotic invasive species can degrade habitat quality, through modification and fragmentation – making indigenous species more vulnerable to the effects of pests, weeds, and diseases.

- Predatory animals (particularly rodents, mustelids, and possums) are a major cause of species decline. Browsing animals (including possums, deer, and goats) can damage indigenous forest, and invasive insects and weeds can out-compete indigenous species. Diseases, such as kauri dieback and myrtle rust, also pose a serious threat to biodiversity.
- Earthquakes, particularly those in Canterbury and Marlborough in the last decade, have had long-lasting impacts across those regions and nationally. The earthquakes have had profound effects on individual and community well-being, landforms, natural systems, and built infrastructure, and have created substantial economic and land management challenges.
- Climate change is already affecting New Zealand's land systems. We can expect severe effects on land and human systems from long-term changes and increased frequency of intense rainfall events. These effects include challenges to productive systems (shifts in the suitability of land for horticulture and agriculture), pressure on indigenous ecosystems (with exacerbated impacts from pest invasions), increased vulnerability to erosion, sedimentation of waterways, and wildfires, through increased risk of rainfall and drought events.
- Rising sea levels and related storm surges will increase the frequency, severity, and extent of coastal flooding and erosion, while also threatening low-lying infrastructure, cultural sites, and habitats. They may also increase the risk of seawater intrusion to groundwater.

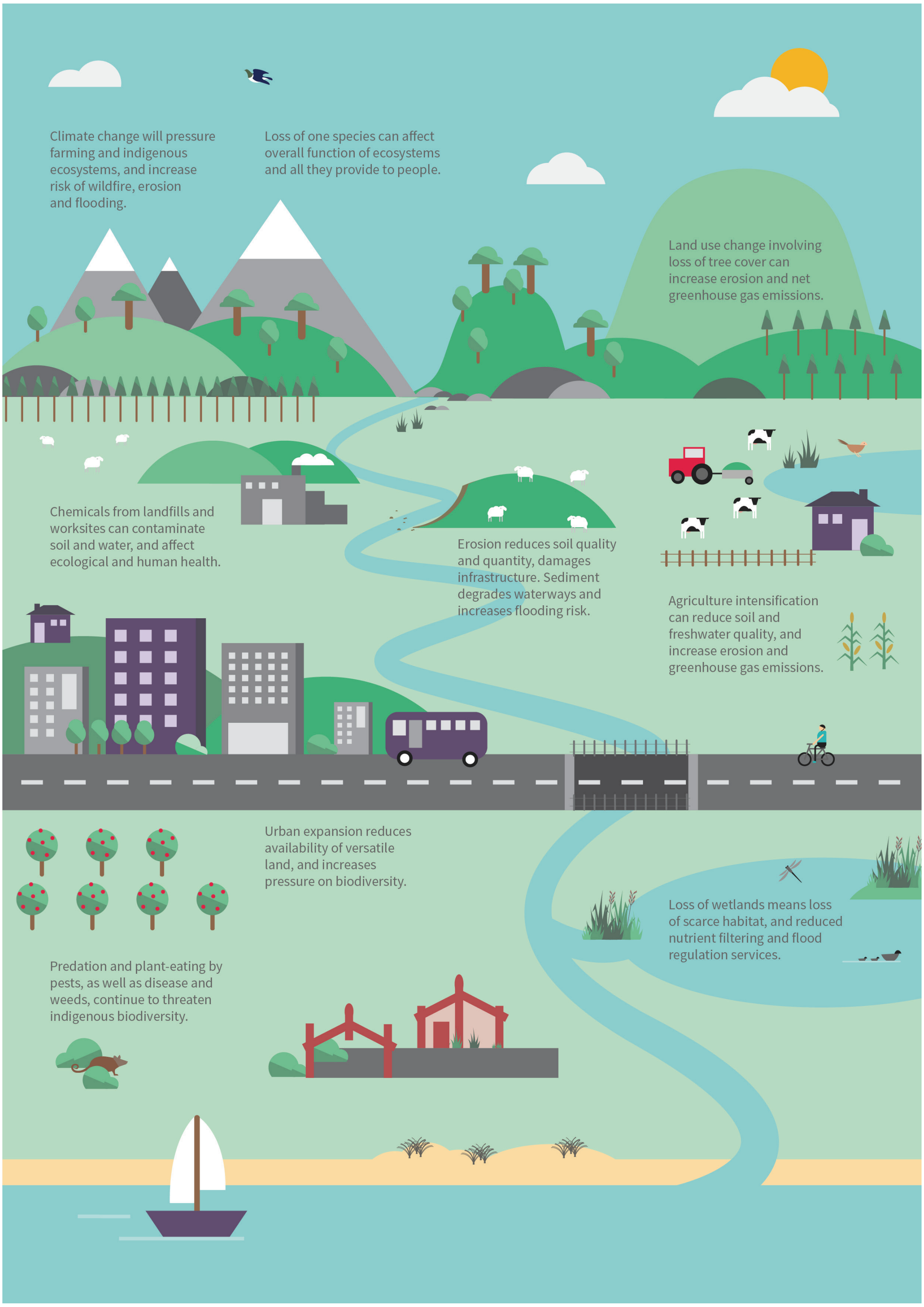
The report has only a partial view of changes in the extent and intensity of other key human activities that put pressure on soil and biodiversity and ecosystems (including tourism, mineral extraction, waste disposal, and contamination of land). These are described, but the lack of national datasets to support reporting of change over time precludes the report reaching specific findings in these areas (see below).

What we need a clearer view of

The Environmental Reporting Act 2015 requires the Ministry for the Environment and Stats NZ to report on the **state** of the environment, the **pressures** affecting its state, and how these **impact** on aspects of environmental and human well-being. The impacts considered include ecological integrity, public health, economy, te ao Māori (the Māori world view), culture, and recreation.

There are significant gaps in data coverage, consistency, and scale that limit the analysis in this report. These gaps also limit the options available to better represent current and future pressures, change over time, and links between state and impact, as well as a more complete range of impacts. The data gaps are outlined in Data sources and limitations in the next section.

Figure 2 How land activities relate to other parts of the environmental system



Introduction

Land encompasses rocks and soil, plants and creatures, and the ecosystems where they interact. The land sustains every aspect of our lives, providing fundamental life-support systems and the foundation of our economy and society.

While information on land features in almost all other state of the environment reports, this is the first dedicated report on land in the series begun in 2015.

The main themes explored in *Our land 2018* include:

- the pressure of human activities on natural resources and likely impacts of climate change
- the threat this presents to New Zealand's soils, indigenous biodiversity and ecosystems
- the impact this and recent natural disasters, particularly earthquakes, can have on our social, cultural, environmental, and economic well-being.

Scope of this report

The Environmental Reporting Act 2015 (the Act) sets the scope of this report. The Act requires the Ministry for the Environment and Stats NZ to report on the state of the environment, the pressures affecting its state, and how this impacts on aspects of environmental and human well-being. This includes ecological integrity, public health, economy, te ao Māori (Māori world view), culture, and recreation. The report does not aim to identify the drivers of pressures, nor the appropriate responses to reduce or moderate pressures (see next section).

The Environmental Reporting Regulations 2016 details the topics for the land domain report, and the Government Statistician sets which statistics are used to measure those topics.

How the report works

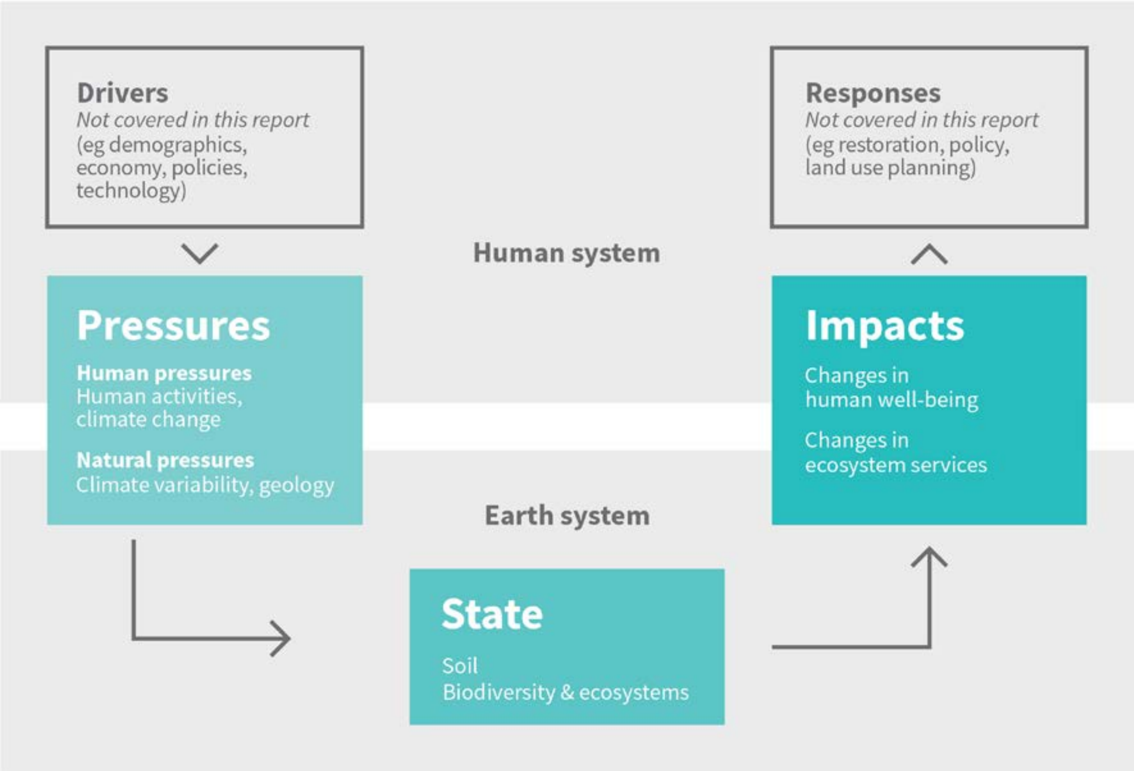
Our land 2018 reports on the biophysical characteristics of Aotearoa New Zealand, providing both a snapshot of condition of the land, and a view of changes to it over time. It reflects the diverse relationships we have with the land – its significance in economic, social, and cultural terms.

The report has a core structure of pressure–state–impact information, a subset of the overarching driver–pressure–state–impact–response framework (figure 3). This framework assumes an underlying chain of causal linkages between drivers (economic sectors, demographics) through to pressures (human, natural), to states (soil, biodiversity), and impacts on ecosystem services (benefits people get from nature) and human well-being, eventually leading to policy or community responses.

The legislation governing environmental reporting intentionally excludes any information on responses. This means that there are no findings about current responses such as biodiversity restoration (including community-level initiatives) or assessment of interventions such as land use planning within this report. Likewise, the report does not make findings about drivers that could explain the likely direction of pressures, such as demographics, economic context, policy, and new technologies.

The framework reflects interactions between human and earth systems, (shown in figure 3 as separate systems) to reflect both biophysical and social processes (Nassl & Löffler, 2015). The report's structure also reflects the complexity of causality. Drawing the connections between pressures and state and eventually impacts is challenging, as one pressure may have multiple consequences in terms of state and impact. The report aims to make those connections clear, rather than to separate them artificially, to make plain the consequences for our society.

Figure 3 The pressure–state–impact framework underlying this report

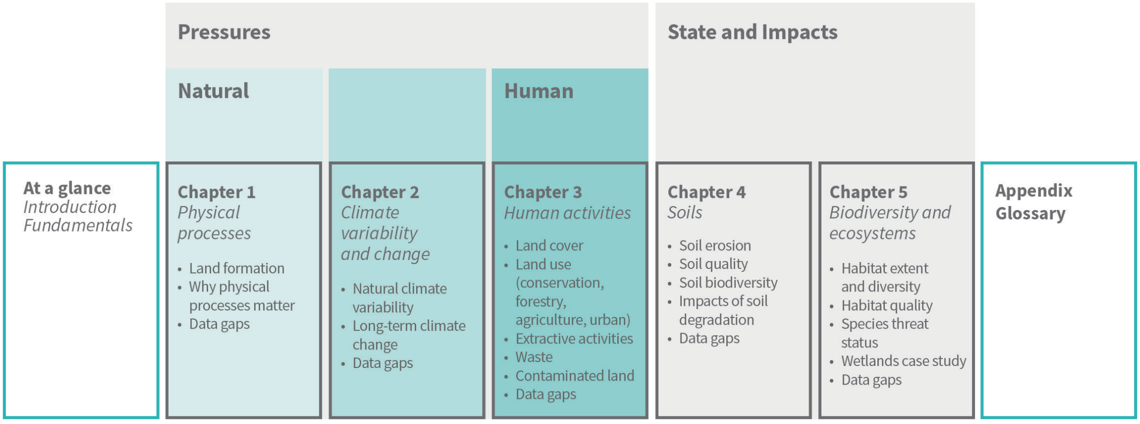


Report structure

This report is divided into three main parts, covering context, pressures, and state – with likely impacts discussed within each part (figure 4). Key findings for each chapter are summarised at the beginning of the chapter, and summarised at the start of the report in 'Our land at a glance'. The report presents no conclusions beyond the summary of findings.

Pressures from both human and earth systems are presented. Chapter 1 sets the scene, describing the physical processes such as geology and climate that can amplify the pressures of human activities. Chapter 2 bridges the two kinds of pressure in its focus on climate variability and climate change, which represent both natural and human-induced characteristics. Chapter 3 concentrates on human activities. The state of New Zealand soils, biodiversity and ecosystems, and the likely impacts on social, cultural, environmental, and economic well-being are covered in chapters 4 and 5.

Figure 4 Report roadmap for the reader



Human and earth systems operate and interact on a variety of scales such as catchments, landscapes, and regions. The scale of this reporting varies according to theme. For example, for physical processes the land is described by landform type, for human activity by land use, and for biodiversity by species, habitats, and ecosystems.

For convenience and because this is a complex issue, land use has been separated into four broad categories (conservation, forestry, agriculture, and urban), to reflect the main land uses in New Zealand. This approach has limitations, because it cannot provide an integrated view of the complexities and interactions between these broad land uses – for instance, the impact pest species (eg brushtail possums) from conservation land have on agriculture through *Tuberculosis bovine* is not discussed.

The timeframes of the reporting are largely dictated by data availability; where possible, timeframes were selected to support comparison between datasets, and to reflect key periods of change.

Signposts to data, infographics, and interactive maps

More detailed scientific information is available online, through Environmental indicators Te taiao Aotearoa: Land on Stats NZ's website, which includes graphs, tables and interactive maps. The MfE data service provides the methodologies used in the analysis and allows customised analysis of the data.

Our land 2018 at a glance is a condensed version of the report's key findings. It is accompanied by a graphic illustration showing the key points.

Changes since Environment Aotearoa 2015

Our land 2018 is the fourth domain report produced under the Environmental Reporting Act 2015. The last time land was reported was in *Environment Aotearoa 2015*. Differences in this report include some new subject areas, including mineral extraction, waste and contaminated soil, and a deeper review of topics, including a close exploration of land use change and related pressures.

This report took into account the Parliamentary Commissioner for the Environment's commentary on *Environment Aotearoa 2015* (PCE, 2016), which emphasised the importance of selecting issues for focus according to their importance (on a range of criteria) rather than on only the availability of data. This report has adapted the criteria for importance proposed by the Commissioner to identify its key themes, with input from stakeholders and guidance from technical advisers.

The Ministry for the Environment and Stats NZ are working with Māori advisers to develop a Treaty partnership approach to environmental reporting. This report takes some first steps towards providing a view of 'te mana o te whenua' in terms of te ao Māori – see How whenua matters.

Data sources and limitations

Context and approach

The report has used good quality data where they exist for particular issues or locations. This has been quality assured by Stats NZ and meets Environmental Reporting programme quality standards. In compiling this report, however, it is apparent there are significant gaps in data coverage and consistency, and at appropriate scales, including the time scales to reflect key periods of change.

The gaps, in part, reflect the diversity of issues and scales, and the complexity of the land as a subject where human and earth systems interact. To provide the best possible picture of state, pressure, and impact in this report, including emerging issues, the report draws on additional information sources from science and government sectors (see Additional information sources). This use of peer-reviewed research has enabled the report to reflect issues critical to our understanding of land.

Further effort to standardise data and close gaps has been prioritised under the Conservation and Environment Science Roadmap (Ministry for the Environment & Department of Conservation, 2017) and to support Environment Aotearoa 2019. The Environmental Monitoring and Reporting (EMaR) programme, a partnership between regional councils and the Ministry for the Environment, is also working to standardise data and improve coverage of land monitoring datasets.

Data sources

The main sources of information for this report are data and analyses derived from Environmental indicators Te taiao Aotearoa: Land (see Appendix: Data sources and specific gaps). Further detail on the data behind each land domain indicator, and related indicators from other domains (eg atmosphere and climate indicators), can be found in the definition and methodology section of the indicator web pages. Datasets are available on the Ministry for the Environment's data service.

See Appendix: Data sources and specific gaps for limitations of the data sources.

Additional information sources

To supplement the data reported above and to present a more complete picture of pressures, state, and impact for land, information from peer-reviewed papers and technical reports has been analysed and used. Examples of the use of these sources include analysis to spatially depict change in extent (eg land cover on Māori land, public conservation land, and forest area), and case studies that provide insight into aspects of the land that are nationally important and culturally unique (eg mātauranga Māori and kaitiakitanga).

These sources are invaluable because they highlight significant developments and emerging issues (eg effects of recent earthquakes, loss of versatile land on urban fringes, and spread of wilding conifers). Using these sources ensures the report is relevant, and it allows readers to make conclusions about the relative significance of different environmental issues on the basis of science and reason.

Data gaps

There are significant gaps in data coverage, consistency, and scale that prevent the presentation of a complete picture of the state of, pressures on, and impact from land. These limitations include:

- Spatial coverage: it is well established that there is a shortage of comprehensive, nationally representative data that characterise New Zealand's land use, soil, and indigenous ecosystems, and how this is changing spatially and temporally. The main barriers include an inconsistency in sampling methods and an unsystematic and uncoordinated approach to monitoring nationally. Additionally, more work is required to access, harmonise, and integrate data that come from a variety of sources and owners, and were collected for different purposes.
- Trends over time: There is a shortage of time series data for most land indicators. Data over longer time periods and with greater granularity are required to better identify when and how quickly change is occurring, and the changes between successive reporting periods. This will improve our understanding of the effects of recent pressures, for example, irrigation, winter grazing, or high-density housing.
- Understanding what constitutes soil and ecosystem health, and how it relates to the provision of services: While we can report on individual species or measures of soil quality, we lack holistic understanding of what represents a healthy soil or ecosystem. More understanding is also required to determine the degree to which changes in state (eg increasing erosion or declining indigenous biodiversity) are due to human activity or to predisposing environmental factors, and when change does occur how it will affect the benefits people get from land.
- Impact on social, cultural, environmental, and economic well-being: Our reporting on impact relies heavily on additional sources or is described through case studies. More systematic data are needed to understand the impacts that result from changes in state. There is a critical challenge to develop comprehensive systems that support assessment of impacts from the perspective of te ao Māori, particularly characterising impact through mātauranga Māori and tikanga Māori, and on kaitiakitanga, customary use, and mahinga kai. (See How we measure what matters in the next chapter.)

The Appendix: Data sources and specific gaps summarises the specific data gaps referred to at the end of each chapter. Filling these gaps would help improve future environmental reports and ensure they are relevant.

Fundamentals

Why land matters

Whatungarongaro te tangata **Toitū te whenua**	*As man passes from sight,* *the land remains.*

The land sustains every aspect of our lives, providing fundamental life-support systems and the foundation of our economy and society.

It is the place we stand. And also the place we act. It is where we make decisions that affect not just the land, but also water, oceans, air, and atmosphere, and the life they support. This puts land at the centre of most environmental conversations in New Zealand.

This chapter explores the key ideas that underlie how we talk about land. These are the fundamentals of this report – they reflect the interweaving of human relationships to land with the biophysical characteristics of the environment.

Land as the foundation of human life

Humans have always used land for survival: for food, water, raw materials, dwellings, and shelter. Land ecosystems are central to the maintenance of fundamental life-support systems for the planet: the air we breathe, temperatures we can endure, water we can drink, soils that support the plants we use, and the creatures we co-exist with.

Land is also the foundation of New Zealand's economic activity. Even in this digital era, Aotearoa New Zealand remains an economy grounded in land-based production.

Land is important for other aspects of being human: it provides a connection to place and history – a space to play and learn, define culture, express spirituality, and anchor memory and identity.

These different aspects of the human relationship with the natural environment can be categorised as 'uses' or 'benefits'. Collectively, these benefits are known as 'ecosystem services', a concept popularised by the Millennium Ecosystem Assessment (2005) and currently used by the Intergovernmental Platform on Biodiversity and Ecosystem Services. Ecosystem services include *provisioning* services – these describe the material or energy outputs from ecosystems (eg clean air, food, wood, and fibre); *regulating* services (eg water and climate regulation, crop pollination, pest and disease control, and soil loss prevention); and cultural services (eg recreation, scientific/educational, aesthetics, spirituality, and well-being) (figure 5). These services are underpinned by *supporting processes* such as nutrient cycling, soil formation, or primary production.

Figure 5 **Ecosystem services**

Core components of the human system

Our relationship with land is a complicated product of history, politics, philosophies, ideas about ownership and responsibility, legal and planning frameworks, and fundamentally, values – what people hold dear.

Surrounding those core concepts is a framework of rules and principles, both cultural and legislated. See Box 1: Rules and principles surrounding land issues.

One starting point for discussions about land is when land changes its use – this can trigger the need for dialogue and sometimes the giving of formal consent by other parties, under the systems described in Box 1. In contrast, changes in community goals or expectations can drive legal or planning changes (eg at the level of a whole water catchment) that can further constrain how land is used.

Generally land owners and lessees (and developers) make decisions about their land under a framework of national and regional legislation and rules, as they exercise their day-to-day responsibilities. For example, under the Te Ture Whenua Māori Act 1993, when Māori land owners make decisions about their land, their choices are still constrained by their region's plans and land use rules, and national legislation such as the Resource Management Act 1991 (RMA).

Other interested parties get involved in decisions about land less often, usually only when it is about the bigger picture (eg public works such as roading and infrastructure), or setting broad regional or catchment goals (eg for regional planning exercises). These important groups include:

- Māori – when acting more broadly as mana whenua and kaitiaki, such as in community, district, and regional processes (especially RMA planning), usually as a Treaty partner or to legislative requirements
- central government – as land owner, or through its wide range of statutory responsibilities, or as Crown Treaty partner
- local government – as land owner (eg of reserves) and community representative with planning responsibilities under the RMA and broader roles under the Local Government Act 2002 and other statutes
- communities and society – acting locally, regionally, or nationally, either formally or informally, often through non-governmental organisations and service organisations with a specific focus, sometimes authorised by statute
- industry and enterprise – as land owner or user, manager, business, or as financier and insurer, without whom land use is difficult to sustain – including a critical role as the Earthquake Commission
- visitors – as domestic and international tourists who shape land use as consumers and influencers, and therefore change what is valued and why.

These groups, when acting as decision-makers and influencers, respond to a range of drivers including economic incentives, social and cultural factors, and the values they and others hold. The Māori relationship to land as tangata whenua, mana whenua, and kaitiaki is critical here – these roles are enshrined under the Treaty of Waitangi and recognised in legislation such as the RMA. The RMA has also established legal precedents around the values all New Zealanders attach to their environment, including specific landscapes.

Values may be constant or may change over time – this variability flows through to how we use our land. Values also affect how we make decisions about that use, as individuals, businesses, communities, and the nation. For instance, Māori as tangata whenua talk first of whakapapa, and their links and connections (physical and spiritual) to land – see How whenua matters. Legal systems talk first of rights, uses and interests – see Box 1.

Box 1: Rules and principles surrounding land issues

- *Tikanga* and locally *kawa* – customary frameworks that shape the way tangata whenua engage with councils and communities to protect and manage natural and customary resources under legislation, and to carry out responsibilities of kaitiakitanga.
- *Te Tiriti o Waitangi/the Treaty of Waitangi (the Treaty)* – partnership between the Crown and Māori that imposes a number of obligations on both parties; it is directly relevant to New Zealand law to the extent that it is incorporated into statute (PCE, 2002).
- *Resource Management Act 1991 (RMA)* – regulates how councils, stakeholders, communities, industry, and tangata whenua engage to manage and sustain natural and physical resources and mitigate effects; establishes key national instruments, including the:
    - New Zealand Coastal Policy Statement
    - National Policy Statement for Freshwater Management
    - National Policy Statement for Urban Development Capacity
    - National Environmental Standard for Assessing and Managing Contamination of Soil to Protect Human Health
    - National Environmental Standard for Plantation Forestry.
- *Te Ture Whenua Māori Act 1993* – governs Māori freehold land and Māori customary land; general land owned by Māori is also subject to some provisions.
- *Local Government Act 2002* – determines the way councils and communities engage for planning and decision-making.
- *Conservation Act 1987* – sets rules for managing public conservation land.
- *National Parks Act 1980* – governs land use and pest and weed control on that land.
- *Reserves Act 1977* – defines, regulates, and guides management of reserves which may be established under a wide range of Acts.
- *Wildlife Act 1953* and other legislation such as the Wild Animal Control Act 1977 – authorises agencies to act to protect indigenous species and control pests.
- *Biosecurity Act 1993* – authorises pest management plans.
- *Hazardous Substances and New Organisms Act 1996* – sets up a system for preventing or managing adverse effects on people of hazardous substances and new organisms.
- *Waste Minimisation Act 2008* – encourages waste minimisation and a decrease in waste disposal.
- *Soil Conservation and Rivers Control Act 1941* – provides for conservation of soil resources, prevention of damage by erosion, and better protection of property from damage by floods.
- *Land Drainage Act 1908* – establishes powers of local authorities relating to watercourses and drains.
- *Heritage New Zealand Pouhere Taonga Act 2014* (replaces Historic Places Act 1993) – promotes the identification, protection, preservation, and conservation of the historical and cultural heritage of New Zealand.
- *Crown Minerals Act 1991* – governs prospecting, exploration, and mining of Crown-owned minerals.

Other legislation establishes the land title system which governs our formal relationship to land, such as the Land Transfer Act 1952.

How whenua matters

> "To the early Māori, land was everything. Bound up with it was survival, politics, myth, and religion. It was not part of life, but life itself." (Asher & Naulls, 1987)

The story of Māori land is an interweaving of profound connection and alienation. There is an abiding link to whenua, to Papatūānuku (see Box 2). There is a history of loss, disempowerment, conflict, and unrelenting protest since the signing of Te Tiriti o Waitangi, the Treaty of Waitangi in 1840. Recent developments, such as the shift to establishing legal entities for Te Urewera land and the Whanganui River, raise the prospect of a renewed collective responsibility for our impact on the land, where the focus is on management of people for the benefit of the land (Te Urewera Board, 2017).

Box 2: The connection to Papatūānuku

According to Māori history and legends, Papatūānuku (the Earth Mother) is the realm in which whenua (land) is a fundamental component. Papatūānuku (also known as Papa) is honoured by Māori as tangata whenua, the indigenous people of Aotearoa New Zealand.

In terms of Māori identity, whakapapa (genealogy) is an important cultural process demonstrating how someone connects to and with Papatūānuku. The whakapapa process acknowledges and describes the historical connections Māori have to their land, water and mountains in their tribal region. It demonstrates the specific, detailed mātauranga Māori (Māori knowledge) that local Māori have with different land types (eg geothermal muds, soils and land processes like earthquakes).

Another expression of Māori connecting with Papatūānuku is the focus on papakāinga (homelands). Inherent in Māori cultural identity is the understanding that who Māori are as a people is demonstrated through clear connections and historical ties to tribal lands – as explicitly set out in the Māori language, customs and traditions. Māori values and the related practices such as communicating your whakapapa, paying homage to Papatūānuku in formal cultural exchanges (pōwhiri), and having a cultural focus on reconnecting with your papakāinga remain important to ensure this cultural heritage is protected today for current and future generations.

Connection to land through whakapapa is constant, across rural and urban Māori. Identity based on connection to land is part of Māori cultural well-being. The 2013 survey of Māori well-being (Te Kupenga, Stats NZ, 2014) reported nearly nine out of ten Māori adults (89 percent) knew their iwi, and 70.5 percent knew their marae tipuna (and more than half knew their hapū, maunga, awa, and waka). Sixty-two percent had been to their ancestral marae, and 34 percent had done so in the past 12 months.

In 2017, nearly two centuries after the first organised European settlements were attempted by the New Zealand Company in 1826 (Wilson, 2016), about five percent of the land area of Aotearoa New Zealand can be described as 'Māori land'.[3] This is mostly concentrated in the North Island (Harmsworth & Mackay, 2010).

3 This is primarily Māori customary and Māori freehold land, but also includes general land owned by Māori, Crown land reserved for Māori and a small area of treaty settlement reserves, mahingā kai, and fishing rights areas.

Since 1975, when the Waitangi Tribunal was formed to report on and suggest settlements for Māori claims to the Government, there has been a flow of settlements of historic claims that have returned land, mana, and financial compensation to iwi (Ministry for Culture & Heritage, 2016).

A recent, ground breaking development is the shift in status of Ngāi Tūhoe homelands from a national park to a 'legal entity' in 2014, and the similar shift in status of the Whanganui River in 2017. Māori legal expert Jacinta Ruru has argued the shifts are "about honouring the uniqueness, the essence, and the inherent value of nature. It's a model centred on a Māori world view; that of a people who see themselves as being part of nature, and their own welfare and health being reflected back by that of their environment" (Mitchell, 2016).

This world view is, according to the 2011 Waitangi Tribunal report known as WAI 262, "also defined by relationships between people, land, water, flora, fauna, and inhabitants of the spiritual world – all bound together in a web of mutual responsibility. The most important of these responsibilities is known in te reo Māori as kaitiakitanga – the obligation of kinsfolk to nurture or care for their relations. In the human realm, those who have mana (authority) must exercise it in accordance with the values of kaitiakitanga – acting unselfishly, with right mind and heart, and using correct procedure. Kaitiakitanga is an obligation not just of individuals but of the community as well" (Waitangi Tribunal, 2011).

Kaitiakitanga, and a model of environmental health interwoven with people's well-being, is at the core of several case studies later in this report – see chapter 5 Biodiversity and ecosystems.

How we measure what matters

Aotearoa New Zealand has a critical challenge to provide other perspectives in reporting, and especially to develop comprehensive systems that support the assessment of impacts of changes in the environment from the perspective of te ao Māori. Full reporting of the impacts on social, cultural, environmental, and economic well-being requires methodology that encompasses and respects the depth and differences of te ao Māori based on mātauranga Māori and tikanga Māori.

There is work underway. Māori have been developing cultural indicators for environment across a wide number of applications, including for water, mahinga kai, and ecosystems (Awatere & Harmsworth, 2014). It is at a very early stage of development.

An example of current research is presented in chapter 5, where local traditional knowledge and observation of change in kererū abundance is part of mapping forest ecosystem services in Te Urewera. This emerged from a study to identify community-based indicators and metrics used by Tūhoe Tuawhenua to monitor forest health and community well-being (Lyver et al, 2008 and 2016).

Indicator systems developed to bring te ao Māori perspective to environmental decision-making, particularly in freshwater, have included cultural health indicators and mauri assessments (Lyver et al, 2016; Scheele et al, 2016). These could be developed and extended for land and soils.

1 Physical processes

This chapter briefly describes the natural forces that underlie and accentuate the effects of human activities on the land.

The country's geology and climate are dynamic systems, presenting constantly changing pressures. These natural processes are the core characteristics of our physical environment. They occur in combination with human action – in the case of climate, these forces are now inextricably comingled, as discussed in chapter 2 Climate.

The map showing landforms in this chapter is echoed in later maps that show the combined effects of natural processes and human activity (eg for erosion in chapter 4 Soils).

Natural forces can at times present as natural disasters, profoundly affecting land use, and human and ecological communities. This is illustrated in a case study of recent earthquakes.

Key finding

Earthquakes, particularly in Canterbury and Marlborough in the last decade, have had long-lasting impacts across those regions and nationally. The impacts include profound effects on individual and community well-being, landforms and natural systems, built infrastructure, and related economic and land management challenges, with implications for pre- and post-disaster planning in New Zealand.

Aotearoa New Zealand – land formation

Ko au te whenua,	*The land defines my quality of life.*
ko te whenua, ko au	*I am the whenua, the whenua is me.*

Anyone who has driven along the Desert Road, cutting through the North Island's Central Plateau, would sense something special about the surrounding landscape. The peaks of Ruapehu, Ngāuruhoe, and Tongariro rise abruptly from the stark alpine desert surrounding them. These volcanic mountains are not just geologically significant, they represent sacred ancestors to tangata whenua.

Māori consider many landscape features to be ancestors of humankind, just as plants and animals are part of the wider kin relationships (Waitangi Tribunal, 2011). Beginning with the birth of Hineahuone from the soil in Kurawaka, tribal narratives describe and illustrate a fundamental connection between the people and the landscapes they depend on. In 1923 Ira Tahu, of Ngāti Porou, commented, "What our ancestors did was consider the essential aspects of the world and to relate to them as if they were human" (Royal, 2005).

Later settler groups formed their own intense connections with these islands, in all their difficulties and beauty. "Landscape", as historian Simon Schama observes, is a "text on which generations write their recurring obsessions" (Eggleton, 1999).

The relationship between the land and its people is a two-way relationship – how people live in Aotearoa New Zealand is shaped by the land, and how people use the land has an impact on the land and all its composite systems.

Building blocks – physical processes

Aotearoa New Zealand is a relatively young country in geological terms, still in the process of rising out of the sea. The landmass is constantly changing and evolving over a long time period (thousands of years) under the combined natural forces of uplift, tectonics, earthquakes, volcanism, and erosion.

The landmass has formed on the boundary of two main tectonic plates: the Australian and the Pacific. Once part of a supercontinent known as Gondwana, the island group has been isolated in the South Pacific for about 25 million years, as the visible tops of the undersea continent of Zealandia (McSaveney & Nathan, 2006).

The current tectonic process of uplift is countered by downward forces, including storms and floods, which erode mountains and hills and fill rivers with sediment. The sediment is then transported and deposited to floodplains, and coastal and marine areas.

These natural forces have made Aotearoa New Zealand a comparatively steep and narrow landmass (figure 6). Overall, the country is characterised by physical diversity. The wide range of distinctive landforms stretches from dunelands, through rolling hill country and extensive plains, to mountain ranges featuring 23 peaks over 3,000 metres (Dennis, 2017).

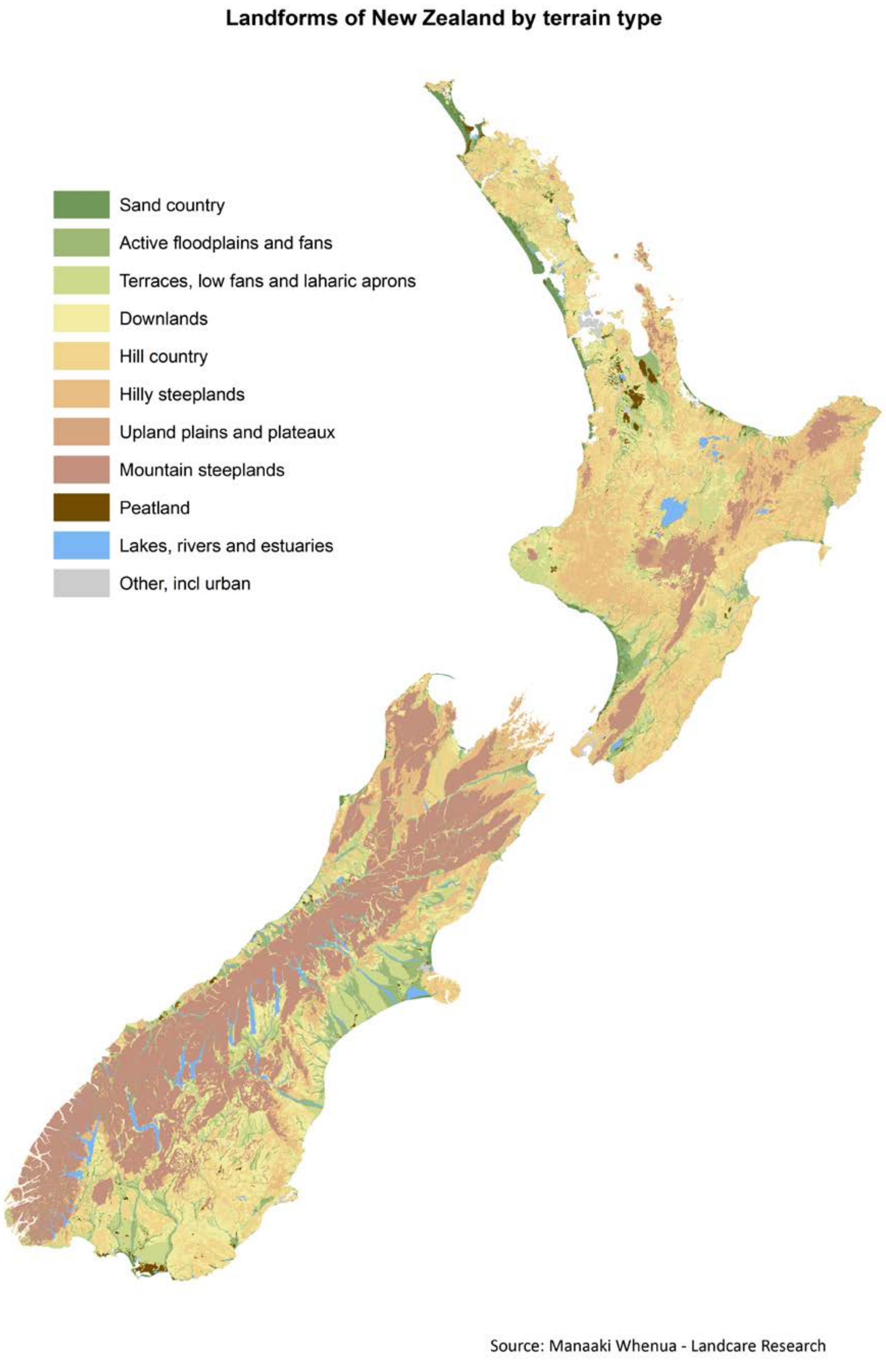
The landmass is geologically very active. Earthquakes are common in the two main islands – every year, GNS Science locates over 15,000 earthquakes in New Zealand, with about 100–150 of these large enough to be felt. Historic trends and records dating from the 1840s show that, on average, the country can expect several magnitude 6 earthquakes every year, one magnitude 7 every 10 years, and a magnitude 8 every century (GNS nd, Petersen et al, 2011).

Active geothermal and volcanic zones are present across the central North Island – including erupting geysers and occasionally active volcanoes (Stewart, 2006; Smith et al, 2006). Our largest city, Auckland, is underlain by a 'currently quiet' volcanic field (Smith & Allen, 1993).

As an island nation we are exposed to strong maritime and climatic forces (see chapter 2 Climate). While New Zealand's total land area is about 269,000 square kilometres (including offshore islands), the coastline is about 18,000 kilometres – about one-third of the length of the Australian coastline, a landmass over 28 times the size of New Zealand (Land Information New Zealand, 2012; Walrond, 2005). For more information about New Zealand's estuaries, beaches, and marine environment, see the separate report in this series, *Our marine environment 2016*.

There are over 425,000 kilometres of rivers and streams across the country, while large lakes are notable features in both main islands (including partly-filled calderas of volcanoes in the north, including Lakes Rotorua and Taupō). For more information see the separate report in this series, *Our fresh water 2017*.

Figure 6



Note: Classification based on grouped classes from the New Zealand Land Resource Inventory (Dymond et al, 2010).

Soil formation

Geology and climate have formed and shaped our soils over time, and continue to influence soil use and stability across the country (see chapter 4 Soils).

Age, climate, wetness, and rock type are the main factors that determine soil character. Organic material and topography (relief) play a part too. An example of climate's influence is the semi-arid soils of the inland basins of Central Otago and Canterbury, where low annual rainfall (350–500 millimetres) means elements such as sodium and calcium have not been washed out from the parent material, and remain in the soils (Hewitt, 2013). The soil characteristics have led to the development of microhabitats, such as the Central Otago salt pans, with specialised indigenous flora and fauna (Allen & McIntosh, 1995). Semi-arid soils are unsuitable for cropping without high added water volume, which in a dry climate requires irrigation.

Another example that demonstrates the influence of geology is the pumice soils of the central North Island. These began as ash and pumice thrown from a huge volcanic eruption that left the crater now filled by Lake Taupō. These soils drain quickly after rain. They are low in some trace elements such as selenium and cobalt, which historically restricted their use for livestock farming, and instead led to extensive plantation forestry across the central North Island. Knowledge of the role of trace minerals and the profitability of dairying (making it economically viable to apply fertiliser at the required amounts for productive use) has since driven a shift of land use back to dairying (Grace, 1994; Manaaki Whenua Landcare Research, nd).

Overall, most New Zealand soils tend to be slightly acidic with low levels of nutrients such as nitrogen and phosphorus. Productive farming often requires the application of lime and diverse nutrients (Molloy, 1988; Gibbs, 1980).

Why physical processes matter

The geologic, tectonic, climate, and weather processes that formed this land continue to shape the landscape and impact on people's lives. These forces of nature sometimes strike hard (see Box 3: Marlborough and Canterbury earthquakes).

Another example is Cyclone Bola, which struck Hawke's Bay and Gisborne–East Cape in 1988, killing three people, and resulting in farming and horticulture losses of $90 million (equivalent to $170 million in 2016), and a government repair bill of more than $111 million (equivalent to $210 million in 2016) (Ministry for Culture and Heritage, 2016). Major storms and flooding are part of New Zealand's variable maritime climate, and are predicted to increase with the more frequent intense rainfall events that accompany climate change – see chapter 2 Climate.

Natural processes can accentuate the effects of human activity. For instance, the likelihood of major slips damaging roads and farm infrastructure is higher in heavy rain on steep slopes of young rock and soils where tree cover has been removed. This combination can result in high rates of soil loss and sedimentation of freshwater and marine environments.

This is explored in chapter 3 Human activity and in more detail in chapter 4 Soils.

Box 3: Marlborough and Canterbury earthquakes

The Kaikōura earthquake on 14 November 2016 was a magnitude 7.8 earthquake centred 15 kilometres north-east of Culverden in North Canterbury. It was one of the most complex quakes recorded with modern instruments, rupturing over 180 kilometres along 21 different faults (Stirling et al, 2017). The quake triggered up to 20,000 landslides over 10,000 square kilometres, uplifted coastal areas up to 3 metres, exposing the seabed (Massey et al, 2018), and triggered the biggest local-source tsunami in New Zealand since 1947 (nearly 7 metres at Goose Bay).

Two people died, hundreds were injured, and several thousand were evacuated along the east coasts of both the North and South islands. The most severe impact on human structures was on transport: the quake damaged roads and bridges throughout the area, closing State Highway 1 and the main trunk railway for months, and affected ports in Kaikōura and Wellington. Building losses were modest despite the size of the earthquake, although there was substantial damage to farm infrastructure, and in the capital Wellington, 11 percent of office space closed within a week (Stevenson et al, 2017). Across the region, the long-term stability of slopes and landslide dams is still an ongoing concern (Massey et al, 2018).

State highway and main trunk railway line buried by landslides at Ōhau point. Photo: Dougal Townsend

Six months after the earthquake, direct costs of the earthquake were estimated at $2–3 billion, with a net cost to Government of about $1 billion (Stevenson et al, 2017). The Insurance Council of New Zealand (2018) calculated total insured losses at $2.14 billion in December 2017; $631 million of this was for domestic claims (88 percent partially or fully settled). Longer-term effects on tourism and primary production are still to be seen. While the marine mammals that are the key attractions for tourists to Kaikōura have remained in the area, tourism, farming, and fishing were hit hard. So was beekeeping, and Marlborough wine-making (which accounts for 70 percent of the national wine industry). The 2016 earthquake compounded the stresses on these regional communities, already affected by the 2010/11 Canterbury earthquakes, the 2013 magnitude 6.3 Seddon earthquake, and three years of drought conditions (Stevenson et al, 2017).

A longer view: the impacts of the 2010/11 Canterbury earthquakes

The greater interval since the Canterbury earthquakes allows a deeper, more integrated view of the effects of a major earthquake sequence. The Canterbury quakes began as a magnitude 7.1 quake on 4 September 2010, centred 40 kilometres west of Christchurch. This was followed by a magnitude 6.3 aftershock on 22 February 2011, centred 13 kilometres southeast of the city centre. This killed 185 people, injured several thousand, and damaged nearly 170,000 properties, or three-quarters of the region’s housing stock (Potter et al, 2015; Wood et al, 2016). The vertical ground accelerations were among the highest ever recorded in an urban environment, and there was widespread liquefaction. Much of the central business district was cordoned off (for nearly two years), and some suburbs permanently red-zoned (Kachali et al, 2015; Smith et al, 2017).

In 2013, Treasury estimated the cost of recovery and reconstruction at between $30 and $40 billion, approximately 20 percent of New Zealand GDP (Kachali et al, 2015). By September 2016, private insurers had paid out nearly $19 billion to settle commercial and residential claims, nearly $9 billion of it in domestic claims (Insurance Council of New Zealand, 2016). The cost to the Earthquake Commission almost exhausted the $5.6 billion in the Natural Disaster Fund, meaning the cost of a future major disaster is likely borne to a much greater extent by the Government until the fund is replenished (Wood et al, 2016).

The earthquakes caused major changes to ground and water systems that increased flood risks in some areas. Demolition of damaged structures produced dust that lowered air quality, and more permanently generated 8.75 million tonnes of waste (nearly 40 years of normal city waste volumes), which required the creation of new landfill sites (Environment Canterbury, 2017; MWH, 2017a). The city faced major land planning challenges, initially needed to manage public safety, and subsequently to guide rebuilding and facilitate recovery (Chang et al, 2014).

Disruption to business, education, work, and social connections was substantial, in “an environment of constant uncertainty” where successive aftershocks kept “resetting the recovery clock” – over 10,000 earthquakes hit the region in five years, at least four of them over magnitude 6 (Kachali, 2015). While the Reserve Bank reported house prices and rents were beginning to drop again in 2015, it also noted the effects of ongoing uncertainty in a slow rebuild. Population and business activity had recovered and employment was boosted by construction activity, but tourism and tertiary education remained markedly below pre-quake levels (Wood et al, 2016).

Social sector reports revealed a similar mix of recovery, resilience, and long-lasting damage at individual and community levels. Marae through the South and North islands provided support and housing for people who were displaced, emphasising “the resilience of Māori cultural values and skills” (Potter et al, 2015). The rebuild has been characterised by a new low-rise city model, and transitional activities that have seen the city noted internationally as a “hotbed of creative activity catalysed by natural disaster” (Brand & Nicholson, 2016). Comparison of education and health statistics with other parts of New Zealand show many individuals and communities have been able to weather earthquake stresses well, but a substantial minority have increased disaster-related difficulties (Smith et al, 2017). These included domestic violence, housing and welfare issues, psychological difficulties, and a marked rise in demand for children and youth mental health services (Shirlaw, 2014; Beaglehole et al, 2017).

Data gaps for physical processes

Natural forces and their impact: We need to identify indicators for the incidence of earthquakes and fires, and other natural disasters that put pressure on the land environment and can have impacts on human well-being.

2 Climate variability and change

This chapter discusses how climate affects the land environment. It covers how natural processes of weather and climate variability can accentuate the effects of human activities, as well as the human-induced phenomenon of climate change, which is reported in detail in the recent report in this series *Our atmosphere and climate 2017*.

This chapter focuses on providing a 'land-based' summary of the key impacts of weather and climate, particularly of climate change. It also notes key gaps in our knowledge.

Key findings

- Climate change is already affecting New Zealand's land systems. We can expect severe effects on land and human systems from long-term changes and increased frequency of intense rainfall events. The effects include challenges to productive systems (shifts in the suitability of land for horticulture and agriculture), pressure on indigenous ecosystems (with exacerbated impacts from pest invasions), and increased vulnerability to erosion, sedimentation of waterways, and wildfires, through increased risk of rainfall and drought events.
- Rising sea levels and related storm surges will increase the frequency, severity, and extent of coastal flooding and erosion, while also threatening low-lying infrastructure, cultural sites, and habitats. They may also increase the risk of seawater intrusion to groundwater.

Natural climate variability

New Zealand's day-to-day weather and longer-term climate patterns vary naturally across the country, reflecting the influence of our geography and location in the mid-latitude westerlies of the South Pacific Ocean. Our climate's classification as temperate maritime reflects the overall influence of the surrounding ocean.

Climate varies naturally over timescales ranging from months to millennia. These are the normal variations in the world's climate patterns, relating to seasonal and yearly variations around a long-term average (see *Our atmosphere and climate 2017*).

Some variations can have a marked effect on our land. When a year is wetter, drier or windier than average, it can affect productive farming and indigenous biodiversity alike (and other activities such as construction). It can make a real difference to recreation and even to safety of people – for instance, if there are severe floods.

How climate variation affects us

New Zealand is long and narrow (1,600 kilometres by 400 kilometres), with a total land area of 269,000 square kilometres (including offshore islands) and a coastline of about 18,000 kilometres (LINZ, 2012; Walrond, 2005). The North and South islands stretch across a wide span of latitudes (34–47° south), with mountain ranges affecting the patterns of wind and rain. This varied geography contributes to marked variation in climate across the country, particularly between the east and west, and to extreme weather events, such as flooding and droughts.

Climate oscillations such as El Niño Southern Oscillation (ENSO) – which is the cyclical shift in movement of wind and warm equatorial water across the Pacific Ocean – can have important influence. For example, over summer, the El Niño phase tends to lead to increased westerly winds, with more rain in the west and drought in the east (Salinger & Mullan, 1999).

Long-term climate change

While the impacts of climate variations are already a challenge, the likely impacts of climate change are expected to be far-reaching across the land domain.

Climate change is an adjustment in climate that persists for long periods, typically decades or more. *Our atmosphere and climate 2017* reported the global climate is changing because of increased greenhouse gases and aerosols in the atmosphere from human activities.

These gases accumulate in the atmosphere and absorb additional energy, making Earth warmer than it would otherwise be. The main sources of greenhouse gases are burning fossil fuels, emissions from activities such as industry and agriculture, and land use changes (particularly when vegetation cover is reduced, which reduces how much carbon dioxide is absorbed).

How climate change may affect our land

Climate change is already potentially irreversibly affecting our natural systems, and we can expect more severe effects on the environment and on human systems as the change continues. On land, this could have a wide range of important effects:

- Rising sea levels and more frequent intense rainfall events are projected to increase the risks of coastal flooding, erosion, and saltwater intrusion to groundwater, threatening low-lying infrastructure, cultural sites, and habitats (PCE, 2015).

  See Coastal sea-level rise

  We can expect tides, waves, and storm surges to reach further inland more regularly. Coastal flooding, usually due to storm surges coinciding with very high tides, already causes disruption and damage in some places.

  See Rainfall intensity

  See *Our atmosphere and climate 2017* for a case study of South Dunedin.

  Sea-level rise poses a particular threat to Māori interests, assets, and values (King et al, 2010; Manning et al, 2015). Many Māori communities have ancestral ties with coastal areas, and these relationships are maintained with cultural heritage (eg marae, papakāinga and urupā) and mahinga kai (food-gathering sites). These interests and activities are deeply connected to identity and well-being.

- Increased frequency of intense rainfall events over most of the country is expected to increase erosion, predominantly in steep hill-country areas. With higher rates of soil loss, greater sedimentation of waterways, estuaries, and marine areas is likely. See chapter 4 Soils for more information about erosion.

- The frequency and intensity of drought in drought-prone regions are expected to increase, with important implications for our primary industries. They may also increase the likelihood and extent of wildfire risk in New Zealand's drier regions (Pearce & Clifford, 2008; Pearce et al, 2011).

See Soil moisture and drought

- Changes in weather systems would change soil and temperature conditions for plant growth, with implications for suitability for primary production, including shifts in yields (pasture, forestry), and in viable areas for kiwifruit (Rutledge et al, 2017; Tait et al, 2017).

See National temperature time series

- Since the 1972/73 measurement season, soils at one-quarter of monitoring sites around New Zealand have been getting drier.

See Frost and warm days

- 2016 was New Zealand's warmest year since at least 1909, and the five warmest years on record have occurred in the past 20 years. At the same time, the number of frost days (below 0 degree Celsius) decreased and the number of warm days (over 25 degrees Celsius) increased at around one-third of measured sites over the period 1972–2016.

See Growing degree days

- From 1977 to 2016, it is estimated our glaciers lost almost 25 percent (13.3 cubic kilometres) of their ice volume. Decreasing volumes of our glaciers will affect ecological and hydropower resources, and cultural and tourism activities.

See Annual glacier ice volumes

- We do not yet have a detailed understanding of how the changing climate will add to the pressures faced by already vulnerable native flora and fauna. However, emerging evidence suggests it is already affecting some species and their ecosystems (Lester et al, 2017) (see *Our atmosphere and climate 2017*). For example, the numbers of invasive wasps, which eat indigenous insects and compete with indigenous birds, bats, insects, and lizards for honeydew, has increased in beech forests near Nelson because of increasing spring temperatures.

Data gaps for climate

In the case of climate change, the gaps are in people's understanding of what may happen in the future and how to model the impacts, rather than in data itself. These knowledge gaps (as they relate specifically to this report) are mostly about biophysical characteristics of changing systems.

- Physical processes: there are still key uncertainties in understanding how global circulation models translate to the New Zealand context. Better downscaled models specific to New Zealand will help improve our understanding of key challenges such as future precipitation changes, sea-level rise, extreme events (droughts and floods), and tropical cyclone frequency and intensity.

- Quantifying vulnerability to climate change is another area where we lack knowledge. For instance, we do not yet have a detailed understanding of how a changing climate will add to the pressures of habitat loss and fragmentation, and pests, weeds, and diseases faced by already vulnerable indigenous flora and fauna. For productive systems, we need to understand how climate change would impact on productivity and on the environment (eg risks of sedimentation or nutrient loss). We also need to understand how changes in frequency of extreme events could affect both productive and natural systems, to enable New Zealand to anticipate, adapt and prepare.

3 How human activity affects the land

Human use of land has always had an effect on the environment. What has changed in our lifetimes is the extent and intensity of this impact – as population increases and technology and society change. This report reviews the pressure our activities place on the land, to provide a clear view of the state of the environment and impacts that human actions have. It aims to support decision-making about how we respond to the challenges and opportunities presented.

This chapter covers the overall changes in use of land, with a closer look at these land use types:

- conservation land – focusing on public land managed by the Department of Conservation
- forestry – exotic production forestry
- agriculture – pastoral farming, horticulture, and cropping
- urban land.

The focus for each major land use is on how it matters: what benefits people get from the land use, and how the land use affects land and people – addressing the specific pressures of each major land use type.

The chapter ends with a review of issues relating to mineral extraction, waste, and contaminated land, and a summary of data gaps around the pressures from human activities.

Key findings

- While there has been little change in the total exotic grassland area between 2002 and 2012, there was a reduction in the total agricultural land in the same period. Between 2002 and 2012, the total area recorded in the Agricultural Production Census dropped from approximately 13.4 million hectares to 12.6 million hectares, a decrease of 7 percent, mainly in pastoral farming land for sheep and beef.
- Land under dairy has increased to a total area of 2.6 million hectares in 2016 (a 42 percent increase from 2002) and the area under sheep and beef farming decreased to a total area of 8.5 million hectares (a 20 percent drop). This shift from sheep and beef farming to dairy farming was most pronounced in Canterbury and Southland.
- Agricultural intensification includes a shift in the past 15 years to higher stocking rates (especially in dairy) (see findings in chapter 4 Soils).
- Urban expansion is reducing the availability of some of our most versatile productive land. Urban areas increased by 10 percent between 1996 and 2012. This expansion, combined with fragmentation of former rural areas into lifestyle blocks, may block future options for agricultural production.

The report notes some key characteristics of current use, including increased visitor numbers to Department of Conservation (DOC) destinations, and ground-breaking shifts in conservation land management in partnerships between the Crown and iwi. This information is important in a country where 32 percent of the land area is under DOC management. These recent developments are described, but the lack of national datasets to support reporting of change over time precludes the report reaching specific findings in these areas. This also applies to the pressures created by mining and other extraction, waste disposal and past land use that has resulted in land contamination.

Introduction

Toitū te whenua, **Ka ora ai te tangata**	*The well-being of the land provides* *for the well-being of the people*

Land is the foundation of New Zealand's economic activity. It is important for other aspects of being human: it provides a connection to place and history, and a space to play and learn, define culture, express spirituality, and anchor memory and identity.

Land use: New Zealand's economic dependence on land

Land underpins New Zealand's top two export earners: primary production and tourism. In 2016, land-based primary production (agriculture, horticulture, and forestry) earned $35.4 billion in exports (MPI, 2017a), while international tourism expenditure in New Zealand was $14.7 billion (Stats NZ, 2017c). In the same year our total exports were worth $70.9 billion (Stats NZ, 2016a). Land-based primary production's share of total GDP was 3.7 percent in 2016 (Stats NZ, 2017b), while tourism's share was 5.7 percent (Stats NZ, 2017c) – see Box 4: Tourism – an economic land use dependent on social and cultural values. New Zealand's sizeable agricultural sector supports a range of other industries, such as manufacturing, which use natural resources indirectly.

Ecosystem services: our inter-dependence on the physical environment

The physical world provides humans with the essentials for life. These ecosystem services include:

- provisioning services including clean air, food, wood and fibre, medicines, genetic materials, and energy
- regulating services including water purification, climate regulation, crop pollination, pest and disease control, waste regulation, maintenance of soil quality, soil loss prevention, water flow regulation, flood and storm regulation, wind and fire protection
- cultural services including recreation, scientific/educational, aesthetic, spiritual, and well-being (figure 5) (Roberts et al, 2015).

See the Fundamentals chapter, for more on ecosystem services, the New Zealand system of land management, and an exploration of the place of whenua in te ao Māori.

Box 4: Tourism – an economic land use dependent on social and cultural values

Tourism provides a way to look at the different kinds of values we give to land. It is a growing industry: in the year ending March 2016, the economic contribution of international tourism increased 19.6 percent from the previous year. Spending by visitors to New Zealand including for travel on local carriers reached $14.7 billion (Stats NZ, 2017c). International tourism depends on attracting people from across the world to visit and spend their money here – and that depends on those people viewing New Zealand's offering as more valuable than other competing destinations.

Key drawcards for visitors to New Zealand are its landscape and nature. These are characteristics of the country that depend on values given to them: that international visitors are motivated by being close to a geyser or a glacier, or on a landscape that features in a movie they have seen. Importantly, it is the land that pulls tourists to New Zealand: 45 percent of international visitors surveyed between 2013 and 2017 said 'spectacular landscapes and natural scenery' were a factor in stimulating their interest in visiting, and 20 per cent said it was the most important factor (MBIE, 2017a, 2017b).

If the 'unspoiled' qualities of New Zealand's landscapes are damaged by pollution, overcrowding, or landscape change, New Zealand could be disadvantaged twice over: by reduction in what locals themselves value, and by reduced tourism revenue.

In a similar way, much of our primary product is branded in ways that link it to the 'natural' state of New Zealand. A shift in the quality of that '100% pure' perception risks reduction in market value. This is closely attached to actual change in the state of aspects of our environment, but not necessarily directly linked (Poulston, 2017).

Land cover

Kia whakatomuri te haere ki mua

To walk into the future our eyes must be fixed on the past

Land cover describes the types of vegetation and features that cover the land's surface. These types range from snow and bare rock to urban areas, with a range of indigenous and exotic vegetation types between.

See Predicted pre-human vegetation

New Zealand has been occupied by people for only about 700–800 years (Wilmshurst, 2008), but in that time the surface of the land has been transformed. When humans first arrived, forests covered about 80 percent of the land – all but the tops of mountains and the most poorly drained of the lowlands (Nicholls, 1980). Wetlands covered around one-tenth of the country, particularly in lowland and coastal areas. Today, only about one-third of this indigenous forest remains, concentrated mainly in mountainous and hilly areas, while wetlands are about one-tenth of their original extent.

See Land cover

The Land Cover Database (LCDB version 4.1) uses satellite imagery to map vegetation types and other land cover. The latest version (2012)[4] shows New Zealand's dominant land cover is exotic grassland (10.7 million hectares, nearly

4 Production of the next round of the Land Cover Database is under investigation in 2018.

40 percent of the country's total land area) – see figure 7. Indigenous forest covers 26 percent of the land, and exotic forest 8 percent. Other major indigenous cover types are tussock grasslands (9 percent) and scrub/shrubland (7 percent) (figure 8).

The proportions of land cover for Māori land (as defined under the Te Ture Whenua Māori Act 1993)[5] differ slightly from the national picture (figure 9). There is proportionally more exotic forest (about 13 percent of Māori land), more indigenous forest and scrub (totalling 33 percent and 14 percent, respectively), and relatively less exotic grassland (29 percent).[6]

Some of these differences can be attributed to Māori land blocks being more often located on land with moderate to extreme limitations for arable use (Harmsworth, 2003). See also Box 7: Looking at agricultural production data through a 'Māori land' window.

5 Primarily Māori customary and Māori freehold land, but also includes general land owned by Māori, Crown land reserved for Māori and some treaty settlement reserves, mahingā kai, and fishing rights areas.

6 Analysis based on LCDB 4.1 and 2017 Māori land block (Harmsworth & Sutherland, pers. com).

Figure 7

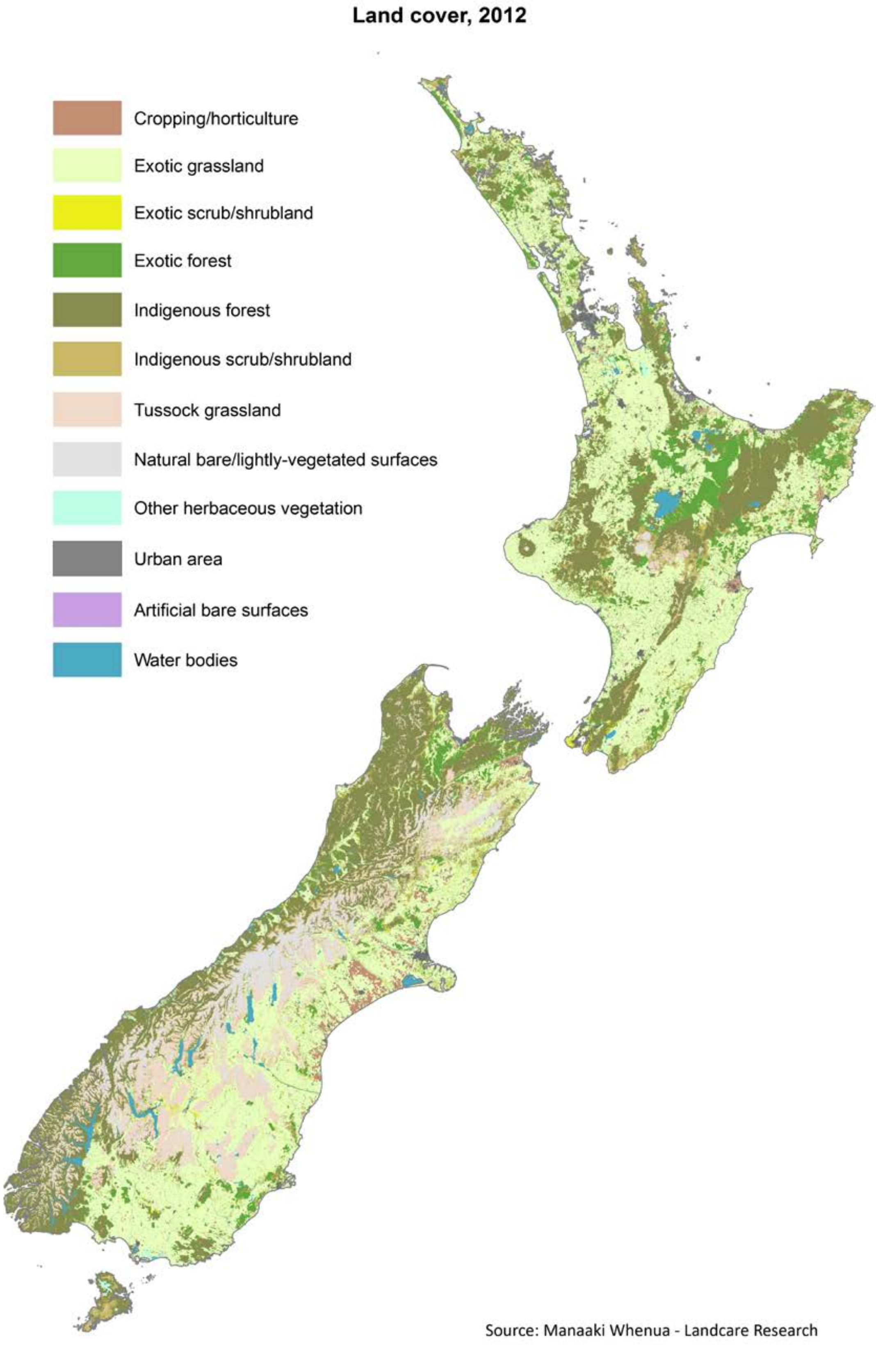

Land cover, 2012
Cropping/horticulture
Exotic grassland
Exotic scrub/shrubland
Exotic forest
Indigenous forest
Indigenous scrub/shrubland
Tussock grassland
Natural bare/lightly-vegetated surfaces
Other herbaceous vegetation
Urban area
Artificial bare surfaces
Water bodies
Source: Manaaki Whenua - Landcare Research

Figure 8 Share of New Zealand's total land area in different kinds of cover, 2012

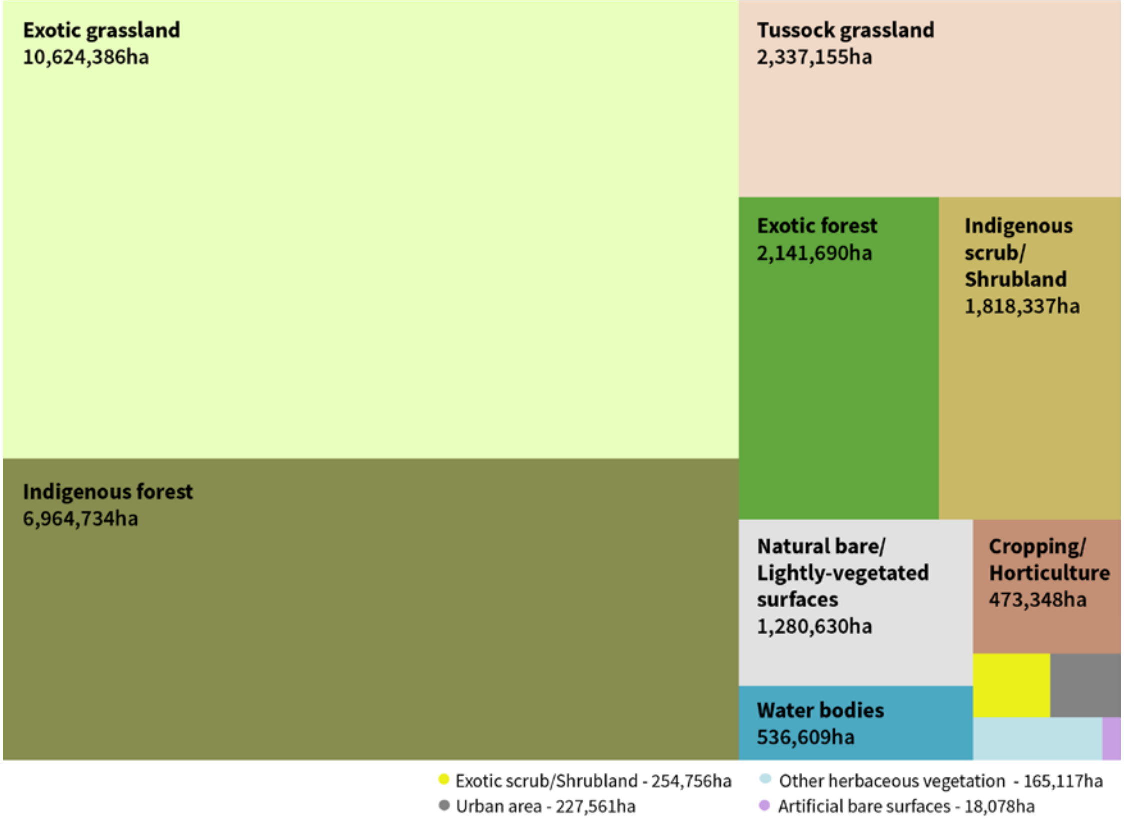
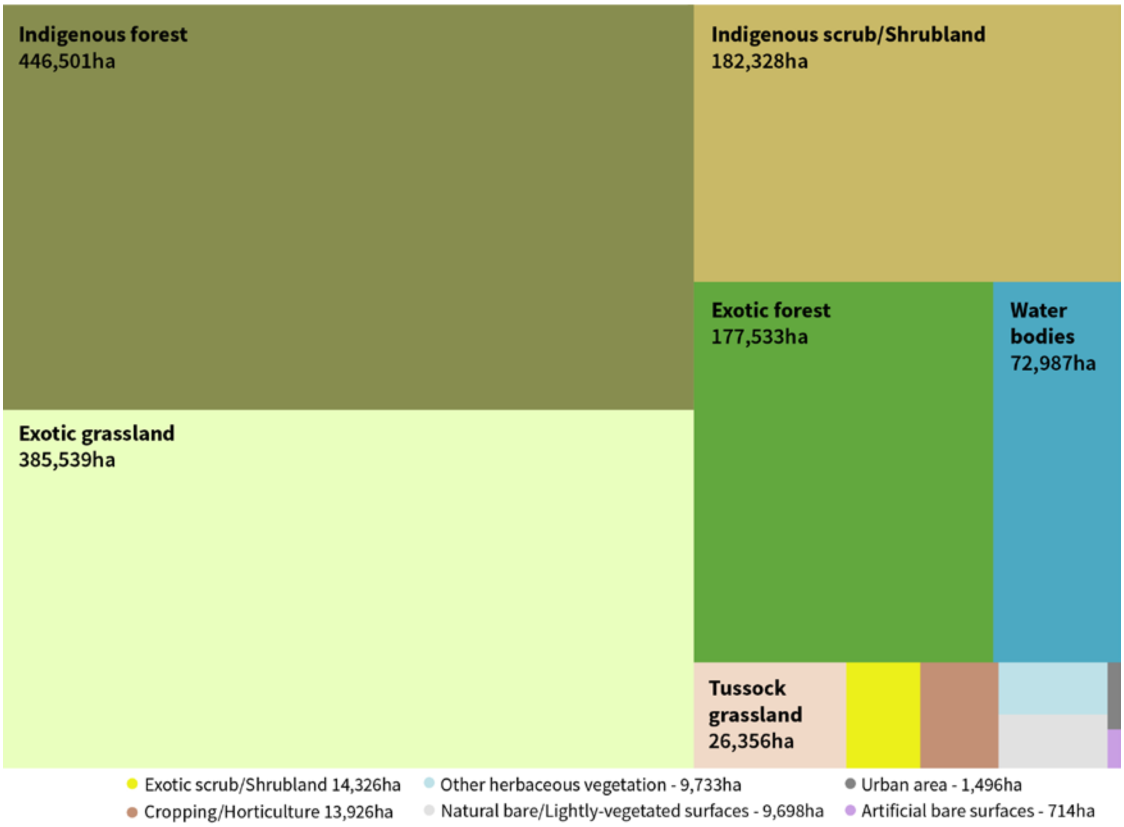


Figure 9 Share of Māori land in different kinds of cover, 2012[7]



[7] Analysis based on LCDB 4.1 and 2017 Māori land block (Harmsworth & Sutherland, pers. com).

Recent land cover changes reveal land use shifts

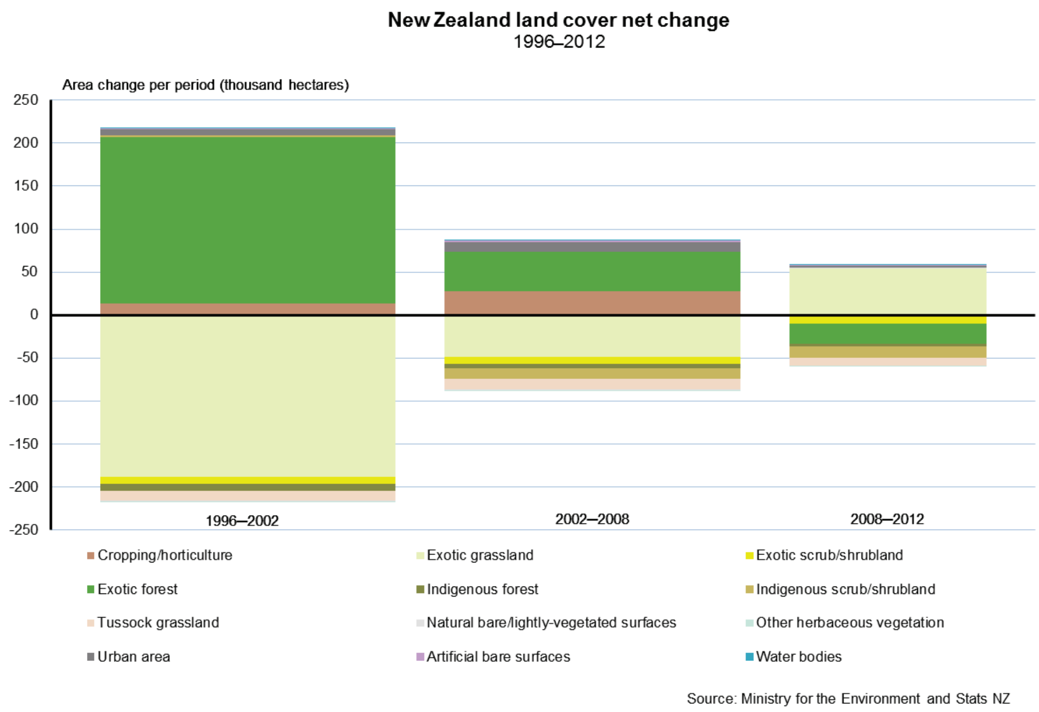
The historical understanding of changes to land cover, especially from when people first arrived in Aotearoa New Zealand, relies on a range of knowledge types: traditional Māori knowledge, local narratives, early settler and surveyor maps, and more recent scientific evidence such as pollen analysis (Beever, 1981; McGlone, 1989).

This report focuses on change in land cover in the 15 years from 1996 to 2012.[8] It draws on the Land Cover Database (LCDB 4.1) as a proxy dataset to examine land use in New Zealand for this period. This provides three measures, between 1996 and 2002, 2002 and 2008, and 2008 to 2012, that have been spread on a yearly basis to account for the varying reporting time period (see the Land cover indicator web page).

A review of gains and losses in those periods shows a shift from exotic grassland to exotic forestry cover (slowing in the second period) and then reversing (figure 10).

Cropland expanded in area between 1996 and 2002 and more so between 2002 and 2008.

Figure 10

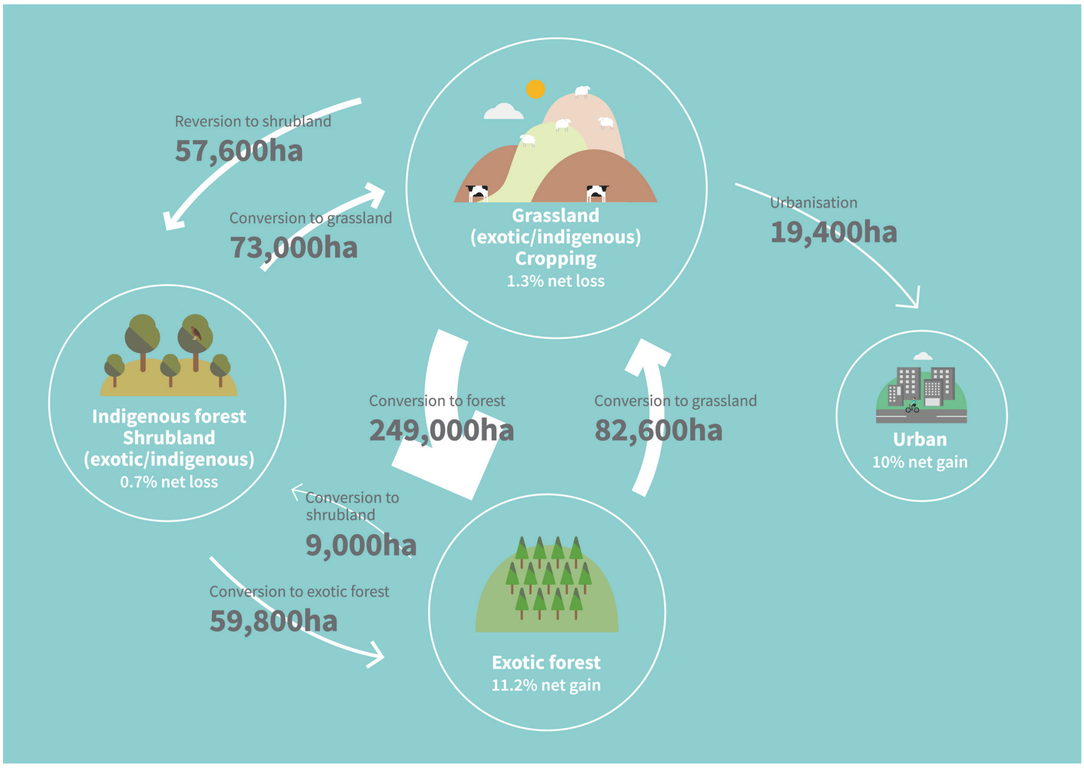


Across the 15 years between 1996 and 2012, the dominant shifts have been from exotic grassland and shrubland to exotic forest, some conversion in the opposite direction, and a 10 percent expansion of urban land (figure 11).

Changes in grassland use are explored in the Agriculture and Urban land sections. For an examination of change in indigenous land cover, see chapter 5 Biodiversity and ecosystems.

8 The latest available LCDB version is for 2012. Production of the next round is under investigation in 2018.

Figure 11 Shifts in land cover types, 1996–2012



Note: Circles are only indicative of share of land area. Image is based on changes shown in the Land Cover Database (LCDB) from 1996 to 2012. Grassland areas include exotic grassland, cropping and horticulture, and indigenous tussock grasslands. Indigenous forest and shrubland include all shrub and indigenous covers from the LCDB. Exotic forest includes harvested forest and exotic forest.

Other analyses offer other views of land cover change. Stats NZ's System of Environmental Economics Accounting provides regional insights. At a regional level, between 1996 and 2012, Gisborne, Manawatū, and Otago had the highest gain in tree-covered area, while Waikato had a net loss (Stats NZ, 2018a).

The New Zealand Greenhouse Gas Inventory 1990–2015 provides more recent information about tree cover. This shows in the early 1990s there was considerable planting of forests on land previously in exotic grassland (MfE, 2017a). New forest planting continued through the late 1990s and early 2000s, at a slower rate – see the Forestry section in this chapter.

Major land uses

This report focuses on these key categories of land use: conservation, forestry, agriculture, and urban. These are the largest or most significant kinds of land use in New Zealand – in terms of land area, economic value, and population.

The focus for each major land use is on how it matters: what benefits are created for people and what pressures result. While the way people use land creates pressure, it is also important to recognise the benefits these land uses provide to people. These benefits can be summarised in terms of environmental, economic, and social/cultural aspects (table 1).

This summary is followed by a more detailed assessment of the specific benefits and pressures that relate to each major land use type. The pressures considered in this chapter are those resulting from change from one kind of land use to another (change in area), or from a change in the level or intensity of the activity (change in condition).

This section includes a case study looking at agricultural production data through a 'Māori land' window (Box 7). Māori GDP contribution is still dominated by the primary sector and, in 2013, the primary sector contributed $1.8 billion to GDP (Te Puni Kōkiri, 2013).

The chapter ends with an examination of other human activities that can have a marked effect on the land environment, particularly on soil and biodiversity. These sections focus on mineral extraction, waste, and contaminated land.

Table 1 Summary of major land uses and their related benefits and pressures[9]

Primary use of land type	What people get from this land use	How the use affects land and people
Conservation Recreation Tourism Culture and education Human well-being	*Environmental*: climate regulation, soil loss prevention, water-flow regulation, flood regulation, habitat provision, water purification, carbon storage and sequestration (see chapter 5) *Economic*: tourism activities and earnings *Social*: recreation, culture and education, human well-being	Pest and weed infestation (chapter 5) Habitat degradation due to tourism increase Change in soundscapes and other impacts on recreational experiences
Forestry Introduced plantations Indigenous production forestry (very limited)	*Environmental*: climate regulation, soil loss prevention, water flow regulation, flood regulation, habitat provision for some indigenous species such as kārearea/falcon, bats *Economic*: forestry products and other non-forestry income, eg beekeeping; also helps New Zealand meet net emissions reduction commitments *Social*: Recreation – including walking, hunting, and mountain biking	*At harvest*: soil erosion and soil quality issues, reduction in carbon storage, loss of water filtering, flood mitigation *New forest area:* affects water availability *Wilding conifers*: compete with native plants, reduce value of productive land and water availability, affect soil carbon, facilitate establishment of other alien species, alter natural character of landscapes
Agriculture Pastoral farming Horticulture Cropping	*Environmental:* food provision *Economic*: primary exports (eg dairy, meat, wool, kiwifruit, wine, apples, honey) *Social*: employment, recreation, New Zealand identity	Intensification leads to impacts on: – soil quality (chapter 4), soil erosion through vegetation clearance – fresh water through nutrient loss – atmosphere (gross greenhouse gas emissions) – water availability reduction through irrigation
Urban area Includes residential, institutional (eg schools, hospitals, courts), transport infrastructure (roads, rail, ports, airports), commercial, industrial, and social uses such as recreation on sportsfields and parks	*Environmental*: energy consumption efficiency, green spaces provide contact with indigenous biodiversity *Economic*: intensive economic and entrepreneurial activity, cost efficiency for drinking water, wastewater, and sewerage services *Social*: connection, diverse cultural and recreational opportunities	Increasing population leads to impacts on: – fresh water, air quality, marine environment, soil and waste contamination – biodiversity loss Urban expansion on and fragmentation of versatile land can reduce economic opportunity for agriculture

9 There are a range of land uses *not* allocated to these categories, including extractive industries such as mining, transport, water bodies used for hydro-electric or irrigation purposes, shrubland not currently in grazing use, and conservation outside Department of Conservation managed land.

a. Conservation land

This section focuses on land managed by the Department of Conservation (DOC). The area of public conservation land has increased from approximately 7.4 million hectares in 1990 to 8.5 million hectares in 2016 (32 percent of New Zealand's total land area).[10] This is the third highest proportion of national land area 'under environmental protection' across Organisation for Economic Co-operation and Development countries (OECD, 2017).

This section focuses on changes in area and activity on that land: in the total area managed by DOC (since 1990), the increasing partnership with iwi for this management, and the number of visitors and types of activity there. This information provides a picture of the pressures of human activity occurring on public conservation land. (It is important to note that public conservation land and areas of indigenous biodiversity are not one and the same thing – see Box 5: The ins and outs of conservation land management.)

This report's ability to report on the *condition* of public conservation land is limited, as noted in the Introduction: Data sources and limitations, and in the data gaps section at the end of this chapter. There are, however, several indicators reported in chapter 5 that provide a view of the state of public conservation land, in the Pests, weeds, and diseases and Species threat status sections.

Benefits of conservation

The area managed by DOC covers 44 percent of the South Island and 15 percent of the North Island. It includes land on Rakiura/Stewart Island, on the Chatham Islands, and on hundreds of smaller islands from the Kermadec Islands in the north to the subantarctic Campbell Island group. In 2016, DOC-managed areas included 13 national parks, 36 conservation parks, and a multitude of reserve types (DOC, 2017a).

Three areas are listed as World Heritage sites under the UNESCO World Heritage Convention: Tongariro National Park, Te Wāipounamu – South West New Zealand, and the Subantarctic Islands of New Zealand.

The reservation of these areas for conservation purposes supports a range of ecological benefits to Aotearoa New Zealand and the world. Environmental benefits include, for example, water purification, soil loss prevention and carbon sequestration, while social benefits include cultural and educational practice, and contribution to human well-being (see chapter 5 Biodiversity and ecosystems for a summary, and the explanation of ecosystem services in Fundamentals). An important element of this is the proportion of the land area in public conservation management. New Zealand's public conservation lands also provide a major drawcard for tourism, which is the country's second largest individual export earner (see Introduction to this chapter). They are important recreation areas, for locals and visitors alike (Dalziel, 2011; Sport NZ, 2016).

10 Based on spatial analysis of public conservation land extent, using DOC datasets.

Box 5: The ins and outs of conservation land management

The area of land managed by the Department of Conservation (DOC) is often described as 'the conservation estate' but this can lead to some incorrect assumptions.

- DOC-managed land is not the only land in New Zealand where conservation is the primary purpose – many areas in private and community management are dedicated to conservation.
- There is other public land where conservation is the primary purpose – regional and local authorities also administer important areas with a biodiversity focus, such as the Waitakere Ranges Regional Park (supported by Te Kawerau-a-Maki, the tangata whenua), and Travis Wetland Nature Heritage Park in Christchurch.
- Land under DOC management is not entirely covered in indigenous vegetation (see below) and it is not the only area in the country that has indigenous land cover (as above).
- It does not cover a fully representative range of ecosystem types – it includes a higher proportion of alpine ecosystems and montane indigenous forest than ecosystems such as lowland forest, coastal forest, or wetlands.
- There are different levels of land status and protection within DOC management, set up under three different Acts.[11] The range of protection stretches from stewardship land in conservation areas, where a wide range of activities is permitted, to wilderness areas in national parks where there are no tracks or buildings or aircraft landing sites (DOC, 2017b).
- There are different levels of management that reflect different kinds of land status and different levels of threat to species and ecosystems protected there. The management scale includes intensive integrated species and ecosystem management, or landscape-scale predator control, or ongoing monitoring, review, and smaller scale action.
- DOC focuses on cultural heritage as well as natural heritage preservation (as defined in the Conservation Act 1987), and actively manages about 600 of 12,000 known archaeological and/or historic sites (DOC, 2017a).
- Land managed by DOC is also used for recreation, tourism, and cultural and education activities – for example, Molesworth Recreation Reserve is a working high-country station that combines conservation and recreation use with farming. In some areas of public conservation land, specific permitted activities (such as mining, bee-keeping, and wild animal recovery operations) are allowed under carefully negotiated terms.

Conservation outside DOC's boundaries

Private land covenants such as those under the Queen Elizabeth II (QEII) National Trust allow private individuals to retain ownership of a piece of land, but protect portions of it by voluntarily placing a covenant on part of it – such as a remnant of lowland indigenous forest on a farm. Covenants conserve an area in perpetuity, even if the property is later sold. This is monitored for compliance by the QEII National Trust. The amount of land protected by QEII covenants increased from approximately 10,000 hectares to 170,000 hectares between 1990 and 2016, nearly doubling since 2010 (QEII National Trust, 2017). The Banks Peninsula Conservation Trust also has covenanting authority.

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[11] National Parks Act 1980, Conservation Act 1987, Reserves Act 1977.

Ngā Whenua Rāhui is a similar means of conserving land with important ecological and cultural significance for Māori land owners. These 25-year reviewable kawenata have been applied to 171,733 hectares since the Ngā Whenua Rāhui Fund's inception in 1990 (DOC, 2016).

Regional councils (and unitary councils such as Auckland) also manage significant tracts of conservation lands, and can set land use controls through the Resource Management Act 1991.

Local (district and city) councils generally do not manage land solely for conservation purposes, but along with community organisations, play an important role in enhancing and restoring habitat, and setting the direction of development in their area.

Since 2000, intensively managed sanctuaries (areas where intensive multi-species pest control is undertaken for ecosystem restoration), such as Zealandia in Wellington and Sanctuary Mountain Maungatautari in the Waikato, have become important components of conservation activity in Aotearoa New Zealand. All of the 85 sanctuaries on or near mainland New Zealand in 2018 are run as partnerships, mostly with local iwi (Sanctuaries of New Zealand, nd). The removal of introduced predators such as rats and stoats has allowed the recovery of some indigenous species. In addition to their role as strongholds for endangered species, these sanctuaries have become educational and tourism resources for their regions.

Other government agencies have some responsibility for biodiversity on land they manage – this includes biosecurity work – to prevent or reduce damage caused by unwanted organisms. See Fundamentals chapter for information on Crown land management agencies.

The area of land protected for conservation reasons outside of public conservation land serves an important role in achieving a reserve network that is more representative of a full range of ecosystem types, given that certain ecosystems (eg beech forests, alpine ecosystems) are over-represented in land managed by DOC, and other ecosystems (eg braided rivers, geothermal areas) are under-represented (DOC, 2017c). Attempts to pull together an integrated national dataset of protected land have been made, but this has not been achieved to date.

Pressures associated with conservation

This section looks at changes in the area and status of land under DOC management, increasing partnership with iwi for this management, and changing intensity of use for recreation and tourism.

Change in area and growth in partnerships with Māori

There has been substantial change in the area of land under DOC management in the past 25 years. This includes new land area added and a recent shift to a new kind of management regime through Crown–iwi partnerships, for example in Te Urewera, Tongariro, Whanganui, and Aoraki (Ruru et al, 2017).

Iwi have been closely involved in public conservation efforts for a long time. The first national park at Tongariro was made possible by a gift of land to the nation by Ngāti Tūwharetoa in 1887, so preserving the iwi's mana – these are also sacred mountains to Ngāti Rangi and other iwi. Similarly, Ngāi Tahu had a major role in supporting the listing of Te Waipounamu – South West New Zealand as a World Heritage site.

Joint land management for conservation purposes between iwi and DOC has been explored across the country since 2005, when first introduced in the Te Waihora/Lake Ellesmere joint management plan. This is described as representing “a coming together of the rangatiratanga of Ngāi Tahu and the Kāwanatanga of the Crown for the enhancement and protection of this taonga” (DOC, 2005).

A ground-breaking shift in 2014 was the transfer of 213,000 hectares of former Te Urewera National Park to a joint Crown–Tūhoe governing board. The Te Urewera Act 2014 created a precedent in vesting Te Urewera as its own legal entity, giving it “…all the rights, powers, duties, and liabilities of a legal person”. See Box 11: Kererū abundances in Urewera and impacts for Tūhoe.

Overall, the area of land within DOC management (solely and in partnership) has increased by 1.1 million hectares since 1990. This includes the addition of Molesworth Recreation Reserve in 2005 (180,787 hectares, about the size of Rakiura/Stewart Island (DOC, 2013) (see Box 5: The ins and outs of conservation land management).

One main mechanism for adding land to DOC management in the past two decades is ‘tenure review’ of Crown pastoral leases on high-country grasslands. This process gives lessees of pastoral land an opportunity to buy some of their leasehold land, while the rest returns to Crown ownership, usually for conservation purposes. Between 1998 and June 2017, 119 pastoral leases have gone through tenure review on behalf of the Commissioner of Crown Lands, covering about 620,000 hectares. Of that, almost 300,000 hectares have been retained by the Crown with the majority of that land given to conservation purposes.

Tenure review has contributed to 12 conservation parks and areas – including Hakatere Conservation Park, Hāwea Conservation Park, Pisa Conservation Area, Ruataniwha Conservation Park, Ahuriri Conservation Park, and The Remarkables Conservation Area (LINZ, 2017).

Change in intensity of use

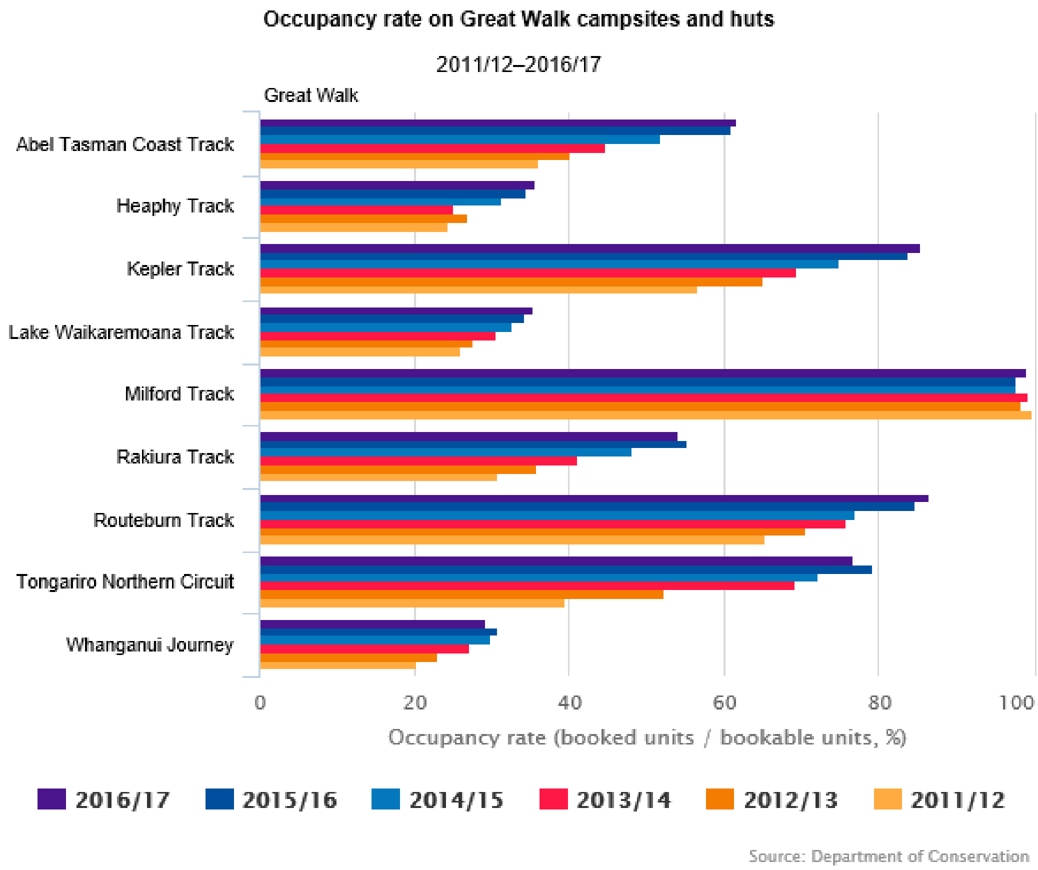
The number of visitors to conservation land is rising. DOC reports based on track counters show visitor use rose at 55.5 percent of DOC destinations across New Zealand between the 2015/16 and 2016/17 financial years; more generally, 67 percent of DOC destinations had more visitor numbers over time (depending on when the track counter was installed, this could be up to eight years) (DOC, 2017d).

See Use of public conservation land

An indicator of this change is the number of bed nights (in huts and campsites) booked on DOC’s Great Walks system. This shows a marked increase between the 2011 and 2017 booking seasons (1 November to 30 April).

Occupancy of huts and campsites on Great Walks increased 52 percent (from 154,999 to 235,738 bed nights) between the 2011/12 and 2016/17 seasons. For all Great Walks, except Milford Track (which was already at or near capacity), this was a significant increase (figure 12). Tongariro Northern Circuit, Rakiura Track on Stewart Island, and Abel Tasman had the highest increases in booked bed nights (Tongariro had the highest increase at 107 percent, with Rakiura and Abel Tasman at 78 and 77 percent, respectively). For the most recent booking season (2016/17), all three Great Walks in Fiordland National Park operated at near to full capacity: Milford Track (99 percent), Routeburn Track (87 percent), and Kepler Track (85 percent).

Figure 12



Impacts of increased visitor numbers

Increased visitor numbers to conservation land can contribute to the pressures that cause habitat degradation (see Box 10: Kauri dieback in chapter 5 Biodiversity and ecosystems). Both national and international studies show that this can include the introduction of invasive species and diseases (Anderson et al, 2015), trampling of delicate plant and ground-dwelling animal species (PCE, 1997), and the effects on wildlife of frequent or close human contact (Shannon et al, 2017).

There can also be impacts on the human relationship with these areas, and the cultural, recreational, and spiritual benefits people gain from them. Examples include changes in the soundscape experienced (Harbrow et al, 2011), or the loss of an experience of a place ‘on nature’s terms’ (Cessford, 1998; Espiner & Wilson, 2015).

These pressures can have greater impact if visitor numbers intensify to overwhelm the existing infrastructure and management systems set up to minimise environmental degradation (eg access roads, toilet and waste facilities, and permitting limits).

b. Forestry

This section focuses on production forestry: on the contribution it makes, the impact it has on the condition of land, and on how production forestry land use is shifting – particularly in the face of climate change.

Exotic forests (predominantly planted in *Pinus radiata*) increased by 11 percent from 1996, to cover approximately 2 million hectares in 2012, which is 8 percent of New Zealand's total land area.

See Land cover

Exotic forests cover 13 percent of the total Māori land as defined under the Te Ture Whenua Māori Act 2003, compared with 8 percent of total New Zealand land (figures 8 and 9 in the Land cover section).

There have been fluctuations in the area in forestry over the past two decades – showing the diverse forces operating on this land use: dairy, log, and carbon prices, as well as the influence of the New Zealand Emissions Trading Scheme. Measuring forest area change over different timeframes can show quite different gain or loss figures. To provide an update to the change information available from the Land Cover Database (2012), this report refers to the detailed mapping for the New Zealand Greenhouse Gas Inventory 1990–2015. This shows a slight decrease in the forestry area between 2012 and 2015 (MfE, 2017a). See the earlier Land cover section in this chapter, and Change in area below.

Forestry provides a range of ecosystem services

Almost one-third of New Zealand's production forest is located in the central North Island. Another third is in the South Island. The remainder is spread across Northland, East Coast, Hawke's Bay, and the southern North Island.

About half of the wood harvested from these forests is exported. In 2016, forestry export earnings (which include the exports of both raw and manufactured timber goods) were $5.1 billion, or 13.8 percent of the value of primary exports (MPI, 2017a). The forestry and logging industry contributed 0.6 percent, or $1.5 billion, to total GDP in 2016.

Some 'non-forestry' income also comes from exotic forest areas, including beekeeping, game hunting, and possum trapping (MPI, 2015).

These forests return a wide range of benefits, across a range of ecosystem services (Brockerhoff et al, 2013). Many large plantation areas were first created in the mid-20th century to stabilise land prone to erosion following clearance of indigenous forest cover (see also Change in area below). Production forests continue to provide that soil-stabilisation role, as well as water filtering and flood mitigation, until they are harvested.

Forest absorption of carbon dioxide from the atmosphere through photosynthesis, and storage of carbon as biomass in trees can help reduce the effects of greenhouse gases. See *Our atmosphere and climate 2017*.

Production forests are also increasingly important as recreation areas. Key uses are recreational hunting, mountain-biking, tourism, and adventure activities such as high wire courses (Yao et al, 2013).

In the absence of large areas of indigenous lowland forest, the plantations also provide some level of habitat for some indigenous species, such as kārearea/falcon, and bats (Seaton et al, 2010). There are 118 species classified by the Department of Conservation as threatened that occur in plantations (Pawson et al, 2010; Brockerhoff et al, 2013; Yao et al, 2013).

Forestry can affect soil properties and stability during harvest

This section covers changes in area of land used for production forestry, and the accompanying pressures of those land use shifts as well as the standard harvest cycle. It finishes with a case study on wilding conifers – the 'escaped' exotic trees that have become a major environmental challenge across both main islands.

The main pressures associated with exotic forests are potential changes to soil properties in long-term forestry blocks (Davis, 2001), the effects on water availability when new forests are created, and the loss of water filtering, soil stabilisation and flood mitigation services when the forest is felled. Reduced forest carbon storage is another important temporary ecosystem service loss at harvest.

Change in area

Government policy and market forces have heavily influenced New Zealand's forestry land use. Forests established for a variety of purposes including timber production and environmental management such as erosion control, were sold from government ownership in the 1980s as production forests. In the early 1990s extensive new areas were planted in exotics, in response to favourable international log prices and the removal of agricultural subsidies. As the relative profitability of dairy and forestry changed, planting rates dropped from a high of 98,000 hectares in 1994 to 3,000 hectares in 2015 (MPI, 2016a; MFE 2017a).

The increased profitability of dairy also contributed to deforestation and land use conversion of forest areas, for example in the central North Island. The introduction of the New Zealand Emissions Trading Scheme (ETS) in 2008 reduced the rate of this conversion – through the introduction of deforestation liabilities payable to the Crown when forests planted before 1990 are deforested. Under the ETS, forest owners are also able to earn credits for the carbon stored in forests first planted after 1989.

In total, from 2006 to 2015, there was about twice as much deforestation (120,115 hectares) as afforestation (64,207 hectares) in plantation forest, and this is similar for the period 2013 to 2015 (MfE, 2017a). These are actual changes in land area committed to forestry, not the temporary loss of tree cover during harvest.

See carbon stocks in forests

Forestry harvesting does not necessarily change the area committed to forestry use, but can affect rates of erosion and reduce the forests' water filtering and flood mitigation qualities. As forests planted in the early 1990s reach harvest age, there is a gradual increase in annual harvest areas, although this will eventually decline to reflect lower planting rates through the 2000s. In 2016, approximately 45,000 hectares of plantation forest were harvested, compared to approximately 20,000 hectares in 1990 (MPI, 2016a).

Change in level or type of activity

The practice of clear-felling in New Zealand forestry, and accompanying road-making, construction of skid sites, and machinery use can result in soil loss and sedimentation of waterways. Slopes prone to erosion are vulnerable for six to eight years following harvest, until canopy closure is achieved on the replanted area (Marden & Rowan, 1994). For more about sedimentation, see chapter 4 Soils, and the separate report in this series *Our fresh water 2017*.

Creating a plantation forest on a former grassland area can also have an impact on the water availability in surrounding country. This is because of the forest canopy's interception and evaporation of rainfall before it reaches the ground. Afforestation of a grass-covered catchment can reduce water yields by 30–80 percent (Davie & Fahey, 2005). This reduction can cause tension in areas where there is already existing pressure on water supply, for example in tussock areas of the South Island (Dymond et al, 2012).

Box 6: Spread of wilding conifers threatens millions of hectares of high-country land

New Zealand's favourable tree-growing conditions have led to the rapid spread of exotic conifer species, most notably contorta pine and Douglas fir. These tree species present an environmental pressure of their own. Their adaptive qualities have seen them spread by wind and other means across large areas of open country. Current estimates show that wilding conifers (commonly known as wilding pines) currently cover about 1.8 million hectares, and before the national control programme, were increasing that coverage by about 90,000 hectares annually (MPI, 2017b).

Wilding conifers present a particular issue in high-country pastoral land and on public conservation areas in Marlborough, Canterbury, Otago, Southland, and on the central plateau of the North Island (Manaaki Whenua – Landcare Research, 2013). The conifers can dominate indigenous species, and can reduce the value of productive land, reduce water availability, affect soil carbon, facilitate the establishment of other alien species, compete with native plants and animals, and alter the natural character of landscapes (Froude, 2011).

Wilding conifer can spread if left unchecked, as seen in Mid Dome, Upper Tomogalak catchment, Southland, from 1998 to 2015. Photos: Environment Southland (left and right), Department of Conservation (middle)

c. Agriculture

This section looks at agriculture: the benefits this primary industry brings, and the pressures it can place on land. Agriculture covers pastoral farming (including dairy, sheep, and beef), horticulture (including viticulture, fruit, and berries) and cropping (including market gardens).

The focus of the section is on change in the land area involved, and in particular on changes in types of farming and the level of each kind of activity.

Agriculture accounts for half of all export earnings

Farming is the economic foundation of contemporary Aotearoa New Zealand. Land-based primary exports accounted for over $35.4 billion export earnings in 2016, which was 50 percent of the total value of exports.[12] Of the total primary export earnings, 74.4 percent was agriculture based, most of it from dairy and meat exports (MPI, 2017b). Agriculture accounted for 3.1 percent of New Zealand's total GDP in 2016.

While horticulture (including fruit and berries) and vegetable growing occupied only 191,000 hectares of land in 2016 (1.6 percent of the total agriculture land area of 12.1 million hectares), horticulture's contribution to our export income has grown rapidly in recent years. Total horticultural exports exceeded $5 billion for the first time in 2016 (14 percent of total exports). This was a 121 percent increase since 2005. Horticulture's high value products makes this kind of land use the second highest export earning activity per unit area (behind mineral extraction) – higher than dairy and meat (Dymond et al, 2014). In 2016, the three main contributors to horticultural exports were kiwifruit exports ($1.673 billion), wine ($1.558 billion), and apples ($0.691 billion) (Horticulture NZ & Plant & Food Research, 2016; New Zealand Winegrowers, 2017).

Another fast-growing sector is honey: the value of honey exports has more than doubled since 2013, to $0.315 billion in 2016 (MPI, 2017a).

Agriculture and forestry accounted for 3.6 percent of filled jobs in the December 2016 quarter, 69,400 in agriculture, and 4,340 in forestry (Stats NZ, 2018b). Our farming way of life is core to New Zealand culture and identity, even for a largely urban population (Carter & Perry, 1987). Farms, orchards, and vineyards also provide recreational opportunities to New Zealanders, as well as to international tourists.

Changes in agriculture activities can create environmental pressure

This section looks at changes in area of land used for agriculture, including pastoral farming, horticulture, and cropping, and at the changes in farming type and intensity of activity.

The existing condition of our natural resources, in particular the soil, reflects over 150 years of farming activity across almost half of the country's land area. Impacts of agriculture include loss of indigenous biodiversity and ecosystems, particularly when land was first cleared (see chapter 5 Biodiversity and ecosystems). Vegetation clearance (and tillage and harvesting) have also resulted in soil loss and sedimentation of waterways. Soil in productive land use can become depleted over time if nutrients are not added, or affected by compaction or the use of agrichemicals, including fertiliser, herbicide, and pesticides (Manktelow et al, 2005) (see chapter 4 Soils).

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12 'Land-based primary exports' is total exports excluding seafood.

Many impacts of agriculture show up in other parts of the environment. As reported in *Our fresh water 2017*, intensified agricultural practices put increasing pressure on water bodies due to the increased use of fertiliser; urine and faecal matter deposited by livestock; the taking of fresh water for irrigation; accelerated erosion from forestry, livestock, and cultivated soils; and infrastructure and housing development. Agriculture contributed almost 48 percent of New Zealand's gross greenhouse gas emissions in 2015, including methane and nitrous oxide (MfE, 2017a) – see *Our atmosphere and climate 2017*.

Change in land use area

See Agriculture and horticulture land use

While there has been little change in the total exotic grassland area between 2002 and 2012, Stats NZ's Agricultural Production Census showed total agricultural land decreased. In 2012, the total area covered by the census for these activities was about 12.6 million hectares, compared with approximately 13.4 million hectares in 2002. This difference represents a decrease of 7 percent, mainly in pastoral farming land for sheep and beef. Reasons for this change are likely to include the impact of tenure review, which has seen high-country pastoral land move into management by the Department of Conservation (see Conservation land section) and the subdivision of productive land into lifestyle blocks (see Urban land).

Between 2012 and 2016, data from the annual Agricultural Production Survey (APS) show the area of agricultural and horticultural farms reduced to 12.1 million hectares or 45 percent of New Zealand's land area.

Change in activities and intensity

APS data also show a change in the mix of farming activities since 2002. Dairy land use increased from 1.8 million hectares in 2002 to 2.6 million hectares in 2016 (a 42 percent increase from the 2002 area). Over the same period, the area in sheep and beef farming decreased from 10.7 million hectares to 8.5 million hectares (a 20 percent decline).

This shift from sheep and beef farming to dairy farming was most pronounced in Canterbury and Southland, with over half the new dairy area in these regions (440,000 hectares) and a corresponding drop of more than 1 million hectares of sheep and beef farming. The shift from dry livestock farming (sheep and beef cattle) to dairying also indicates possible environmental impact (see chapter 4 Soils).

The area of land used for grain growing also increased, almost doubling from 2012 levels to reach 450,000 hectares in 2016.

While the total area of land in horticulture and vegetable growing decreased slightly in recent years, the changes are uneven between sectors. Vegetable growing reduced in area, while the area for 'fruit and berries' increased. The area of vegetable growing decreased 29 percent between 2002 and 2016, from nearly 100,000 hectares to about 70,000 hectares. This is a small but very important area for food production. The two regions with major reductions were Manawatū (down 12,000 hectares, a 62 percent decline), and Canterbury (down 11,000 hectares, a 30 percent decline). These reductions were offset by small increases in Gisborne (up 3,000 hectares), Hawke's Bay (up 2,000 hectares), and Auckland (up 1,000 hectares). See also Urban land section, for a discussion of a decrease in the availability of versatile land on the urban fringe.

The area in fruit and berries increased from about 107,000 hectares in 2002 to about 121,000 hectares in 2016. In particular, viticulture has seen a sharp expansion in production area and export earnings. The export value has grown since the early 2000s, doubling in value since 2007. The area planted for viticulture increased 23 percent since 2008, reaching an estimated 36,000 hectares of producing vineyards in 2016 (New Zealand Winegrowers, 2017). This increase occurred mainly in the Marlborough and Nelson regions. Kiwifruit area also increased slightly, from about 10,200 hectares in 2000 to about 12,200 hectares between 2000 and 2016 (Plant & Food Research, 2016).

Box 7 provides a view of changes in agricultural activity on Māori land in the 10 years to 2016, including an increase in plantation forestry, dairy farming, and horticulture. The changes included the expansion of honey production from Māori land through the use of large areas of scrub or shrubland, especially those covered in mānuka/kānuka.

Intensification of farming is increasing pressure on the environment

Farming is considered to be intensifying when the amount of agricultural inputs going into the farm are increasing per hectare of land. Inputs include water, feed, agrichemicals, and livestock numbers. Intensification generally leads to an increase in production levels per hectare. It often provides an increase in efficiency. However, if the production system does not absorb all the increased inputs, it can result in negative impacts on the environment (Eurostat, nd).

Recent changes in New Zealand agriculture show a change not just in the area of land in particular types of farming (as above), but also in stocking rates. The APS data show a 42 percent increase in the land area that has predominant dairying (see the Agriculture and horticulture land use indicator web page), and a general increase in dairy cattle density.

Density of dairy livestock varies between regions (figure 13). While Waikato and Taranaki have high dairy cattle density in 2012, the greatest increases in density between 2002 and 2012 were in Canterbury and Southland (matching the farming activity change above), and to a lesser extent in parts of Waikato and the Manawatū (figure 14). In Taranaki, overall numbers remain high but the density of stocking dropped in this period (see note below figures 13 and 14 about the density measures used).

See Change in livestock numbers

Figure 13

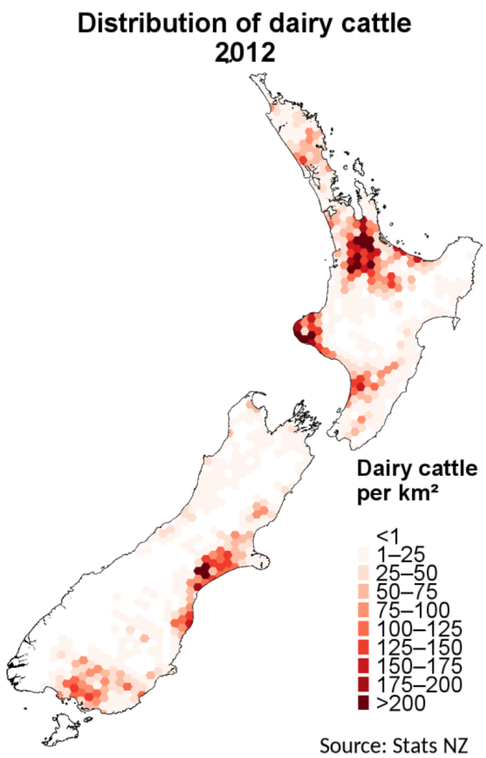
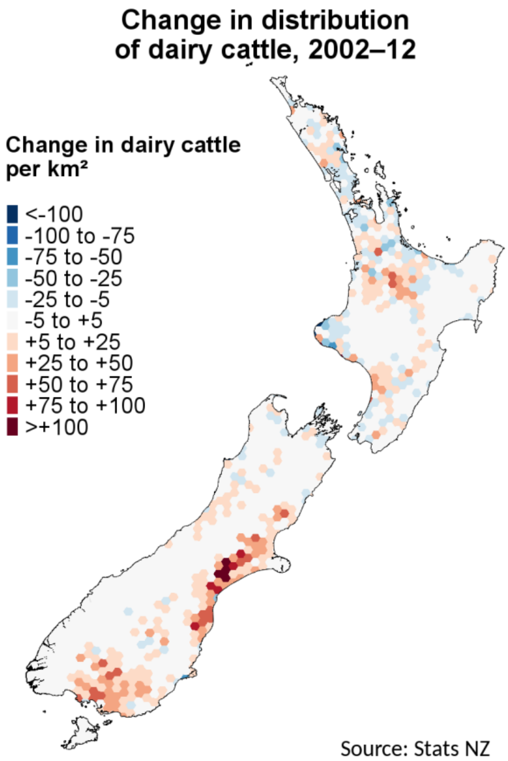


Figure 14



Note: Agricultural Production Survey data available was restricted to livestock count per square kilometre. This is a limited measure of stock density because it includes all area within each grid unit, not just grazing area. This measure therefore underrepresents actual stock density.

How much a change in farming intensity will impact the surrounding environment depends to a considerable degree on management decisions, often made at an individual farm level. For example, decisions on livestock numbers, fertiliser application, manure disposal, and the use of irrigation will change production levels and the condition of the land and water. This is also influenced by local environmental factors, such as soil types, climate, terrain, and proximity to waterways.

Recent reporting has clearly shown indication that intensification in farming is increasing pressure on the environment (see chapter 4 Soils, and *Our fresh water 2017*).

Nearly 800,000 hectares of New Zealand is irrigated

Irrigation is used to support intensive land use in areas with low or seasonal rainfall. Irrigation can improve productivity and reduce risk on land used for pastoral farming, horticultural, and cropping activities, and support amenity or recreational land uses within urban environments. Irrigation can also alter the natural character of landscapes (eg change dry land to greener and wetter land), increase nutrient (phosphorus and nitrogen) runoff and leaching into waterways, and reduce flows in rivers. For more on irrigation effects, see *Our fresh water 2017*.

In 2017, national mapping of irrigated land was carried out (except in Nelson City Council's area). It used a combination of aerial photographs, Normalised Difference Vegetation Index (a measurement of the amount of live vegetation in an area) imagery from dry summer conditions,

See Irrigated land area

and resource consent and property boundary information, using data mostly from 2015 to 2017 (figure 15). In 2017, the area of irrigated land covered 3.0 percent of New Zealand's land area, or about 794,440 hectares (with an estimated uncertainty of ± 46,022 hectares) (Dark et al, 2017).

The majority of irrigated land was in Canterbury (507,420 hectares, which is 63.8 percent of the total irrigated land). This covers a large part of the Canterbury plains (figure 15). Other regions with large irrigated areas were Otago (93,080 hectares, 11.7 percent of the irrigated total), and Marlborough (31,420 hectares, 4.0 percent of the irrigated total). Except for the Canterbury region and the Tākaka catchment, the national mapping has not had any primary sector verification.

Box 7: Looking at agricultural production data through a 'Māori land' window

Across New Zealand, the total area of Māori land (as defined under Te Ture Whenua Māori Act 1993) is 1.35 million hectares. Much of this land is collectively owned and managed as an Ahuwhenua Trust (5,000 trusts, for 750,000 hectares) or an Incorporation (166 incorporations, for 210,000 hectares) (Kingi, 2013).

See Change in use of Māori land for primary production

The 2016 Agricultural Production Survey (APS) of farms in New Zealand covered 456,000 hectares of Māori land across 381 farms. Selecting the farms identified in the APS as 'Māori-owned' showed some interesting patterns. While this selection cannot be considered completely representative of farming practices on collectively owned Māori land, it offers a view of farms with Māori ownership working as commercial entities.*

The data show that the main farming activity on Māori farms continued to be mixed sheep-beef farming (with sheep dominating livestock numbers), and forestry.

Between 2006 and 2016, there were increases in:

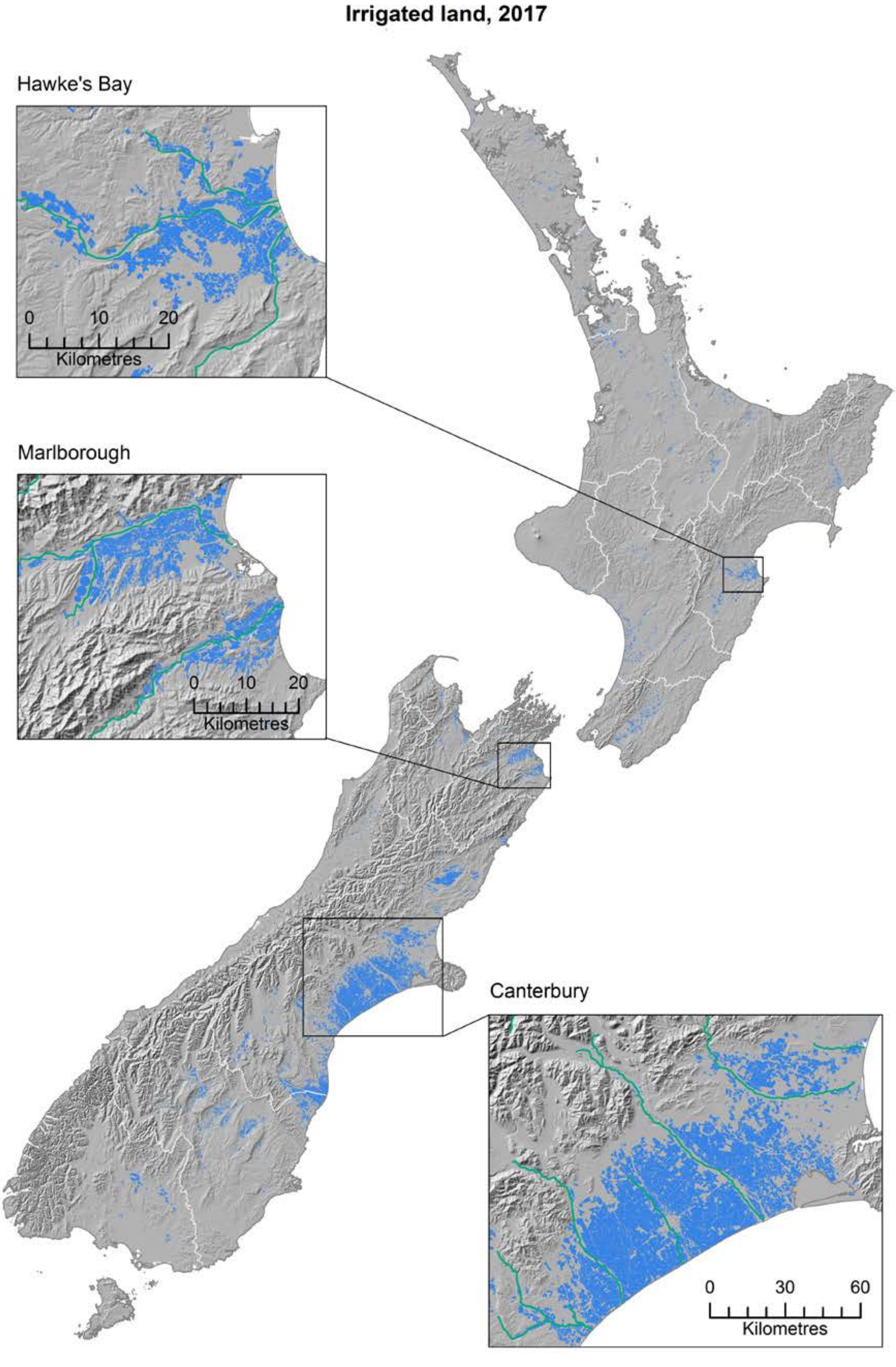
- area in plantation forestry – a 67.6 percent increase to reach about 110,400 hectares in 2016
- area in horticulture – there was a 65.1 percent increase to reach about 2,700 hectares in 2016
- dairy cattle numbers – these almost doubled 2006 levels (an 85 percent increase), reaching about 106,400 in 2016.

In the same period, there were decreases in:

- sheep farming – about 860,000 sheep were on Māori farms in 2016, down 25 percent from 2006, when there were about 1,150,000
- area in bush and scrub – this decreased 32.5 percent from 111,700 hectares in 2006 to 75,300 hectares in 2016.

* The dataset captures only larger business entities (only those registered for GST are included in the Agricultural Production Survey), and does not reflect other non-farming uses of the block.

Figure 15



Source: Aqualinc

d. Urban land

This section covers changes in urban land use in Aotearoa New Zealand – particularly in terms of increase in urban area and intensity of use. The focus is largely on the zone on the edge of our towns and cities, and on these key pressures:

- expansion of urban areas, and the accompanying loss of New Zealand's most versatile land
- change of land use on the fringes of urban areas, in particular the increase in lifestyle blocks
- change in green space in and around cities.

Urban areas provide concentrated services to people

Urban centres provide major benefits in social and economic terms. Concentrated services and infrastructure support strong social connections, and diverse cultural and recreation activity (Colmar Brunton, 2016), and the conditions for technological innovation and intensive economic and entrepreneurial activity. The cost efficiencies of close living within smaller areas of land make it possible to provide drinking water, wastewater, and sewerage services with lower set-up and maintenance costs per individual.

Urban areas also provide environmental benefits, such as the lower volume of land and other resources needed to support the same population. For example, efficient public transport is possible in a sufficiently dense city, and this can reduce energy consumption per capita (United Nations, nd).

Open space and green space in cities also offer cultural and recreational opportunities to many people and can bring indigenous biodiversity back into urban areas.

Urban land use impacts locally on land, fresh water, and the marine environment

Approximately 86 percent of New Zealand's population lives in an urban centre, based on estimates from Stats NZ. As at 30 June 2013, around 73 percent lived in a city or a major urban area of over 30,000, 6 percent in a large regional centre between 10,000 and 29,999, and 8 percent in smaller towns of between 1,000 and 9,999 (Stats NZ, nd-a; nd-b).

The concentration of people in urban areas intensifies pressure on the environment. The impact is often on fresh water and the marine environment, as well as on air and atmosphere. Direct impacts on land include the loss of high-value agricultural soils, and negative effects of waste and soil contamination – see Waste and Contaminated land sections following.

Our fresh water 2017 reported on how urban run-off and the modification of waterways can affect water quality. Factors that influence the level of stormwater and wastewater pollution of fresh water include the degree to which urban land is covered by impervious surfaces such as roofing, asphalt, and concrete, and the design and maintenance of infrastructure.

Changes in area and intensity of activity

The expansion of urban areas can be an important pressure on land, because it can reduce our access to highly productive soil, with related economic and social impacts. Land Cover Database (LCDB version 4.1) data show our urban land area increased by 10 percent between 1996 and 2012 to approximately 228,000 hectares.

See Land cover

The greatest expansion of urban areas was in Auckland (up 4,211 hectares), Waikato (up 3,900 hectares) and Canterbury (up 3,829 hectares).[13] For comparison, a full-size rugby field is just over one hectare in size (including 22 metre in-goal areas, it is 1,008 square metres) (World Rugby, 2018).

This urban expansion is driven in part by population growth. Between 1996 and 2013 the New Zealand population increased 19 percent (Stats NZ, nd-a), with growth expected to continue (Stats NZ, 2016b). In 1991, the population passed 3.5 million; in 2003, it passed 4 million (Stats NZ, nd-a). Stats NZ estimates the 5 million mark will be surpassed by 2028 (with a 5 percent probability that the actual population will be less than 5 million by then) (Stats NZ, 2016b).

There is some evidence of increasing density of population in urban areas – since 1996 the population density of Auckland's urban area rose from 21 people per hectare to 25 people per hectare in 2013 (Auckland Council, 2014).

Urban expansion is eating into New Zealand's most versatile land

'Versatile land' has many potential agricultural uses and is highly productive. This report usually refers to this land as 'versatile', but in this section also uses 'high-class land'– this is because the section is directly reporting studies using that terminology within the context of the Land Use Capability (LUC) system.

Versatile land is important to retain as it has few natural limitations to production. It has generally been classified as classes 1–2 or 1–3 in the LUC system (Lynn et al, 2009). In New Zealand, this 'high-class land' is also quite scarce: LUC 1–2 covers only 5.2 percent of the total New Zealand land area, while LUC 1–3 covers 14.4 percent (Rutledge et al, 2010).

Spatial analysis of areas around Auckland shows that 8.3 percent of high-class land (LUC 1–3) in the region (Andrew & Dymond, 2013; Curran-Cournane et al, 2014; Rutledge et al, 2010) was converted for urban development. Most of this (10,080 hectares of the total converted 10,399 hectares) was converted between 1975 and 2012. The analysis also showed that from 1996, the majority of land used for urban extension was high-class land (Curran-Cournane et al, 2014). This loss of high-class land is happening at the same time as our food production system is under pressure to increase production without increasing environmental effects (Curran-Cournane et al, 2016), and is facing the uncertainties of climate change (Funk & Brown, 2009).

There is limited national information about how quickly our most versatile land is shifting to urban use. We do know that between 1990 and 2008, 29 percent of new urban areas were on high-class land (based on LUC 1–2 only). At a regional level, the same study shows that

[13] LCDB 4.1 is based on 2012 satellite imagery. It does not reflect urban shifts in Canterbury in rebuilding after the 2010/11 earthquakes, or more recent expansion elsewhere.

between 1990 and 2008 the greatest areas of conversion from high-class land to urban use were in Canterbury (4,800 hectares) and Auckland (2,600 hectares) (Andrew & Dymond, 2013).

Fragmentation of land on urban fringes also impacts on productivity

There is another land use change that can impact the productivity of the land outside cities. This is the creation of lifestyle blocks – where larger commercial agricultural areas are subdivided into smaller lifestyle blocks and units with housing on the fringes of urban areas.

Creation of lifestyle blocks may pose a greater risk to the availability of high quality soil resources for the primary sector than does urban expansion. While the outward growth of urban centres in New Zealand between 1990 and 2008 consumed 0.5 percent of high-class land (LUC 1–2), analysis in the same 2013 study shows that lifestyle blocks had already occupied 10 percent of high-class land (data to 2011).

There has been a sharp increase in the number of lifestyle blocks in recent decades. The 2013 study shows that of the 175,000 lifestyle blocks that occupied 873,000 hectares of land in 2011, over 40 percent had been established since 1998 (an average of 5,800 new blocks a year). The same study found that 35 percent of Auckland's most versatile land was used as lifestyle blocks (Andrew & Dymond, 2013).

Changing land use on the urban fringes can also result in fragmentation of land parcels. This is well demonstrated in the wider rural Auckland region. In the Pukekohe area, the number of property parcels increased 58 percent between 1998 and 2015 (Curran-Cournane et al, 2016). Most lifestyle blocks were created on the urban fringe; by 2015 most land parcels in the Pukekohe area were less than 8 hectares.

Fragmentation of land ownership is legally reversible, but it is not often practical to do so, because a property's value increases when it is converted to a lifestyle block (Andrew & Dymond, 2013; Curran-Cournane et al, 2018). The impact of this fragmentation is hard to quantify, as there is no information on the productivity of lifestyle blocks and their actual impact on food production.

Urban expansion puts pressure on biodiversity

Land use change on city fringes can put pressure on biodiversity in urban areas. Research shows that indigenous land cover is higher on the edges of New Zealand cities than in the middle of them. Indigenous land cover is less than 2 percent on average within urban centres, and increases to over 10 percent on the urban–rural boundary (Clarkson et al, 2007). Other ecological studies indicate that a drop below 10 percent for indigenous vegetation cover may trigger a decline in many species (McIntyre & Hobbs, 1999; Drinnan, 2005).

Most of New Zealand's urban fringe areas are above that threshold, but urban expansion on the edge of cities, and the loss of indigenous vegetation cover there, could cause disproportionate change in the remaining biodiversity. This risk is accompanied by the pressure of pests (from population settlements). This can include predation by household pets and urban pests such as rats and mice; and the spread of exotic plants from gardens, including fast-growing pest plants such as tradescantia (wandering willie) and climbing asparagus – see chapter 5 Biodiversity and ecosystems: Pests, weeds, and diseases.

Extractive activities

This section provides an overview of mining, quarrying, and onshore oil and gas extraction in New Zealand.[14] This focuses on the benefits of extracting these in-ground resources and the associated pressures.

Minerals have long been important for people in Aotearoa New Zealand. Pounamu (greenstone) and other rocks such as obsidian, flint, and basalt were key resources for Māori (Ruckstuhl et al, 2014). Gold, coal, and other minerals have been extracted since the mid-nineteenth century, including aggregates and limestone used in industry and building. Petroleum (oil and gas) has been produced since 1865, with major discoveries and industry development in Taranaki since the 1950s (gas) and 1970s (oil) (Christie & Barker, 2013).

While export volumes have declined recently for key products such as coal and oil, exploration activity in the sector (and public discussion about potential impacts of extractive activities) intensified in New Zealand in the last decade (PCE, 2014; Ruckstuhl et al, 2014).

Current extractive production for export focuses on oil and gas, gold and silver, high-quality coal, ironsand, and some specialised minerals such as clay for high-quality ceramics. Production for New Zealand use includes gas and coal for industry and electricity generation use, aggregates for roadmaking and construction, and limestone for agriculture and cement-making (Christie & Barker, 2013; New Zealand Petroleum & Minerals (NZP&M), 2017a).

Production and value of extractive activities

The known export earnings from extractive activities in 2016 were $1.386 billion. This was from oil, gas, gold, and silver – earnings from coal and ironsand exports were not available for this report (Stats NZ, 2017a). Overall, extractive industries directly contributed about 1.0 percent to New Zealand's total GDP in 2016, or $2.429 billion (Stats NZ, 2017b). Of oil and gas, about 25 percent of production is onshore (Stats NZ, 2016c); the remainder is from offshore stations. While marine-based activity generally is out of scope for this report, the offshore oil and gas activities are closely interlinked with onshore operations, and include land-based waste disposal.

Extractive activities also contribute to further economic activity in the manufacturing, energy supply, and construction industries (Stats NZ, 2013). For instance, coal provides about 10 percent of New Zealand's primary energy (excluding transport fuels). It is used in steel making and milk processing, with a declining amount going to electricity generation. It is also used for cement making, and to provide process heat for the meat and timber industries. Coal is important for industrial plants and primary production in the South Island where there is no reticulated gas (NZP&M, nd; MBIE, 2017b).

The sector's contribution can be affected by volatility in commodity prices, which affect production levels and value of the activities over time; supply and demand can both be influenced by international and domestic factors, including regulatory systems. Ministry of Business, Innovation and Employment (MBIE) statistics show that 2016 was the fourth

[14] Under the Crown Minerals Act 1991 minerals include "all metallic minerals, non-metallic minerals, fuel minerals, precious stones, industrial rocks and building stones". For readability this is divided into more valuable solid substances that are mined, lower value aggregates and limestone that are quarried, and oil and gas primarily extracted from wells.

consecutive year of decline for coal exports (down 12 percent in volume that year), while oil exports fell 22 percent in volume (MBIE, 2017b). In 2016, the Government's revenue from petroleum and mineral royalties and energy resource levies was $221.6 million, down from a peak in 2008/09 of $557.7 million. Royalties go into the Government's central funds (NZP&M, 2017b).

The costs of extractive activities differ from other industries in that resources have first to be discovered (Christie & Barker, 2013). Producers and operators are also required to manage potential impacts and invest in site closure and post-closure rehabilitation and treatment costs, if necessary.

Extent of extractive activities

Coal reserves in New Zealand are found mainly in Waikato and Taranaki in the North Island, and the West Coast, Otago, and Southland in the South Island. These resources range in quality, with over 80 percent of in-ground resources being lower-grade lignite in the South Island. Export of higher-grade coal is only from the West Coast (MBIE, 2017b).

Closures of mines at the end of 2015 reduced 2016 production levels – down 15 percent to 3.0 million tonnes, of which 1.2 million tonnes (mostly bituminous coal) were exported. The underground Huntly East mine was closed, while the Strongman, Cascade, and Escarpment opencast mines were put into care and maintenance primarily in response to market conditions. Solid Energy produced 68 percent of national production in 2016, but operated under voluntary administration from August 2015; a sale of company assets to other coal companies was completed in August 2017 (MBIE, 2017b).

Modern goldmining in New Zealand is dominated by two hard rock mines, Waihi (Coromandel) and Macraes (Otago), operated by one company. In 2016, production from these two mines represented 83.5 percent of all gold produced in New Zealand. A third hard rock mine (near Reefton on the West Coast) closed in 2015 – this was a key factor in gold production decreasing by 22 percent between 2015 and 2016. The silver produced in New Zealand is a by-product of gold mining at the Waihi mine site.

Alluvial gold mining currently accounts for approximately 15 percent of New Zealand's annual production. Production rose steadily over 10 years from 6,269 ounces in 2005 to 47,264 ounces in 2016, based on about 45 commercial operations on the West Coast, and the Waikaia mine in Southland (Cotton and Wood, 2016; NZP&M, 2017b).

Ironsand has been mined since the 1970s at Waikato North Head (mainly for steelmaking at Glenbrook, south of Auckland) and at Taharoa on the North Island's west coast (for export). An ironsand mine at Waipipi in South Taranaki closed in 1987. Production at the two mines increased between 2013 and 2016 to around 3.5 million tonnes despite a drop in iron ore price in 2013 (NZP&M, 2017b).

Several precious and industrial minerals are also the focus of current exploration. They include garnets on the West Coast and tungsten and diatomite in Otago. The recovery of lithium from the water extracted in geothermal power generation is also being investigated (Mroczek et al, 2015).

Extraction of industrial rock and building stone, including quarrying for aggregates and limestone, is harder to quantify. There is no legislative requirement to report this production, other than for Crown-owned minerals, and the proportion of quarries working other resources is not known. Aggregate production, including from riverbeds, generally follows demand in the construction, roading, and building sectors. To date all petroleum production has been from onshore and offshore in the Taranaki Basin – in 2015, about 75 percent came from offshore stations, which are largely outside the scope of this report (Stats NZ, 2016c). Petroleum production overall has been declining in New Zealand since about 2008 due to maturity of some existing fields and lack of exploration success (MBIE, 2017a & 2017b).

Pressures associated with mining, quarrying, and onshore oil and gas extraction

Two key types of pressure on land come from extractive activities: legacy effects from historic activity, and potential impacts of contemporary activity. Contemporary activities can be grouped into two categories: unavoidable impacts that need to be negotiated (such as landscape changes) and impacts that can be managed or mitigated (such as acid mine drainage, or subsidence risk). This section looks first at the potential pressures from current activities, then legacy effects.

This report does not examine the effects of offshore oil and gas extraction, except for noting possible impacts on coastal areas.

The potential effects of extractive activities on land range from more or less imperceptible to highly intrusive. They can include disturbance and deformation of landscapes and soils, air and noise pollution, light from flaring natural gas, and contamination of groundwater and waterways (Sengupta, 1993; Bell et al, 2006; Pope et al, 2010; PCE, 2014).

The degree of impact that a particular extractive activity can have depends on the methods used, the mineral being extracted, scale of the operation, local topography, drainage, geology, existing land use, and cultural values associated with the landscape. The actual impact is highly dependent on the environmental mitigation and rehabilitation processes that accompany production, often as required in consents and permits (National Academy of Sciences, 1999; PCE, 2014).

New Zealand's regulatory system requires a permit from New Zealand Petroleum & Minerals for any prospecting, exploration and mining of Crown-owned minerals, as well as access permission from the land owner and occupier (DOC, nd). While mining and drilling for oil and gas is very limited in the 40 percent of public conservation land listed on Schedule 4 of the Crown Minerals Act 1991, those activities can take place in other areas that have high conservation value (PCE, 2014).

The environmental effects of extractive activities are managed through access agreements, and by regional and district councils under the Resource Management Act 1991 (RMA). Controls are set under the RMA in two ways – through policies and rules in council plans, and through conditions in resource consents (PCE, 2014). Mining generally requires companies to lodge bonds to recover remediation. Cultural impacts are also addressed through RMA processes, as well as through Heritage New Zealand. New Zealand Petroleum & Minerals also has a statutory responsibility under the Treaty of Waitangi to consult with iwi and hapū whose rohe (traditional area of occupation) may be directly affected by new permits (NZP&M, 2018).

Identifying the cultural impacts of extractive activities depends in part on recognising which values guide responses, particularly given the scale and long timeframe of extractive projects. Ruckstuhl et al (2014) note when reporting analysis of the documents from 44 iwi and hapū groups that "the values guiding iwi responses are not finely focussed on matters of environmental management. Rather, they relate to considerably broader, enduring underpinnings: a distinct worldview." In addition, issues around extractive activities were also considered against "a long legacy of 'constitutional' struggles and a sustained adherence to traditional values and practices." See also How whenua matters.

Mining

Mining activities can change soils and landscapes, disturb and degrade habitat for indigenous biodiversity, and can affect nearby surface water and groundwater without appropriate management (Cavanagh et al, 2015; Pope et al, 2010). Other impacts can include the creation of air-borne pollutants, noise from blasting and machinery, traffic, and subsidence issues (Sengupta, 1993; Bell & Donnelly, 2006).

The particular risk to fresh water is from mine drainage (particularly when highly acidic), where this is not well managed. Mining opens up the rock, exposing minerals within to oxygen and water, which can result in mine drainage water having distinctly different composition to natural background waterways (Cavanagh et al, 2015). This can affect microbial communities in streams, and markedly reduce the biodiversity of aquatic plant, benthic invertebrates, and fish (including migratory freshwater fish, such as iconic whitebait species) (Gray & Harding, 2012; Greig et al, 2010; Harding & Boothroyd, 2004). Drainage can vary between areas of different geology, even for similar mining methods. For example, there is considerable difference in the chemical make-up of drainage from coal mines on the West Coast of the South Island: mines within the Paparoa Coal Measure have neutral mine drainage (ie pH range 6.5–7.5), while in the other key rock sequence, the Brunner Coal Measure, the mine drainage is acid (ie pH range 2–4) due to the availability of sulphur when the coal was deposited (Pope et al, 2010).

The water discharges from processing of tailings at mine sites are a key issue, particularly for gold mining operations. The rock types where gold is found can produce drainage with high trace elements, commonly including arsenic or less often antimony. The discharge water from gold mine processing often requires treatment to remove arsenic or antimony (Cavanagh et al, 2015). Other water issues can include the precipitation of metals (particularly iron and aluminium) on streambeds (this can occur as the pH levels of the water increase from low pH), as well as loss of clarity (turbidity), salinity, temperature change, stream diversions, and changes in water quantity. While these issues are expected to be managed in consenting processes, if they are not they can cause considerable and sometimes long-lasting effects (Cavanagh et al, 2015) – see Legacy issues.

Extraction of aggregate

Quarrying of aggregate on solid land can also have environmental impacts, although these tend to be lower in intensity than potential mining effects, given the smaller scale of operations and general absence of acidic drainage. Creating large holes in the ground can be accompanied by landscape changes, loss of habitat, noise, dust, and blasting effects; and if not appropriately managed, also by erosion and sedimentation of waterways. In areas of population pressure, or major construction effort (such as in Canterbury following the earthquakes), this can lead to concentration of extraction operations that can compound effects (Langer & Arbogast, 2002).

Riverbeds can also be affected by gravel extraction, particularly where the rate of removal exceeds the natural rate of supply. This can modify the flow of water, and degrade riverbed areas up and downstream. It can trigger riverbank erosion, and also limit fish migration, degrade in-channel habitat, and increase sedimentation which can affect downstream invertebrates and fish populations. Gravel extraction can also have positive outcomes for flood protection and avoiding riverbank erosion (Taranaki Regional Council, 2012).

Oil and gas

Drilling for oil and gas on land can have potential impacts on biodiversity, soil, landscapes, and water. The key factors influencing impact are the location of a well-site, local geology, and the hydrogeology of the area – for instance if the drilling was through a freshwater aquifer – as well as the design and management of the operation. Soil and water contamination can also occur as a result of spills and leaks of chemicals, wastewater, and oil and gas, when these materials are being transported, handled, stored, or used (PCE, 2014; MfE 2014a).

Oil and gas exploration and production create large volumes of liquid and solid waste containing hydrocarbons, salts, and heavy metals. In Taranaki these wastes, which come from both onshore and offshore operations, are disposed of through three methods: deep well injection (liquid waste pumped deep into the ground), mix-bury-cover (waste is buried in the ground), or land application by 'landfarming' (Cavanagh, 2015; PCE 2014).

Land application of drilling wastes presents a risk of contamination from the non-biodegradable components of the waste – these heavy metals include cadmium which can accumulate in animals, and mineral salts. There is also the possibility of wind erosion spreading contaminated soil during the breakdown phase (PCE, 2014). A Manaaki Whenua – Landcare Research study focused on food safety and animal welfare found that land application (or landfarming) posed no attributable direct risk to humans or animals "particularly when wastes are incorporated into the shallow subsoil with topsoil overlying the soil/waste layer". There is less information about impacts on soil organisms and waterways (eg from leaching or salinity), and about the environmental concentrations and effect of drilling additives (Cavanagh, 2015).

Other possible impacts on land of oil and gas operations include those related to coastal and land-based facilities created to transport, process, store, and treat oil products. These can alter coastal habitat through the construction of jetties, groynes, pipelines, and dredging (and associated dredge waste including sediment) (Swan et al, 1994).

Legacy issues

The effects on land of mining and other extractive activities are often concentrated locally, but can linger for many decades after production ceases. When there is mine drainage affecting waterways, this can often have severe effects. Up until the 1970s mining was conducted in New Zealand with little regulation of the impact on downstream water quality or ecosystems. Many historical mine workings occur throughout the country, particularly in the West Coast region, with some historical workings causing significant impacts on downstream water quality (Cavanagh et al, 2015). Legacy mining activities are noted as one of the causes of contaminated land.

The legacy water quality issues on the West Coast can include acidification of waterways and pollution with heavy metals. This relates particularly to the Stockton–Denniston Plateau, within the Rapahoe region north of Greymouth and near Reefton (PCE, 2006). As for current mining operations, this can affect stream life and water quality (Cavanagh et al, 2015; Gray & Harding, 2012; Greig et al, 2010; Harding & Boothroyd, 2004).

The likelihood of arsenic (and less often antimony) in water discharges from gold mine tailings creates a particular risk to human health, such as at the Prohibition Mill mine at Waiuta on the West Coast before remediation. This is a result of the weathering of the arsenic bearing rocks that were processed with gold ore and then deposited in waste rock piles and tailings. Over time with exposure to rainwater and oxygen, the arsenic can dissolve out of the wastes and wash into streams, with potentially toxic consequences for stream-life downstream and risk of enduring high concentrations in areas where people live (Haffert & Craw, 2008a; Haffert & Craw, 2008b).

Some of the most significant risks come from the combination of mining leachates and residual pit lakes and tailings dams – for example at the Tui Mine near Te Aroha in the Waikato region. This site was the focus of a $21.7 million remediation project by local and central government and local iwi to stabilise the tailings dam. Water quality and stream ecological health is also gradually improving at this site (Waikato Regional Council, 2016).

Waste

This section looks at how waste is disposed of in New Zealand, and how the way we dispose of waste can put pressure on land. It links to the following section on Contaminated land.

We have limited data on waste in New Zealand. This restricts what can be reported in terms of the scale of issues, and how waste disposal is changing. What this report *can* provide is a view of how the waste management system works in New Zealand, some apparent issues, and what information is needed to get a clearer view of how waste affects our land.

The limited information available indicates that:

- the volumes of household waste are increasing steadily, which is associated with an increase in global resource use and greenhouse gas emissions associated with manufacture
- a large proportion of rural waste is disposed of direct to land, which risks discharging contaminants to air, land, and water (Hepburn & Keeling, 2013).

How New Zealand deals with waste matters in two key ways. Materials disposed of on land can affect the soil and water, with potential long-term impacts on human and environmental well-being.

There is also an important environmental pressure earlier in the production chain, from the resource demand required to produce things that are then discarded. This includes raw material and energy used for manufacture. There are related greenhouse gas emissions, as well as discharges from those industrial processes to land, water and air environments.

This report focuses on how waste generated by people affects the land. Other reports in the environmental reporting series focus on the effects of waste on fresh water, marine, and air and atmosphere. See *Our fresh water 2017* for a discussion of sewage and stormwater as well as farm discharges and run-off, and *Our marine environment 2016* for the effects of waste on the sea.

The waste system

New Zealand's waste disposal system involves a mix of managed waste facilities and direct disposal to land (on rural properties). Managed facilities, incorporating re-use–recycling–recovery initiatives, are accessible to 97 percent of the population, but are not used by all (MfE, 2010).

There are some voluntary product stewardship schemes operating in New Zealand. These schemes work to reduce waste disposal to land and reduce environmental pressure early in the production chain, from the resource demand required in manufacturing.

There are 426 waste disposal facilities operating under resource consents across New Zealand (MfE, 2017b). These are run by local government and private enterprise. The ownership is diverse and includes private companies, operators on contract to local government, and council-controlled organisations. Councils are estimated to control between 12 and 20 percent of the country's total waste stream (by weight); this is mostly household waste. For instance Auckland Council estimated in 2011 it influenced approximately 17 percent of regional waste (Auckland Council, 2012). The remainder of the New Zealand waste stream, which includes commercial, industrial, and construction waste as well as household refuse, goes to facilities run by commercial companies.

This diversity of ownership of waste facilities contributes to the lack of information on total volume of waste nationally (generally expressed as tonnages, based on legislative criteria), and limited knowledge of the composition of the country's waste. There is currently no regulatory requirement to report on the quantities or types of waste disposed of – or recycled – except at 45 landfills (11 percent of all known, consented facilities) that pay the Waste Disposal Levy under the Waste Minimisation Act 2008.

Landfills are grouped into four classes, based on the composition of the waste they accept and its risk of contaminating soil and water. Class 1 is the highest risk, because these collect treated hazardous waste, industrial waste, commercial waste, household municipal solid waste, construction and demolition waste, managed fill material, and clean fill material. Class 1 and Class 2 landfills are required to use leachate collection systems with engineered liners and methane recovery systems.

Waste volumes to landfill

The 45 Class 1 landfills that are required to pay the Waste Disposal Levy provide useful data for waste volumes. These are the Class 1 landfills that receive household waste (83 percent of all Class 1 facilities); they are estimated to cover about 30 percent of New Zealand's waste stream.

The levy data shows waste disposed of at these 45 landfills has increased every year since 2009 (except for 2012). Spread across the population, the net total of 3,379,546 tonnes in the year to 30 June 2016, is equivalent to every person in the country disposing of 734 kilogrammes of waste to landfill annually (MfE, 2017b).

Across the 45 landfills, the net tonnage of waste increased for the period 2013–16, from the previous three years. This was a combination of increases in the gross amount, and less being diverted to re-use or recycling (MfE, 2017b).

There is no available national figure for total waste disposed of on land across New Zealand. There is some information from local authority records and resource consent conditions, but the 2017 National Waste Disposal Survey has shown this is likely to underestimate total tonnages. The survey could not determine the total number of landfills in New Zealand, although it does record operating, consented landfills (381 in 2017 compared with the 588 noted in a 2014 survey, 324 of these with unconfirmed status) (MWH, 2017b).

Recycling volumes are also not known at a national level. Access to recycling schemes has increased: in 1996, 20 percent of the population had access to kerbside recycling collections; in 2006 this had risen to 73 percent, with 97 percent having access to either kerbside rubbish collection or drop-off centres (MfE, 2010).

Waste disposal on-farm

Most farm waste is disposed of on-farm. Waste surveys run by regional councils in Canterbury, Waikato, and Bay of Plenty show the most common techniques of rural waste disposal are burning, burying, or stockpiling. These activities risk discharging contaminants to air, land, or water, with compounding effects on ecosystem and human health (Hepburn & Keeling, 2013; Waikato Regional Council, 2014).

There are other disposal options, but they are used less. Many rural areas have no collection services, and disposal at managed facilities depends on people taking it there themselves. Regional and local councils run collection programmes for priority waste streams, such as hazardous substances, waste oil, and agrichemicals. There are also specialist nationwide services for recycling and disposing of farm waste such as plastic wrap and agrichemical containers.

The three regional surveys on waste returned varying estimates of total volume of waste disposed of on-farm. Environment Canterbury's 2013 survey of a cross-section of farm types (53 farms in total) showed on average farms were producing nearly nine tonnes of non-natural rural waste each year in addition to domestic waste and animal remains. The survey identified more than 50 different types of waste, including plastic, treated timber, hazardous waste, animal health products, seed/feed bags, and tyres (Hepburn & Keeling, 2013).

In 2014, the Waikato and Bay of Plenty regional councils replicated the surveys in their regions and received similar results in terms of waste types, quantities, and disposal methods (Waikato Regional Council, 2014).

Contaminated land

The Resource Management Act 1991 defines contaminated land as land with hazardous substances in or on it that are reasonably likely to have significant adverse effects on the environment (including human health) (MfE, 2018b).

Contaminants can be from waste disposed of to land, from industrial processes and agricultural activities, or through leaks from facilities that were meant to keep the materials secure. Contamination can happen in a single event or build up over time, for instance as metals leach out of mining tailings. Sometimes contaminants are by-products of other processes (see Box 8: Cadmium in soils).

Some contaminants are long-lasting, and their effects can endure long after the original activity has stopped. This can affect how a contaminated area can be used. It can also make it difficult to locate historic contamination.

Known effects but unknown overall extent

We know what kinds of land contamination can happen in New Zealand and how these chemicals may impact on human and environmental health, but we are unable to report on the overall extent of land contamination.

The impacts of land contamination can be on the soil, on structures built on it, on plants growing in it, or on animals and humans in contact with it. Hazardous substances can migrate through soils into groundwater, or be carried into waterways by overland flow or as dust. Sites where volatile substances were used or where gases are being generated can also create toxic and/or explosive environments.

Humans are at risk of contaminant exposure by eating food grown in contaminated soils, inhaling contaminated dust, gas, and vapours, or by direct contact with the soil. Contaminated land is a more significant problem when contaminants are close to buildings and people, or close to water bodies and important habitats.

Regional councils (and some district councils) work to identify historic and current sites where the use of hazardous substances could cause land contamination. The Hazardous Activities and Industries List (HAIL) identifies the activities and industries considered likely to cause land contamination resulting from hazardous substance use, storage, or disposal (MfE, 2018a).

The *Resource Management Act: Two-yearly Survey of Local Authorities 2012/13* (MfE, 2014b) reported 19,568 sites nationwide were identified as HAIL land. Many regional councils estimated that up to three times as many HAIL sites could be identified in their regions in further work (MfE, 2016).

There is currently no integrated overall dataset showing the extent of confirmed contaminated sites across the country. Regional councils keep records of sites where land contamination has been confirmed. For instance, the three largest metropolitan centres (Auckland, Christchurch, and Wellington) have information available on contamination at the individual address. Greater Wellington reports that the overall extent of Category III contaminated land in the region is at 0.147 percent.[15]

Local authority records show these types of hazardous activities and substances are frequently encountered:

- persistent pesticides such as the agrichemicals DDT and lead arsenate, from historic use in market gardens and orchards
- pesticides used for animal treatment, for example, sheep dipping to kill parasites, including DDT, dieldrin, and arsenic (old sheep dips can be located on farms as well as stockyards and railway sidings)
- timber treatment chemicals, including pentachlorophenol, copper, chromium, arsenic, and boron
- from mining, metals leaching from old tailings dams, mine shafts, and extraction plants

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[15] 'SLUR Category III – Contamination Confirmed' is where there is evidence that hazardous substances exist above background concentrations and is it likely that adverse effects on human health or the environment will occur based on current or foreseeable use. Information supplied by Greater Wellington Regional Council, March 2018.

- by-products of the historic gasification process in gasworks in most towns and cities, which include coal tars and heavy metals like arsenic
- petroleum contaminants from fuel storage facilities including urban service stations.

Emergent contaminants in 2017 include Per and Poly Fluoro-Alkyl Substances (commonly referred to as PFAS) and in particular the compounds perfluoroocane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and perfluorohexane sulfonate (PFHxS). PFAS have many uses including waterproofing and printing and historically were compounds in specialised foams for fighting flammable liquid fires at airfields and fuel storage facilities.

Box 8: Cadmium in soils

A legacy of our past: Cadmium is a naturally-occurring heavy metal present in low concentrations in air, water, and soils. It is present in phosphate rock, the main ingredient in phosphate fertiliser used in New Zealand agriculture (see also chapter 4 Soils for more information about phosphate fertilisers) (Stafford et al, 2014). As more phosphate fertiliser has been applied, cadmium concentrations in New Zealand's agricultural and horticultural soils have increased, particularly between the 1950s and 1995 (Ministry of Agriculture and Forestry (MAF), 2008). At high intakes, cadmium is toxic to humans and is considered a contaminant.

A tale of complexity: Cadmium accumulates where high levels of phosphate fertiliser have been applied over a long period. Its availability for plant uptake varies according to soil pH, levels of organic matter, and soil type. Some of our volcanic soils that have allophane content require a higher level of phosphorus to produce plant response. Knowing how soils vary, and how to match nutrient, pasture, and crop management accordingly are important steps in reducing the likelihood of cadmium accumulation.

The limits New Zealand works to: A number of initiatives have been developed under the joint government and industry Cadmium Management Strategy to reduce the risk of high levels of cadmium entering the human food chain. The Tiered Fertiliser Management System, for example, specifies management trigger values for soil cadmium, to ensure concentrations in agricultural soils remain within a range that allows for long-term sustainable agricultural production. An upper limit of 1.8 milligrams of cadmium per kilogram (Cd/kg) was set at which no further cadmium accumulation is permitted. The numbers are based on the risk of accumulation over a 100-year timeframe. In some regions with a long history of phosphate use and a prevalence of volcanic soils (Waikato and Taranaki), soil cadmium is generally more elevated. For a small number of sites across New Zealand concentrations of soil cadmium have been recorded above the upper limit (MAF, 2008; Abraham et al, 2016).

Assurance that cadmium remains at a safe level in our foods is also provided through food standards and a regular (five yearly) survey for the Total Diet Survey Study, which assesses the typical dietary intake of cadmium and other compounds (MPI, 2016b). Other measures include preventing the sale of offal from sheep and cows older than 30 months. New Zealand's National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health also sets soil guideline values for future rural residential land use, where remediation may be required before a change of use.

Data gaps for human activities

Land cover

The report relies on the Land Cover Database Version 4.1 (LCDB 4.1), mapped from satellite imagery, to understand extent of and change in land cover. This LCDB has not been updated since 2012. Options are currently being investigated to fund the production of LCDB5 and LCDB6.

Major land uses

Land use (general): We do not have a single, comprehensive, robust, nationally representative land use dataset that characterises New Zealand's land use, and how this is changing spatially and temporally. Current estimates are based on data from a variety of sources and proxies.

Land ownership*:* We would benefit from greater detail on land ownership and protection status (across Crown and other public and private land including Māori land) including how these have changed over time (pre-colonial, post-colonial, 1950s, and today).

Land use (primary sector): The report relies on Agricultural Production Survey (APS) data from 2002 to map the location and extent of primary sector land uses. The data are not spatial, are limited to 'commercial scale' farms, and do not incorporate all forestry.

Land use intensity (primary sector): We do not have an accurate indication of the intensity of land use within land use classes. The indicators used are limited to a few input indicators (irrigation, stock density). We need better input indicators (improved dataset on stock density, fertiliser application, pesticides) and some indicators on agricultural performance such as nutrient use efficiency, to better understand the likely pressures from human activities.

Land use (urban): The report uses LCDB 4.1 to understand the extent of and change of urbanisation. Change since 2012 is therefore not captured.

Visitor activities (conservation): While we have good information about recent increases in international visitors, there is no national dataset that describes visitor activities (eg scenic drive, trekking, and camping) and the locations of those activities with enough detail to be used to signal particular environmental pressures.

Extractive activities

Legacy and current extractive activities: We do not have systematically collated data on environmental impacts from legacy and current mining activities, nor on the impacts of oil and gas onshore production. The report relies on research studies, some which collate compliance monitoring reports and data from regional councils, but these are of variable quality/use for assessing impact. We also lack information on environmental impacts (particularly on streams) of aggregate (and limestone) quarrying operations, and we do not have aggregated information on ironsand operations.

Waste

Waste (overall): We have limited data on waste (from 11 percent of the country's landfills, equating to about 30 percent of the total waste stream). Waste disposal facilities are spread across the private and public sectors, and there is no existing legislated requirement to collect more information about the remaining two-thirds of the country's waste, including about where it is going, how much of it there is, or what it is made up of.

Rural waste: We have regional data to indicate rural waste volumes and disposal methods, but the full extent of disposal of waste to land outside managed facilities is unknown, as is the nature of materials disposed of and the related environmental risks.

Recycling operations: We lack an integrated national dataset covering recycling and re-use operations, and the volumes redirected from the waste stream.

Contaminated land

We know the types of land contamination in New Zealand, and to a degree how these chemicals impact on human and environmental health, but we are unable to report on extent. There is some regional information (from the Specific Land Use Register), but there is no integrated national information about the extent of potential and known contaminated sites.

4 The state of New Zealand soils

People are reliant on a range of services provided by soils. The quality and quantity of soil is crucial to New Zealand's economy and the overall health of our land and the wider environmental system.

This chapter reports on the state of New Zealand's soil with a focus on soil erosion (and sedimentation), soil quality, and soil biodiversity. It includes a summary table of the pressures that can affect soil, and where in the country these have greatest impact. The chapter ends with a summary of the wider impacts of soil degradation, and of soil data gaps.

Key findings

- New Zealand has naturally high rates of erosion, due to a combination of steep terrain, rock and soil types, and climate. Overall New Zealand contributes about 1.7 percent to global sediment loss, while making up only 0.2 percent of the global land area.
- Erosion rates can be accelerated when tree cover is removed. Models comparing soil loss to water with land cover types indicate 44 per cent of the soil that enters our rivers each year comes from pasture (exotic grassland). This is equivalent to 84 million tonnes of soil out of 192 million tonnes estimated lost each year.
- Soil quality monitoring programmes in 11 regions across the country between 2014 and 2017 show that 83 percent or more of tested sites were within target range for five of the seven indicators (pH, total carbon, total nitrogen, mineralisable nitrogen, bulk density).

  However, more than 48 percent of tested sites were outside the target range for two indicators of soil quality: phosphorus content (an indicator of soil fertility) and macroporosity (a measure of how many pore spaces are in the soil, which is an indicator of the soil's physical status).
- Thirty-three percent of the sites tested had soil phosphorus levels that were too high. Excess phosphorus can travel into waterways through erosion and run-off, where it can trigger growth of unwanted plants and reduce water quality.
- Forty-four percent of the sites tested were below the target range for the macroporosity soil indicator (indicating soil compaction). Soil compaction makes the soil less productive, and can reduce soil biodiversity and restrict plant growth. As it impedes drainage, it can also result in increased greenhouse gas emissions from urine on soils, and an increased amount of phosphorus and eroded soil reaching waterways.
- Sites under more intensive land uses, such as dairy, cropping, and horticulture, and dry stock, were more frequently outside the target range for these soil quality indicators. In particular, 51 percent of tested dairy sites had excess soil phosphorus and 65 percent of tested dairy sites were below the target range for macroporosity. Some horticultural and cropping sites also had high phosphorus levels (37 percent) and low macroporosity levels (39 percent). Drystock sites also had low macroporosity levels (41 percent).
- The wide diversity of bacteria, fungi and metazoa in the soil plays a vital role in supporting the ecosystem services people enjoy. There are no national soil biodiversity monitoring programmes currently in place. However, preliminary studies, particularly using DNA, highlight the usefulness of monitoring to understand how land use affects the health and productivity of soil ecosystems.

Introduction

Ka mau tonu ngā tāonga tapu o ngā matua tupuna, koinei ngā tāonga i tuku iho, nā te Atua

Hold fast to the treasures of the ancestors, for they are the treasures that have been handed down to us by God

There's much more to soil than meets the eye. Soil is a living mixture of organisms, minerals, organic matter, air, and water. It is an ecosystem in its own right, like a forest or an ocean.

It is this delicate balance that gives soil the ability to support a range of important functions that people depend on every day, including:

- growing food and providing raw materials
- hosting and supporting around a quarter of the world's biodiversity (FAO, 2015)
- storing and recycling nutrients
- regulating drainage, flow, and storage of water
- storing carbon (which helps reduce and mitigate climate change)
- filtering and breaking down contaminants, helping keep land and water healthy and safe.

The quality and quantity of soil is crucial to the overall health of the land and the wider environmental system. As well as the life it supports above the surface, below the surface there are diverse physical, biological, and chemical processes occurring, and millions of microbial and animal species (FAO, 2015).

New Zealand has a major economic dependence on soil. Approximately half of New Zealand's land area is used by primary industries. Good soil management is vital to continuing productive processes that were the basis of over $35.4 billion in exports in 2016, or 50 percent of total export earnings (MPI, 2017a).

In Māori tradition, the link between Māori and the soil is strong and reciprocal, stretching back to the time of creation, when the first woman Hineahuone was made from the earth. See How whenua matters and chapter 1 Physical processes.

Our precious and fragile soils

Soils, landforms, and vegetation have evolved together over millions of years. This means the characteristics of soil are linked to the underlying characteristics of the land. There is wide variety, from the gumlands in Northland, the volcanic ash soils in the central plateau, to the rich brown soils and peat areas of Southland.

New Zealand's soils have changed significantly since human settlers first arrived as a result of deforestation to grassland, historic land use, and more recent changes in human activity.[16]

[16] New Zealand soils are classified in a system developed in the 1980s (SoilsPortal), while the suitability of different soils for particular uses is reflected in the Land Use Capability system, used since the early 1950s (Lynn et al, 2009).

The factors that can change the quality and quantity of our soils range from physical processes, such as intense rainfall or earthquake triggered slips, to human activity, such as the removal of tree cover or application of fertiliser and other compounds (table 2). See the three pressures chapters: Physical processes, Climate variability and change, and Human activity.

Table 2 Pressures on soil, showing potential impacts, with regional focus

Soil pressure	Natural or human-influenced	Description	Potential impacts on soil	Where it is an issue
Earthquakes and landslides	Natural, although the rate of landslides is highly influenced by human land use, topography and geology	Landslides triggered by rain and earthquakes are a leading contributor to erosion in New Zealand.	Increased erosion Loss of topsoil and reduction in productivity	Widespread – steep terrain is commonly prone to erosion in the form of landslides. See Physical processes
Intense rainfall events	Natural, but human-induced climate change is increasing the frequency of intense rainfall events	Intense rain and wind contribute to erosion. While this is part of the 'natural weathering' of New Zealand's base landforms and geology, rates of erosion are increased in extreme weather events, particularly in the absence of a complete vegetative cover.	Increased erosion Loss of topsoil and reduction in productivity	Widespread but primarily in the Southern Alps and in North Island hill country formed on weak rock types. This is of particular concern in areas such as Northland and the east coast of the North Island. See Climate variability and change
Reduction in vegetation cover	Largely human-influenced, but some natural	Accelerated erosion can be caused by clearing native vegetation for farming or forestry, forestry harvesting, changing from forestry to pastoral farming, cultivation and harvesting of crops, and the effect of pests (eg rabbits) and plant diseases.	Increased erosion Loss of topsoil and reduction in productivity Loss of soil biodiversity Loss of soil nutrients (changed nutrient cycling)	Widespread but hill country formed on weak rock types is particularly susceptible. See Human activity (Land cover)
Agricultural intensification	Human-influenced	Increased production per area of land, often achieved through increased inputs (eg fertiliser, pesticides, water, and supplementary feed), and higher stocking rates.	Increased erosion Degradation of soil and water quality Loss of soil biodiversity	Widespread but especially true for intensive farming areas on flat to rolling land. See Human activity (Agriculture)

Soil pressure	Natural or human-influenced	Description	Potential impacts on soil	Where it is an issue
Urban expansion	Human-influenced	A switch from undeveloped or rural land to urban land use leads to the loss of soil for future use. This is of particular concern for versatile land.	Decreased availability of versatile land Loss of soil biodiversity	Auckland, Waikato, Tasman, Canterbury, Tauranga. See Human activity (Urban land)
Pollution and waste disposal	Human-influenced	A variety of industrial, commercial, domestic and agricultural activities can result in chemical and physical contamination of soil. Historic activities can leave legacy issues of soil contamination.	Degradation of soil quality and reduction in productivity Loss of soil biodiversity	Widespread but usually in hotspots (eg landfills, mining areas, and former sheep-dip facilities). See Human activity (Waste and Contaminated land)

Soil erosion

Erosion is the process that loosens soil and rock and moves them through the landscape. In landscapes undisturbed by human activity, like the remote ranges of the Southern Alps, the rate of erosion is determined by geology, uplift rates, and weather. It is a natural process that is important to the formation of Aotearoa New Zealand – erosion gives us the braided rivers, highly fertile plains, and sandy beaches that support our way of life.

Erosion rates in New Zealand are naturally high by world standards because of the dominance of tectonics and uplift, steep slopes, young and erodible rocks, generally high rainfall, and common high-intensity rainstorms. However, how we use land can accelerate erosion, particularly as a result of removing deep-rooted vegetative cover and by disturbing soil.

Erosion occurs at a variety of scales. The most common and active type of erosion is rainfall-triggered shallow landslides. Other mass movement types of erosion can result in large amounts of soil loss in a smaller area – as in the 2016 Kaikōura earthquake (see Physical processes chapter) (Basher, 2013). Erosion also occurs incrementally across large areas when wind, rain, and/or land use disrupt the soil. This type of erosion occurs predominantly in areas with bare or cultivated ground and heavily grazed or drought-affected flat land and hilly slopes (Eyles, 1983; Dregne, 1995; Basher, 2013).

Impacts of erosion

Too much erosion is a concern because it can reduce farm productivity, increase flooding to towns and cities, and degrade the health of our fresh water, estuarine, and marine environments.

Soil productivity can be affected when the topsoil is lost. Topsoil loss associated with landslides can result in soil degradation and pasture productivity losses that may not be regained within human timescales (Lambert et al, 1984; Rosser and Ross, 2011). Reduced soil productivity can lead to a greater demand for the addition of nutrients (typically through fertiliser) which brings its own financial and environmental burden. There can also be 'downstream impacts' on land where eroded soil is deposited, with accompanying productivity loss. The economic losses associated with soil erosion and landslides were estimated in 2015 to be at least $250–300 million a year (Page, 2015).

Eroded soil can also enter fresh water, estuarine, or marine environments as sediment. Excess sediment loads can carry nutrients from land into water, degrade streambed or seabed habitats, affect organisms, reduce waterways capacity to carry floods, and affect water clarity and recreational activities.

New Zealand's sediment footprint is disproportionate to the size of the country

Soil erosion modelling indicates New Zealand loses around 192 million tonnes of soil into waterways and the ocean every year. This is estimated to contribute about 1.7 percent to global sediment loss, despite New Zealand only making up 0.2 percent of the global land area (Syvitski et al, 2005; Walling, 2008).

Much of this soil loss comes from natural erosion. However, models comparing erosion rates with land cover types (as at 2012) indicate 44 percent of the soil that enters our rivers each year comes from pasture (exotic grassland). This is equivalent to 84 million tonnes of soil out of 192 million tonnes estimated lost each year.

See Estimated long-term soil erosion

Regional erosion and sedimentation hotspots

This section focuses on regions where erosion and sedimentation are more prevalent. It provides two perspectives on erosion: estimates of actual erosion, and modelling that highlights where conditions create high risk for erosion (potential erodibility).

Causes of high rates of erosion differ between the North and South islands

While the rates of erosion are similar between the North and South islands, one region of each island stands out for high rates of soil loss and related sedimentation of waterways.

The national mean rate of soil erosion is 720 tonnes per square kilometre per year. In the North Island, the Gisborne region's annual rate is 4,844 tonnes per square kilometre, while the South Island's West Coast has an annual rate of 2,106 tonnes per square kilometre.

The causes of the high rates of erosion in these two regions are quite different. As a general rule, soil erosion on the West Coast is due to high rainfall and vulnerable, steep, mountainous terrain. Erosion in Gisborne is typically on slopes that combine highly erodible geology with historical clearance of forest for pastoral agriculture. In Gisborne, 70 percent of the sediment loss was estimated to be from exotic grassland; on the West Coast only 5 percent of the sediment loss was from exotic grassland (figure 17).

We do not have the data to accurately estimate accelerated erosion from other land use activities (such as cropping and horticulture, and harvesting of plantation forestry) at a national level.

Approximately 7 percent of the North Island is vulnerable to severe erosion

See Estimated highly erodible land in the North Island

Highly erodible land is defined as "land at risk of severe mass-movement erosion if it does not have protective woody vegetation" (Dymond et al, 2006, 2008). A model has been used to identify 'highly erodible land' based on three main factors: young, weak sedimentary rocks; steep slopes; and absence of woody vegetative cover to hold the soil in place. This land is at risk of severe erosion. The model considers the main forms of mass-movement erosion in New Zealand: landsliding, earth flows, and massive gullying.

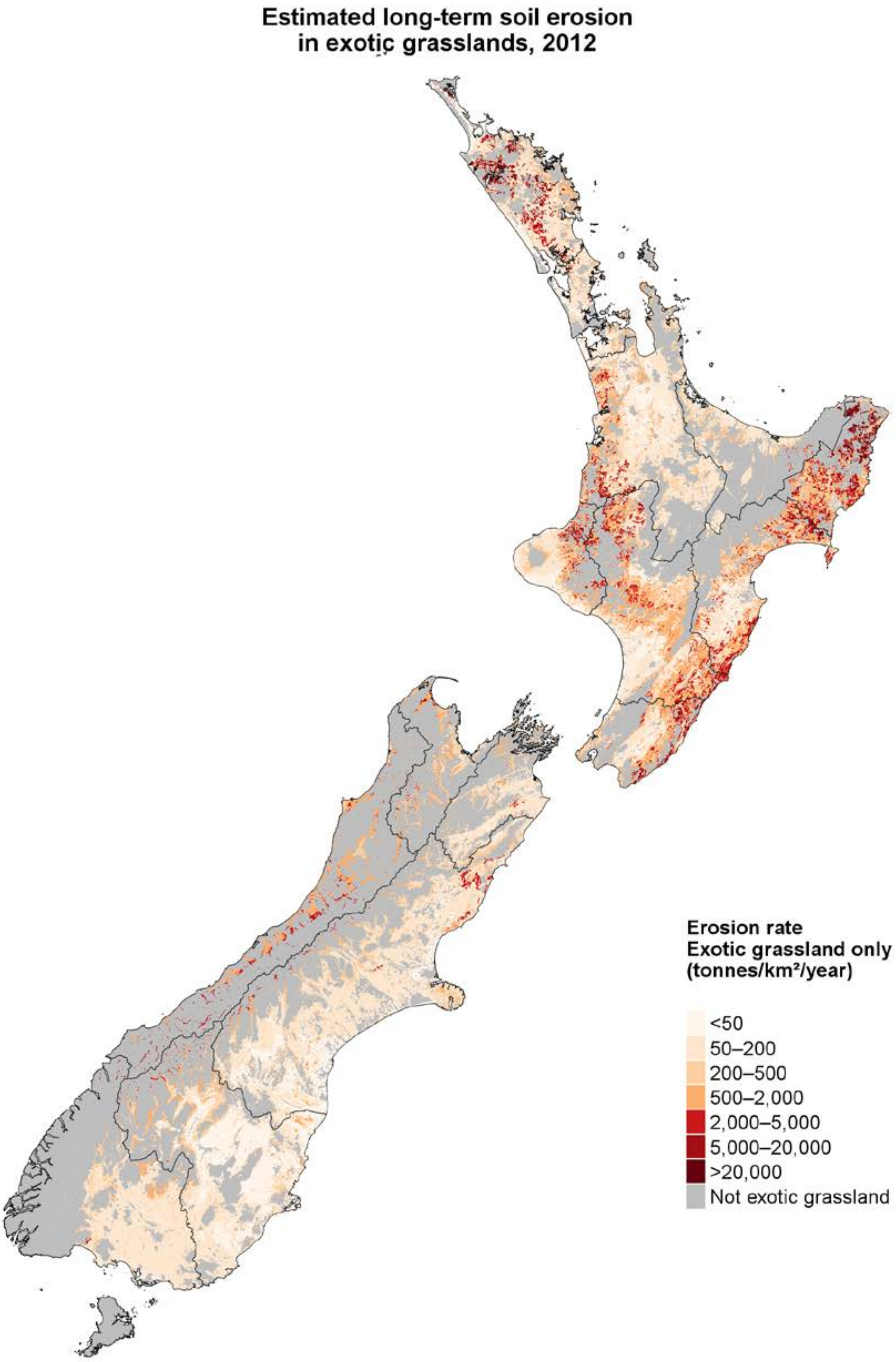
This classification applies particularly to steep hill country areas, predominantly in the eastern and northern areas of the North Island. Approximately 7 percent (840,000 hectares) of the North Island is considered 'highly erodible land' at risk of severe erosion, as of 2012. For comparison, this is larger than the Wellington region (ie all the area between the Kapiti and Wairarapa coasts, south of Ōtaki and Eketāhuna. Gisborne is the North Island region with the largest proportion of land at risk of severe erosion (138,000 hectares, 16.5 percent of the region's total area).

Of the 840,000 hectares in the North Island deemed at risk of severe erosion, 515,000 hectares (61 percent) is classified 'at high risk of landslides'. These can pose risks to people and infrastructure, as well as potentially degrading freshwater and marine environments.

Mapping regional erosion trends

Understanding recent soil erosion trends in Aotearoa New Zealand is challenging, as to date there has been no comprehensive national monitoring programme for erosion (see Data gaps for soil). Results from land cover analyses have suggested erosion has been decreasing since the 1980s, probably as a result of increased scrubland and plantation forestry (Dymond et al, 2010; Basher, 2013). However, several regional council surveys, using aerial studies, have shown some evidence of increases in erosion rates (Basher, 2013).

Figure 17



Source: Manaaki Whenua – Landcare Research

Note: The coloured areas of the map have exotic grassland cover (from LCDB 4.1). All other land areas are shown in grey. The erosion rates shown are based on data from the NZ Empirical Erosion Model, confined to the area of exotic grassland, to show comparative rates of erosion on pasture only. Redder colours indicate higher erosion rates.

Soil quality

This section focuses on soil quality to provide a view of potential risks in terms of environmental impacts and impacts on production. It focuses on chemical and physical properties (while soil biodiversity is covered in the next section).

This section is based on the parameters from soil monitoring programmes run by 12 of the 16 regional and unitary councils across New Zealand (in this reporting period only 11 councils provided data for analysis). The seven key indicators used in these monitoring programmes represent key properties of soil:

- **fertility** – measured by Olsen P – is the amount of nutrients (phosphorus) in the soil and available for supporting plant growth
- **acidity** – measured by soil pH – is how hospitable the soil is for plants and other organisms and is important in determining the amount of nutrients available to plants
- **physical status** – measured by bulk density and macroporosity – is how dense the soil is and how many pore spaces it has; these are both important characteristics for air and water movement through soil
- **organic reserves** – measured by total carbon, total nitrogen, and mineralisable nitrogen – is how much organic material is available to provide nutrients, to hold soil together and to allow air and water movement.

The soil monitoring information reported here does not cover all qualities of soil, nor does it assess all aspects important to soil function (eg sulphur, potassium, and trace elements).

Different plants and land uses require quite different kinds of soil and soil conditions. For example, what is considered appropriate soil quality for growing potatoes will be different to what suits a pine forest. To reflect this, the soil monitoring programmes include adjustments in target ranges for different indicators, depending on the specific land use and soil type.

The 12 regional and unitary councils assess soil quality under four different groups of land uses: forestry, cropping and horticulture, dairy, and dry stock. These four land use types are monitored for two reasons. First, productive land uses are dependent on soil quality. For example, if there are insufficient nutrients in the soil, this is likely to restrict plant growth and impact production. Second, some productive land use activities can reduce soil quality (which can then lead to negative impacts on the surrounding environment), so monitoring is used to inform local and regional land management.

Five out of seven indicators of soil quality are largely within target range, but two indicators present concern

Soil quality data from 11 regions show that results for 83 percent or more of tested sites were within target range for five of the seven indicators (pH, total carbon, total nitrogen, mineralisable nitrogen, and bulk density).

See Soil quality and land use

Soil pH and total carbon are important soil quality indicators. Soil pH can affect plant and crop growth and the availability of nutrients needed for production. Farmers and growers add lime or other compounds to maintain adequate pH to levels. Soil pH was within target range for 98 percent of tested sites.

Soil carbon is important for soil nutrient release and uptake, and helps to maintain soil structure and water storage. It can help reduce soil erosion and is an indicator of soil organic matter. Soil total carbon was within target range for 95 percent of tested sites.

Results for two indicators were outside the target range for more than 48 percent of tested sites. These are for phosphorus content, which is an indicator of soil fertility, and for macroporosity, which is one of two indicators of soil physical status. Monitoring was carried out on 461 sites between 2014 and 2017; for more information, see the indicator web page.

Phosphorus content: The Olsen P results show that 51 percent of the sites tested have soil phosphorus levels that are either too high (33 percent of sites) or too low (18 percent). Soils with phosphorus levels below the target range have too little phosphorus for optimum plant growth. This essential element is necessary to support plant growth in productive systems. Some New Zealand soils have naturally low levels of soil phosphorus, while other soils can become depleted by continuous intensive growing of crops. In 'pasture' and 'cropping and horticultural' land uses, this may lead to reduced yields.

Too much phosphorus in the soil presents a risk for water quality. Soils with phosphorus levels higher than the target range present a risk of phosphorus travelling into waterways through erosion and run-off, where it can trigger growth of unwanted plants and reduce water quality (McDowell et al, 2004; Taylor et al, 2016). High levels of soil phosphorus can result from application of too much phosphate fertiliser or manure over the long term.

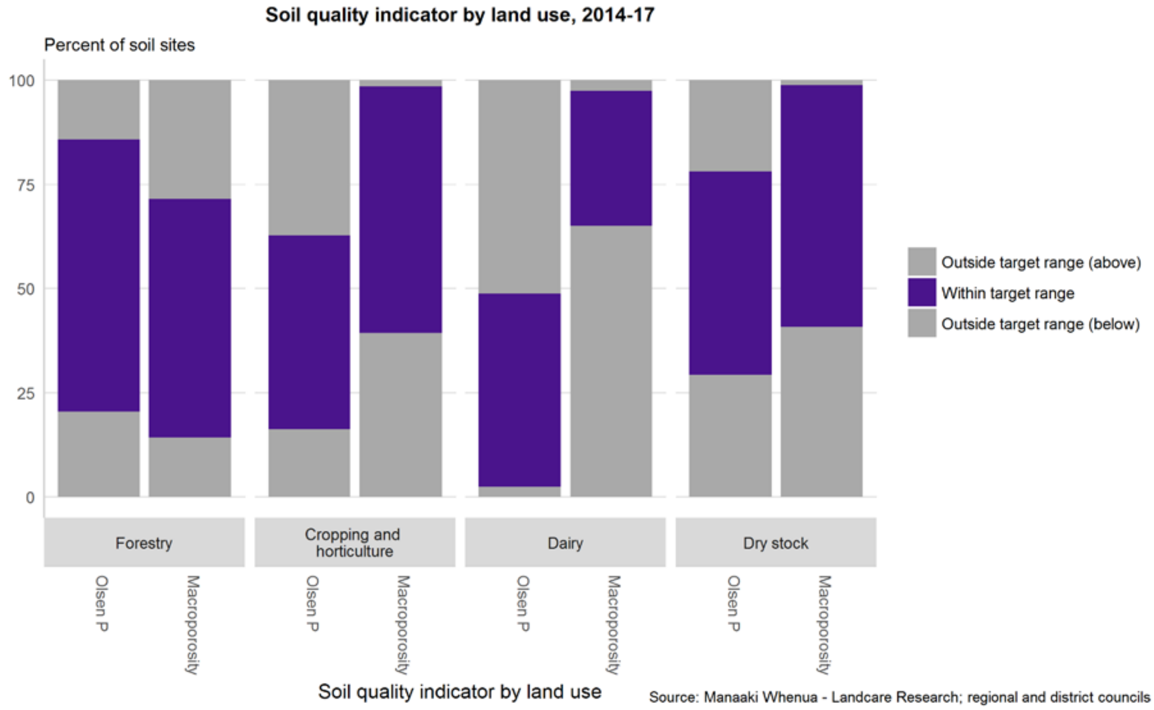
Macroporosity: The macroporosity results show that approximately 48 percent of the sites tested have macroporosity levels that are either too low (44 percent of sites) or too high (5 percent of sites). Macroporosity is a measure of how many pore spaces there are in the soil. Low macroporosity levels indicate soil compaction, which results from soil particles being pressed together, condensing the air space in the soil. High animal stocking rates or heavy loading from vehicles are likely to cause soil compaction, particularly when the soil is wet (Drewry et al, 2008).

Soil compaction makes the soil less productive (Drewry et al, 2004). Compacted soil can also have consequences for soil quality because it reduces soil biodiversity and restricts plant growth, and impedes the soil's ability to drain. This can result in increased greenhouse gas emissions from urine on soils (van der Weerden, 2017) and an increased amount of phosphorus and eroded soil reaching freshwater and marine environments (Curran-Cournane et al, 2011).

Excess phosphorus levels and low soil macroporosity are more frequently outside target ranges under more intensive land uses

Sites under more intensive land uses, such as dairy, cropping and horticulture, and dry stock, were more frequently outside the target ranges for soil quality indicators. In particular, 51 percent of dairy sites had excess soil phosphorus (they were above target range for Olsen P) and 65 percent of dairy sites were below the target range for macroporosity. Some horticultural and cropping sites also had high phosphorus levels (37 percent) and low macroporosity levels (39 percent), while drystock sites also had low macroporosity levels (41 percent) (figure 18).

Figure 18



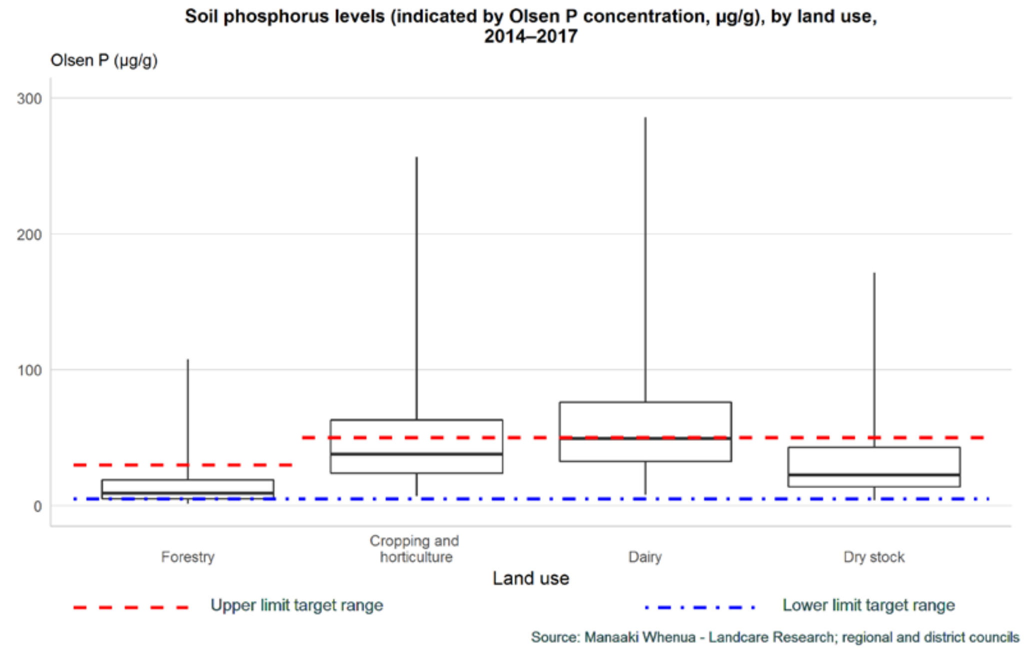
Note: For more information, see the indicator web page.

One feature of the soil quality results is the particularly high soil phosphorus levels at some sites – up to six times higher than the top of the target range (figure 19). This was associated with cropping and horticulture land use, and with dairying.

Similarly, some sites had particularly low macroporosity levels, well below the target range (figure 20). This was noted across all monitored land use types.

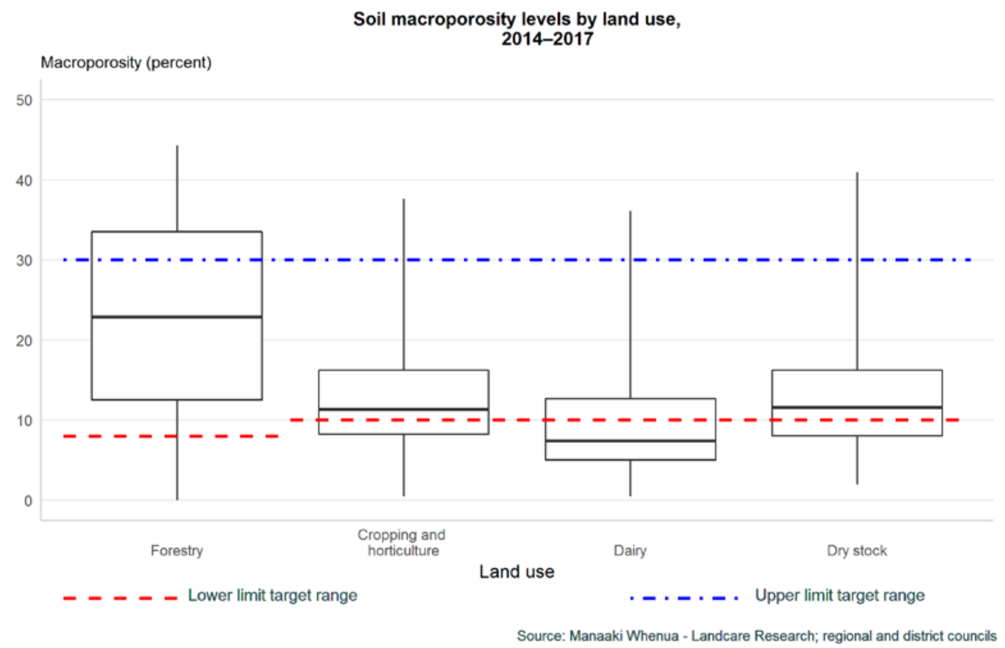
These levels of excess phosphorus and low macroporosity present a greater risk to water quality near those sites.

Figure 19



Note: Values above the red dashed lines are of most concern. The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The target range for soil phosphorus varies for land uses on different soil types. The red and blue lines indicate the highest and lowest recommended levels of soil phosphorus for each land use respectively (Mackay et al, 2013). For more information, see the indicator web page.

Figure 20



Note: Values under the red dashed lines are of most concern. The ends of each 'box' in the box-plot are the upper and lower quartiles (25 percent of the sites are either higher or lower than these values). The top and bottom 'whiskers' represent the highest and lowest value. The middle line of the box represents the median (middle) data point (half the sites are above and half below this value). The target range for macroporosity varies for land uses on different soil types. The blue and red lines indicate the highest and lowest recommended levels of macroporosity for each land use respectively (Mackay et al, 2013). For more information, see the indicator web page.

Soil biodiversity

Approximately one-quarter of all living species are found in the soil (FAO, 2015). A single teaspoon of healthy soil can contain more micro-organisms than there are people on Earth. Soils contain a wide variety of organisms, including bacteria and fungi, nematodes, mites, and earthworms to name a few. Together, these organisms play a crucial role in the key ecosystem services and global cycles that make all life possible (see figure 4 in Fundamentals).

Given the role of soil biota in the provision of ecosystem services, an understanding of soil biodiversity is critical to move beyond soil quality to consider soil health and ecosystem function.

How human activity changes soil biodiversity

A change in land use, such as converting forest to pasture, can cause significant changes in soil habitats. Vice versa, conversion from pasture to forest can result in soil carbon loss (Tate et al, 2005). This can result in strong shifts in soil biodiversity and the services those ecosystems provide (Wardle, 2002; Meyer et al, 2013; Allan et al, 2014; Orwin et al, 2016; Mueller et al, 2016).

New Zealand-based studies that address the full range of soil organisms are rare, largely due to the time involved in manually identifying species. This is changing with the development of new DNA techniques such as meta-barcoding approaches, where DNA sequences are matched to reference databases to determine which organisms are present and their relative abundance. These approaches have provided a means of monitoring the complex biodiversity of soil systems without manual identification.

A case study in the Wairau River catchment in Marlborough used this approach to provide the first New Zealand-based comprehensive assessment of soil biodiversity. It covered bacteria, fungi and metazoa across five different land uses (natural forest, planted forest, unimproved grassland, improved grassland, and vineyards), along with traditionally measured plant community composition. The study showed that the diversity and structure of the microbial communities differed between natural and intensively managed systems, for example, bacteria were richer in more intensive land uses, and metazoa showed the opposite trend (Wood et al, 2017).

Recent research has also demonstrated that the relative abundance of some groups of soil bacteria strongly correlate with soil quality parameters, such as Olsen P (Hermans et al, 2016, 2017).

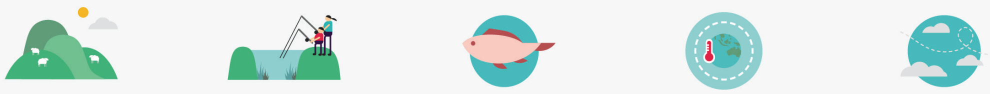
These studies highlight the usefulness of monitoring soil biodiversity to understand how land use affects the health and productivity of soil ecosystems.

Environmental impacts of soil degradation

Impacts of soil degradation extend much further than the land domain. Soil is a natural resource everyone depends on every day. Any degrading effects on soil can have long-term economic, cultural, societal, and cross-domain environmental impacts.

Consequences of erosion, poor soil quality, or a loss of soil biodiversity are seen in other domains (figure 21).

Figure 21 Environmental impacts of soil degradation



Land	Fresh water	Marine	Atmosphere & climate	Air
Soil quality changes can put added pressure on indigenous plant species and raise opportunities for invasive species.	Water quality and the ecological health of rivers, streams, and lakes can be degraded when eroded sediment, contaminants, and nutrients enter waterways.	A reduction in survival rates of many species and the loss of important marine habitats occurs when eroded sediment reaches estuarine and coastal areas.	Soil is a major carbon sink. Land use change can cause the soil carbon stock to increase or decrease, especially if there is a disturbance of the topsoil as in agriculture and production forestry. When a land use change decreases the soil carbon stock, carbon dioxide, a greenhouse gas, is emitted to the atmosphere. When a land use change increases the soil carbon stock, carbon is removed from the atmosphere.	Dry, bare soil can be eroded by wind, suspending particles in the air and causing respiratory issues, dust nuisance, and loss of fertile soil.
Erosion damages infrastructure such as fencing and roads on farms, and when it occurs, can cause significant impacts to roads, housing, and infrastructure (such as water pipelines).	Compacted soils are often slow draining, which can lead to more sediment and nutrients moving off the land and affecting waterways.		Soil carbon is an indicator of soil organic matter, which is important in supplying and retaining nutrients for plants and farm production and reducing the amount of nutrients leached to water.	
Erosion reduces the amount and quality of soil, leading to reductions in plant and animal productivity.	Sediment that enters waterways can build up in river channels leading to an increased flooding hazard and risk to infrastructure such as bridges.		We have limited understanding of the relationship between erosion and the storage/release of carbon.	
Reductions in soil quality can limit plant growth leading to reductions in animal productivity.			Soils that are wet or compacted are likely to have increased emissions of nitrous oxide, a greenhouse gas.	

Data gaps for soil

Soil type: We still rely on soil databases and maps that are patchy in scale, age and quality to describe what soils we have and where. Many maps do not adequately describe the underlying properties of the soil types they represent. S-map integrates existing reports and digital information and updates soil maps where existing data are of low quality but currently only covers 30 percent of New Zealand.

Soil erosion

Soil erosion (actual and over time): We lack national information on erosion over time because there is no comprehensive national monitoring programme. Many of the most prominent types of erosion, such as landslides, are triggered by storms and earthquakes which vary significantly over time.

Soil erosion (natural compared with human-accelerated erosion): We lack a clear understanding of what proportion of eroded material is from natural and what proportion is from human-accelerated erosion. This includes not only the effect of land use but the impacts (and uncertainties) of forecast climate change – in particular changes in rainfall and storm magnitude/frequency.

Soil erosion (and carbon): We have limited understanding of the relationship between erosion and the storage/release of carbon. This is important in considering the role of erosion in greenhouse gas sequestration and release.

Sediment impacts: We still lack understanding of the impacts of large magnitude earthquakes on hill slope erosion, river response, and sediment transfer. This includes the impact of sediment build-up in rivers and how this will affect flooding events and downstream infrastructure.

Soil quality

We use the regional council soil quality monitoring programme to measure the state of soil quality. However, four councils do not contribute to this programme, limiting a national perspective on the long-term trends in soil quality.

Some regions are under-represented (Southland, Northland, Taranaki) while regions with active soil quality monitoring programmes are over-represented (eg Waikato, Wellington, Auckland, Canterbury). Likewise, some soil types can be over-represented (eg brown soils) as well as some land uses (eg cropping and horticulture) (Cavanagh et al, 2017a, 2017b).

Soil biological indicators: While the regional council soil quality monitoring programme has a comprehensive focus on physical and chemical indicators, it does not comprehensively assess soil biological factors. More data on soil biology and its role in ecosystem service provision would take us closer to understanding soil health (see 'Soil biodiversity' below).

Soil biodiversity

Soil biodiversity and health: We lack data on soil biodiversity under different land uses, other than for specific sites. Without assessment of changes in soil communities and the services they provide, we are unable to form a more comprehensive picture of the state of soil biodiversity and ecosystem health in New Zealand.

Soil fauna: We lack data for critical soil fauna, which limits our ability to use meta-barcoding data to confidently identify species. The functional role of some soil fauna is reasonably well understood. However, scientists do not yet have a strong understanding of how changes in the composition and size of bacterial and fungal communities affect ecosystem processes such as nutrient cycling and soil mitigation.

5 The state of New Zealand's biodiversity and ecosystems

New Zealand's biodiversity is iconic – the varied species and ecosystems native to Aotearoa New Zealand are at the core of national identity and are central to our well-being. They provide diverse ecosystem services and have intrinsic value in their own right.

This chapter reports on the state of indigenous biodiversity (terrestrial plants and animals, including taonga species), and on the extent and distribution of indigenous land cover and ecosystems. It examines the pressures from human activity to build a view of the impact on the well-being of New Zealand's indigenous biodiversity, and the ecological integrity of our ecosystems.

The focus is on:

- **habitat extent and diversity** – changes in the extent and distribution of indigenous land cover and ecosystems
- **habitat quality** – the condition of habitats, and the pressures from habitat fragmentation and pests, weeds, and disease
- **species threat status** – the conservation threat status of indigenous plants and animals.

A case study of wetland ecosystems illustrates how these factors interact. The chapter concludes with notes on significant data gaps for biodiversity and ecosystems.

Soil biodiversity is covered in chapter 4 Soils, while chapter 3 Human activity covers how people interact with the environment.

Key findings

- There is continued loss of indigenous land cover. From 1996 to 2012, there has been a net loss of around 31,000 hectares of tussock grassland, 24,000 hectares of indigenous shrubland, and 16,000 hectares of indigenous forests through clearance, conversion, and development. Although these areas represent a small proportion of each cover type, the ongoing loss continues to threaten indigenous biodiversity.
- Coastal and lowland ecosystems that were once widespread (including wetlands) continue to decline in extent.
- Almost two-thirds of New Zealand's rare and naturally uncommon ecosystems are threatened.
- Except for some offshore islands and fenced sanctuaries, exotic pests are found almost everywhere in New Zealand. Predation and plant-eating by pests, as well as disease and competition from weeds, continue to threaten indigenous biodiversity.
- Our view of the conservation status of indigenous land species is restricted to those considered by New Zealand's threat classification system. Of the taxa that are assessed, nearly 83 percent (285 of 344 taxa) of indigenous terrestrial vertebrates (land-based animals with backbones) were classified as either threatened or at risk of extinction. This affects taonga species.
- The conservation status is worsening for some land species (seven bird species, three gecko species, and one species of ground wētā).
- The conservation status is improving for 20 bird species. More than half of these are dependent on intensive conservation management.

Introduction

He kura tangata e kore e rokohanga, he kura whenua ka rokohanga

A treasured person will not remain, treasured land always remains

Our identity as the people of Aotearoa New Zealand is tightly linked to our iconic biodiversity. The kiwi, after which New Zealanders take their nickname, and ponga (silver fern), are common icons that represent the country's unique natural environment and connection to the land.

In te ao Māori, people are kaitiaki for biodiversity, and whakapapa gives the inter-connections between the physical and spiritual world (see How whenua matters). The Māori creation story from Te Kore (the nothingness), through Te Pō (the night), to Te Ao Mārama (a world of light and opening) explains the range of lifeforms that exist and are connected through whakapapa – plants, animals, birds, microorganisms, the genes they contain, and the ecosystems they form (Harmsworth & Awatere, 2013). Te Ao Mārama symbolises a rich diversity of life, resources, and biodiversity and "richness of life" (Harmsworth, 2004). Indigenous species enable, inform, and inspire customary practices including mahinga kai, rongoā, waiata, and whaikōrero.

Man and plants have a common origin. Māori saw plants as having senior status – Tāne created them before mankind, and so were respected as older relatives. Plants are the link between man and the sacred ancestors, Papatūānuku and Ranginui (Harmsworth, 2004).

Biodiversity contributes to human well-being: economically, and socially through recreation and cultural values. The various ecosystem types provide different suites of ecosystem services such as soil formation, pollination, and nutrient cycling (see Land as the foundation of human life).

The variety of natural life also has intrinsic value (ie in its own right), independent of its usefulness or benefit to human society.

Many of our indigenous species, particularly our animals, come from old lineages – they are internationally distinctive and important to global biodiversity. A large proportion occurs nowhere else on earth (they are 'endemic'): this includes 78 percent of vascular plants and 91 percent of animal species (Gordon, 2013). If these species are lost to New Zealand and the world, they cannot be replaced.

New Zealand's species live together and interact with each other and their physical environments (or habitats), creating complex ecosystems that are more than the sum of their parts. This report uses the concept of ecological integrity to assess the well-being of these ecosystems. Ecological integrity has three key components: how much of the full suite of ecosystem types is represented; how well ecological processes (like forest regeneration) are functioning; and if the species present are the ones you would expect naturally.

The focus of this chapter is on the well-being of New Zealand's indigenous biodiversity and the ecological integrity of ecosystems. It includes material from a te ao Māori perspective of well-being. The chapter does not cover how people may benefit from exotic biodiversity for primary production. Chapters 1 Physical processes and 3 Human activity noted the pressures these can place on ecosystems and biodiversity. This chapter examines how those pressures affect the state of our biodiversity and ecosystems – in particular habitat loss, habitat degradation, and species loss – and how these interact to impact on biodiversity and ecosystems.

Habitat extent and diversity

Ko au te taiao, ko te taiao, ko au *The ecosystem defines my quality of life*

The focus of this section is on the diversity of habitats in Aotearoa New Zealand. The overall representation of different kinds of ecosystems (and the habitat provided there) is a core component of ecological integrity. Each habitat type is home to a unique set of species and ecological processes. If the remaining habitat of any one type is lost or severely depleted, the species and processes that have evolved there are also lost. For example, wetlands are home to taonga species such as the threatened matuku (Australasian bittern), and provide ecological processes such as water purification that do not occur in other ecosystems.

Different habitats support different recreational, cultural, and customary values, which cannot necessarily transfer to other habitats. For example, active sand dunes, now scarce, are the only places that support natural populations of pīngao (golden sand sedge). Pīngao is used in raranga and whatu to weave cloaks.

We are continuing to lose indigenous vegetation cover and ecosystems

Before humans arrived in New Zealand, over 80 percent of the country is estimated to have been forested. Other indigenous vegetation types such as shrubland and tussock grasslands made up large parts of drier regions, particularly on and to the east of the South Island's main divide.

See Predicted pre-human vegetation

Ecosystems such as wetlands and sand dunes were also once a large part of lowland and coastal areas. Since human settlement all these habitats have declined considerably through clearance, conversion, and development.

Three key indigenous land cover types (left to right): indigenous forest, shrubland, tussock grassland. Photos: Ministry for the Environment (left), Manaaki Whenua – Landcare Research (middle), Grant Norbury (right)

The Land Cover Database (LCDB version 4.1) uses satellite imagery to map vegetation types and other land cover. The latest available version (2012) shows that indigenous forest cover has been reduced to about one-quarter (26 percent) of New Zealand's land area – this is about one-third of its pre-human extent. Indigenous shrubland covers 7 percent and tussock grassland covers 9 percent.

See Land cover

Comparison of the land cover between 1996 and 2012 shows a net loss of 71,000 hectares of indigenous land cover. By land cover type, this net loss includes: about 31,000 hectares of tussock grassland (1.3 percent decrease); 24,000 hectares of indigenous shrubland (1.3 percent decrease); and 16,000 hectares of indigenous forest (less than 1 percent decrease). These represent further loss of environments that have already reduced, and decreases the area where indigenous plants and animals can live.

Indigenous vegetation is most threatened in coastal and lowland environments

The indigenous vegetation that remains is mostly in hilly and mountainous areas, most notably along the western side of the South Island, with only small fragments of indigenous vegetation remaining in lowland and coastal environments. What remains of lowland and coastal environments are poorly protected, making them at risk of further habitat loss (Cieraad et al, 2015). Areas of particular concern include the east of the South Island and most of the North Island.

See Indigenous cover and protection

Ecosystems once widespread (like wetlands and sand dunes) continue to decline in extent

Many ecosystems are too small or complex to be mapped at the current scale of national land cover mapping. Additionally, the ecosystems are often outside the public conservation areas monitored by the Department of Conservation. These include ecosystems that were once widespread such as wetlands and sand dunes.

Since human settlement, an estimated 90 percent of wetlands have been drained for agricultural or urban development, particularly swamps. Wetlands have been reduced from around 2,470,000 hectares to around 250,000 hectares, and continue to decline in extent.

See Wetland extent

Recent wetland loss between 2001 and 2016 was mapped across the country by visually comparing the Waters of National Importance (WONI) dataset against Sentinel-2 satellite imagery. This mapping shows that over a short period, 214 wetlands (nearly 1,250 hectares) were lost, with a further 746 wetlands declining in size. The regions with the greatest number of wetlands lost or under decline were Canterbury (231 wetlands), West Coast (135 wetlands), Southland (97 wetlands), and Auckland (94 wetlands). The visual comparison only captured wetland loss and does not capture new wetlands or any increases in extent (Belliss et al, 2017). For information on wetland condition, see Box 13.

Most larger wetlands are in public ownership. Between 1990 and 2013, protection status increased for some wetland types mainly in the South Island, but swamps, fens, and marshes have lower protection (Robertson, 2016). The vast majority of smaller wetlands, which contribute to the full diversity of lowland ecosystems in New Zealand, are on private land surrounded by agricultural landscapes (Myers et al, 2013). Around 7,500 hectares of wetlands on private land are protected under QEII covenants, which is about 5 percent of the total area of land cover protected under QEII (Queen Elizabeth II National Trust, 2016) (see chapter 3 Human activity: Conservation land).

Active sand dunes are another ecosystem type that were also historically widespread but now much reduced. Sand dunes are important because they provide a natural defence against coastal storms. These have declined in area by 80 percent between the 1950s and 2008, from around 129,000 hectares to 25,000 hectares. The main causes of the decline were the planting of marram grass to

See Active sand dune extent

stabilise shifting sands for coastal development and farming, and the planting of radiata pine for commercial forestry. Regions with the largest area of active sand dunes have also experienced the greatest decline in extent (eg Northland, Auckland, Waikato, and Manawatū) (Hilton, 2000).

Almost two-thirds of rare and naturally uncommon ecosystems are threatened

To date, 71 different rare and naturally uncommon ecosystems have been identified in New Zealand. These represent less than 0.5 percent of the land area of mainland New Zealand. They are ecosystems that are rare (they were once widespread and are now reduced in extent) and also naturally uncommon (they were never extensive). They occur in unusual physical environments, and include for instance unique geothermal communities and volcanic dunes. Each has distinct environmental conditions that support unique communities of plants and animals.

See Rare ecosystems

Rare and naturally uncommon ecosystems contain half of New Zealand's nationally threatened plant species. Similarly, 38 percent of the 160 nationally threatened Lepidoptera family (butterflies and moths) live in ecosystems that are themselves limited in distribution nationally (Williams et al, 2007).

Almost two-thirds (45) of New Zealand's 71 identified rare and naturally uncommon ecosystems are classified as threatened under the International Union for Conservation of Nature (IUCN, 2017) Red List criteria, based on changes in extent of ecosystems and reductions in ecosystem processes. Of these, 18 (40 percent) are critically endangered, which means they are at the greatest risk of degradation or loss.

Habitat quality

He kawenga ki te whenua,
ki nga uri o ngā atua
nāna i homai, māna anō e tango

The ethic of responsibility towards the natural environment is within the realms of Atua for he gives to us and takes away

The focus of this section is on habitat quality: the condition of indigenous habitats and how that condition is changing. The pressures from human activity and exotic invasive species have resulted in habitats and ecosystems being modified and fragmented (breaking into isolated patches), which in turn results in habitat degradation. (Climate change also contributes to habitat degradation – see chapter 2 Climate variability and change.)

Habitat degradation can threaten and create stress on declining or critically endangered indigenous biodiversity, and impede ecological processes such as regeneration. The degree of dominance of indigenous species (or alternately the dominance of exotic species) in indigenous habitats is a useful indicator of the overall condition of our ecosystems and natural ecological processes. This is the second core component of ecological integrity.

Habitat fragmentation

Many of New Zealand's habitats are now in smaller and more isolated fragments, which can reduce habitat condition and threaten indigenous biodiversity

As indigenous habitat has been lost in New Zealand, there has also been increasing fragmentation of indigenous ecosystems, particularly in lowland and coastal environments. Habitat fragmentation involves the creation of more habitat 'edges', which have different environments to the interior. For example, habitat edges experience more disturbance from increased light and greater wind, and have higher vulnerability to chance events such as fires or droughts. This combination can make habitat edges more vulnerable to pests, weeds, and disease.

Forest fragments in the North Island are on average four times smaller than in the South Island with more habitat edges (Ewers et al, 2006). A study on 769 New Zealand forest beetle species found that beetle communities at the forest edge differed in species richness and composition from those that live in deep forest interior. As many as one in eight common species were affected by edge effects that penetrated as far as 1 kilometre into habitat patches. This indicated that ecological processes operating less than 1 kilometre from forest edges might be altered relative to those in deep forest (Ewers & Didham, 2008).

Fragmentation can also lead to isolation of populations of particular species. Isolation happens at different spatial scales for different habitats and species; for example, more mobile birds can access and use multiple habitat fragments in a landscape, whereas other less mobile animals such as geckos may be restricted to a single fragment. Isolation of populations can lead to inbreeding and loss of genetic diversity, making isolated populations more vulnerable to new pathogens or changing environmental conditions (Jamieson, 2015).

Habitat fragmentation is complex. The influence of fragment size and shape, isolation, and surrounding land use operates across a variety of scales. This precludes the development of a single metric to report at the national scale. This report therefore does not present a measure of its impact beyond what can be understood from area-specific studies.

Pests, weeds, and diseases

New Zealand's indigenous ecosystems are under constant pressure from pests, weeds, and disease

While ongoing habitat loss and fragmentation continue to threaten indigenous biodiversity, some exotic species have become pests and contribute to habitat degradation. Animal pests (including insects) can eat indigenous animals and plants (predation and herbivory). Animal pests and weeds can also compete with indigenous species for food or habitat. Many animal and pest plants affect the productivity of agricultural and other productive land (see chapter 3 Human activity). The impacts of pests, weeds, and disease vary across the country, for different ecosystems and different species.

Except for some offshore islands and fenced sanctuaries, exotic pests are found over almost all (97 percent) land areas of New Zealand

Animal pests and weeds are pervasive and widespread and found almost everywhere in New Zealand. The Department of Conservation (DOC) collects information on the national distribution of some of the most damaging pest animals and plants. In 2014, almost all land areas of New Zealand had at least one serious exotic pest species.

See Land pests

Predatory possums, rats, and stoats are the most widespread of New Zealand's pests – they are present across at least 94 percent of the country (absent only from the tops of mountains and a few predator-free sanctuaries and offshore islands). Other plant-browsing exotic animals, including red deer and feral goats, were present across 57 percent and 30 percent of New Zealand respectively, mainly in forested and alpine areas. Himalayan thar were present across 7.5 percent of the country (in alpine regions of the central South Island). Wilding conifers (forestry species that have spread outside plantations, most notably contorta pine and Douglas fir) were present across 6.3 percent of New Zealand. Wilding conifers are a particular problem on indigenous tussock grassland in high country areas in Marlborough, Canterbury, Otago, Southland, and on the central plateau of the North Island (see chapter 3 Human activity: Forestry).

Other pest animals like rabbits and hares are widespread, with hares predominant throughout non-woody ecosystems, especially in alpine areas (mostly between 700 and 1,800 metres altitude) (Bellingham et al, 2013). New Zealand also has many other animal pests such as introduced wasps, mice, weasels, ferrets, feral cats, hedgehogs, and pigs, which affect indigenous biodiversity in many settings, including within urban areas.

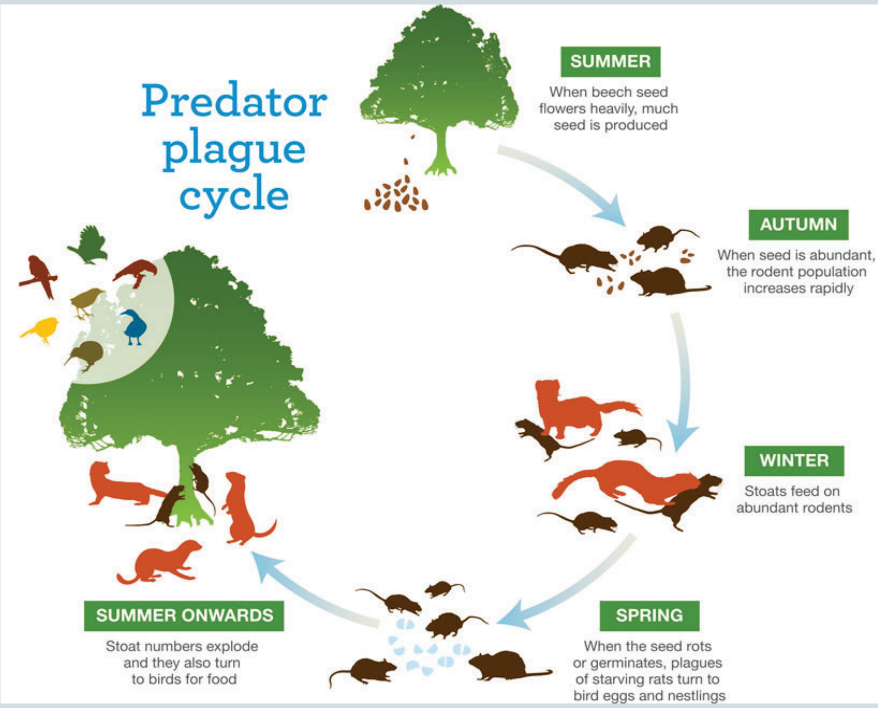
Predatory animals are a major cause of species decline

Exotic predators (such as rodents, mustelids, and possums, as well as feral cats and hedgehogs) eat native birds and their eggs, lizards, and invertebrates. They are a major cause of species decline (see Species threat status section).

Stoats are the most widespread of the New Zealand mustelid pests, and one of the world's most effective predators. Stoats prey on nesting birds and chicks, including larger species like kererū and kākā. Stoats are a factor in the decline of threatened species such as the rock wren, black stilt, kākāpō, and kōkako. Stoats are very mobile: in their average one-year life span, they occupy large home ranges and travel up to 70 kilometres in a fortnight. Stoats are the principal predator of the kiwi: up to 60 percent of young kiwi are eaten by stoats (McLennan et al, 1996; Brown et al, 2015). Researchers filming kiwi nests have observed stoats repeatedly visiting burrows while the eggs were being incubated, waiting for the chicks to hatch. Predation by stoats (as well as possums) can also skew the male to female ratios of bird populations, as females are more vulnerable when they are incubating eggs in the nest (eg kākā, kea, and mohua). Possums have also been recorded killing sooty shearwater (tītī or muttonbird), the brown kiwi, North Island kōkako, saddleback, Australasian harrier, fantail, and Westland black petrel (Brown et al, 1993; Sadlier, 2000).

Rats and mice have caused the declines or extinctions of many insects and lizards, including wētā, beetles, skinks, and geckos (Towns et al, 2006; St Clair, 2011; Newman, 1994). The impact of ship rats on indigenous birds is evident on Big South Cape Island near Stewart Island, which ship rats invaded in 1962. Rat populations grew rapidly, and within three years, nine species of birds declined or disappeared from the island, including South Island saddleback, Stead's bush wren, and Stewart Island snipe. On the New Zealand mainland, rats contributed to declines in populations of forest birds such as the North Island kōkako, kererū, kākāriki, yellowhead (mōhua), and brown creeper (Innes et al, 2010). See figure 22: Pest population responses to mast-seeding events.

Figure 22



Source: Department of Conservation

Mice, rats, and stoats are part of a complex predator–prey relationship. Many New Zealand plants (eg beech trees) produce very large amounts of seeds and fruits at irregular intervals (called masting). This leads to a dramatic increase in the populations of mice and rats, and in turn stoats. Populations can increase to up to five times their normal peak numbers (for rats) and nine times (for stoats). Increased populations of rodents and stoats increase predation on indigenous birds and other species.

See Modelled stoat and rat population responses to mast-seeding events

Browsing animals eat our native plants and can damage the canopy and understory of indigenous forest – some compete with native species for food, and some predate native birds

Browsing animals have food preferences, as humans do. Animals that eat native plants (such as possums, goats, and deer) prefer to eat certain tree species first. Selective browsing of palatable species (preferred food) can alter the makeup of forests. Some forests may become dominated by more unpalatable species (species that pests avoid), which, in turn, can affect food sources for indigenous species, the quality and quantity of leaf litter, and nutrient recycling (Wardle, 2006; Campbell, 1990).

Possums are the major cause of declines in distribution of some of their preferred trees – including canopy species (pōhutukawa, Hall's tōtara, kāmahi, māhoe, tawa, and rātā) and some smaller understory vegetation (such as patē, heketara) (Nugent et al, 2000; Nugent et al, 2001; Gormley et al, 2012). For example, possum browsing has killed nearly all the northern rātā trees from the Aorangi Range, near Wellington (Cowan et al, 1997).

Other exotic animals such as feral goat and deer also damage and modify the understory vegetation of the forest, through browsing on their favourite plants, stripping bark off trees, and trampling seedlings and saplings.

National information collected by the Department of Conservation between 2002 and 2014 (from 874 survey plots distributed across forests on both public conservation and private land) shows an imbalance in the populations of tree species that are palatable to possums and goats: more trees that are palatable to possums and goats are dying than are being replaced.

See Pest impacts on indigenous trees

Invasive insects such as wasps can also compete with indigenous birds and insects for food

Exotic social wasp species present a threat to indigenous species, particularly in beech forests in the eastern South Island (Beggs, 2001). Wasps compete for the sugary honeydew on beech tree trunks, an important food source for indigenous insects as well as birds such as tūī and bellbirds. In Nelson Lakes National Park, several common and widespread indigenous bird species (bellbird, rifleman, grey warbler, New Zealand tomtit, and tūī) declined over a 30-year monitoring period. These declines were attributed to the arrival of common wasps, which added to the existing impacts of rat and stoat predation (Elliot et al, 2010).

Invasive weeds can outcompete and replace indigenous plant communities

Along with animal pests, invasive weeds can directly threaten native biodiversity by competing with and excluding native species. Weeds can also threaten biodiversity indirectly, by altering ecosystem processes (Wotton & McAlpine, 2012). Many reduced and/or depleted and fragmented habitats are vulnerable to invasion by exotic plants; vulnerable habitat types include wetlands (exotic willows are an example of a problem plant), tussock grasslands (eg broom and wilding conifers), dunelands (eg marram grass) and lowland and coastal forest remnants (eg tradescantia and climbing asparagus).

Garden escapees and other weeds also affect indigenous species by preventing regeneration. Highly invasive, shade tolerant ground cover weeds like tradescantia (or wandering willie) are now widely distributed throughout lowland forest remnants in New Zealand (McAlpine et al, 2015). This weed forms thick mats of vegetation and prevents new growth of indigenous species. It also has been shown to reduce species richness and abundance of some invertebrates (Standish et al, 2001; Standish, 2004) (Urban biodiversity pressures are also discussed in chapter 3 Human activity: Urban land.)

Box 9: The status of our common and widespread bird communities is an important indicator of the condition of our ecosystems

See Bird species on public conservation land

Many indigenous birds play key ecological roles, that cannot be replaced by exotic birds. These roles include dispersing seeds and pollinating flowers. Bird monitoring carried out on public conservation land between 2013 and 2016 showed that indigenous bird species outnumbered exotic bird species on 96 percent (739 of 771) of forested sites compared with 75 percent (223 of 298 sites) of non-forested sites distributed across public conservation land. The most widespread bird species (detected in more than 50 percent of sites) include five indigenous species (grey warbler, silvereye, tomtit, bellbird, and fantail) and two exotic species (chaffinch and blackbird).

Two of our most common indigenous bird species on public conservation land – the silvereye (left) and the bellbird (right). Photos: Bernard Spragg (left), Sid Mosdell CC BY 2.0 (right)

Diseases also threaten indigenous biodiversity

In addition to pests and weeds, diseases also pose a serious threat to New Zealand's indigenous biodiversity. Diseases are caused by microscopic pathogens, and may be bacterial, viral, protozoan, or fungal. The impacts of these diseases vary with the nature of the pathogens, as well as the resistance and resilience of indigenous biodiversity. The greatest disease threats tend to come from particularly virulent pathogens that are new to New Zealand's indigenous biodiversity.

Myrtle rust is an example of a new fungal disease in New Zealand (detected on mainland North Island in 2017) that presents a threat to the Myrtaceae family. This plant family includes iconic and taonga plants such as pōhutukawa, rātā, mānuka, ramarama, and the exotic feijoa. The rust is dispersed by wind and therefore difficult to contain and manage.

Diseases can also threaten species that have already been affected by habitat loss or degradation. Kauri is a tree species that is of significant cultural value to Māori and was once widespread across the north of the North Island, estimated to have once covered 1 to 1.5 million hectares (Halkett & Sale 1986; Steward & Beveridge 2010). They were heavily logged in the 19th century, with about 7,500 hectares of mature kauri forest remaining (Steward & Beveridge, 2010). A disease significantly affecting kauri forests is kauri dieback, caused by a species of water mould (*Phytophthora agathidicida*) that is transported by humans and animals. It infects kauri through their roots and has no known cure (see Box 10: Kauri dieback disease impacts te ao Māori).

Diseases can also affect animal species, and further threaten declining or critically endangered indigenous animals. Examples include pathogens that cause 'crusty bum' (cloacitis) in kākāpō, infect bellbirds with avian malaria, and are potentially implicated in population crashes of Archey's frog (Bell et al, 2004).

Disease can have flow-on effects through ecosystems. For example myrtle rust damage to rātā and pōhutukawa trees may result in a loss of nectar available to honey eaters such as bellbirds and tūī. Kauri dieback could change kauri forest dynamics and resources available for other indigenous species in those forests.

There are many unknowns about diseases and pathogens. It can be difficult to identify which pathogens are causing a disease, whether a pathogen is indigenous or exotic, and to understand the source and spread of pathogens. Understanding the impacts of pathogens and diseases also requires a strong understanding of indigenous biodiversity and predisposing environmental factors.

Box 10: Kauri dieback disease impacts te ao Māori

Kauri is one of the longest living tree species in the world. The trees are deeply connected to Aotearoa New Zealand's history and sense of identity.

Tāne Mahuta. Photo: Ministry for the Environment

Kauri are taonga to Māori for their connection to Tāne Mahuta (god of the forest), as a traditional source for creating waka (canoes), and as a link to the spiritual realm. This places kauri at the centre of Māori culture, where plants are seen as having senior status (Harmsworth, 2004).

Toi tu te whenua, Toi tu te Kauri
When the land prevails, Kauri prevails

In New Zealand, our ngahere (forests, both native and exotic) provide resources and homes for our animals and ourselves. They provide sustenance, medicines, food, and shelter as well as a place of spiritual and social activities and connections. The indigenous forest is taonga and our home as tangata whenua.

Kauri trees themselves have unique spiritual, genetic and biological attributes that enable each kauri to grow according to its nature, to be a rākau rangatira, a canopy tree of significance.

Kauri dieback presents a real threat to te ao Māori. The loss to the ecological economy of Te Tai Tokerau, Tāmaki-makaurau, Hauraki, Coromandel, and Waikato, and the loss to the kaitiaki function of Māoritanga are separately and collectively significant. Kauri trees have value in themselves and contribute to both the ecological economy of mana ngahere and the economy of mana tangata. Should the kauri die, the ecological economy of mana ngahere suffers and its natural capital is greatly diminished. In turn, the ability of the kaitiaki, both spiritual and human, to carry out their function as mana atua and mana whenua, would also be profoundly diminished (Henare, 2014).

Species threat status

He kura taiao *Our living treasure*

The presence of indigenous plants and animals typical of an area and ecosystem is important for the integrity of ecosystems. The interactions of indigenous plants and animals result in complex ecosystems, where the loss or decline of a single species can have detrimental effects on other species and the wider ecosystem. For example, the kererū has a large gape (width of the open mouth) and can swallow and disperse the large seeds of plants such as tawa, miro, pūriri, and taraire. Tūī and korimako/bellbird are the only birds with the finely curved beaks that can open (and pollinate) the flowers of some native pikirangi/mistletoe.

The decline of a single species can also have impacts on the contribution an ecosystem makes to human well-being, for instance through recreation and cultural values (see Box 11: Kererū).

Box 11: Kererū abundances in Te Urewera and impacts for Tūhoe

Kererū. Photo: David Unger (CC BY-NC 2.0)

The kererū is a key taonga species that could provide a method of monitoring the environmental health of Te Urewera forest. The kererū (indigenous wood pigeon) illustrates the relationship between the ahikāroa (connection with place) and mahinga kai (food gathering). The number of kererū, the ability to source kererū for mahinga kai purposes and the presence of kererū in toromiro (miro) trees have been identified by Tūhoe people as cultural indicators for the health of the Urewera native forest (Lyver et al, 2016; Lyver et al, 2009).

Kererū are a key Te Urewera forest bird species. Narratives from Tūhoe interviewees describe changes to the kererū population over time. They talk of time before the 1950s when there was continuous 'rustling' sounds of the kererū flock in the forest canopy. Branches of toromiro trees would break as kererū landed to feed. In the decade 1970–80 large flocks of kererū were no longer observed and hunters would wait at the toromiro trees for the kererū to arrive. By 1990–2007 kererū were not present in the toromiro trees for entire fruiting seasons and only a few were observed in the forest during the year (Lyver et al, 2008).

Since humans arrived, at least 76 of our land species have become extinct

See Conservation status of indigenous species

New Zealand has experienced one of the highest species extinction rates in the world (IUCN 2017). Since the arrival of humans, evidence confirms the extinction of 59 bird, 8 plant, 2 reptile, 3 frog, and 4 insect species. This includes species such as the giant Haast's eagle, huia, and all nine moa species.

We do not have enough information to assess the conservation status of more than one-quarter (28 percent or 2,440 taxa) of terrestrial taxa that have been considered by the New Zealand Threat Classification System, particularly invertebrates

The New Zealand Threat Classification System assesses the risk of extinction of New Zealand taxa (all indigenous plant and animal species, subspecies, and varieties). To date, the conservation status of about 12,000 indigenous terrestrial taxa has been assessed – only a fraction of the total that are thought to exist. For vertebrates (birds, bats, and reptiles and frogs) and vascular plants, we have assessed all known land-based taxa in New Zealand. Many of the groups that have not been assessed, particularly invertebrates and lichens, are poorly understood.

We do not have enough information to assess the conservation status of more than one-quarter (28 percent or 2,440 taxa) of known land taxa, particularly our less visible species. These are recorded as 'data deficient' in the classification system. They include about 59 percent of earthworms (105 taxa), 54 percent of lichens (975 taxa), 38 percent of our spiders and terrestrial insects (943 taxa), and 31 percent of land snails (138 taxa) – see figure 23.

Of the taxa that are assessed, nearly 83 percent (285 of 344 taxa) of native terrestrial vertebrates (birds, bats, reptiles and frogs) were classified as either threatened or at risk of extinction

The Parliamentary Commissioner for the Environment offers these translations for the threat classifications: Threatened = in serious trouble; At risk = in some trouble; and Not threatened = doing okay (Parliamentary Commissioner for the Environment, 2017).[17]

Of taxa that have been assessed (figure 23), most reptiles and frogs (85 percent or 103 taxa), most bats (83 percent or five taxa), and most birds (82 percent or 177 taxa) were classified as threatened or at risk of extinction. Over one-third of plants, including vascular plants, mosses, hornworts, and liverworts (37 percent or 1,232 taxa) were threatened or at risk of extinction. These include many of New Zealand's culturally important and taonga birds (eg kākāpō, rock wren, fairy tern, and hoiho/yellowed-eyed penguin) and plants (eg Barlett's rātā and ngutukākā (kākā beak)).

Many species are at risk because they are 'naturally uncommon', meaning they have a small population size and/or restricted geographic range (particularly snails, earthworms, spiders, and insects). This means they are more vulnerable to localised threats and new global pressures such as climate change.

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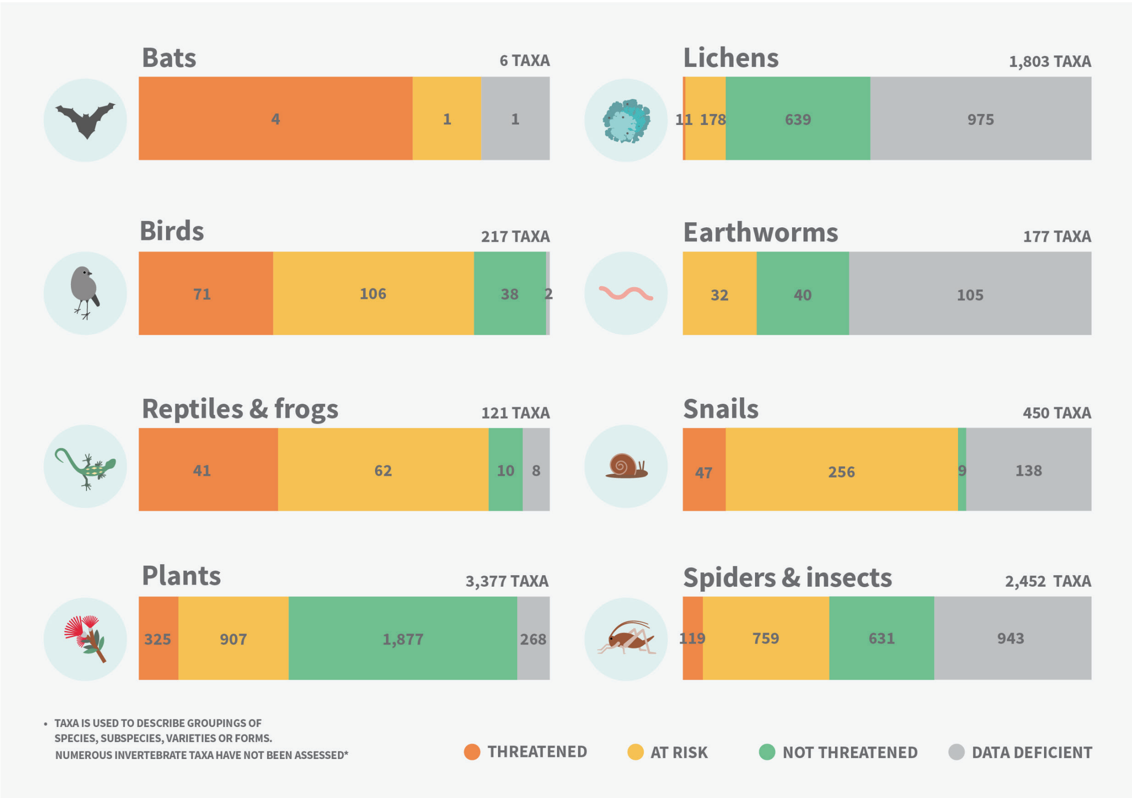
17 *Threatened*: species are at greatest risk of extinction. They are either extremely rare, rare following severe historical decline, declining at an extremely high rate, or both uncommon and declining. *At Risk*: not considered threatened but could quickly become so if declines continue or if a new threat arises. At risk species are either declining but not uncommon, or uncommon but not declining.

As a species declines to low numbers, its genetic diversity reduces. The low genetic diversity of some of the most threatened species makes them less resilient to disease, and to environmental change such as habitat degradation and climate change. The 2017 Parliamentary Commissioner for the Environment report on birds describes low genetic diversity as a major risk for the iconic and taonga kākāpō, which produces many infertile eggs and has a low hatching rate as a result of inbreeding (Parliamentary Commissioner for the Environment, 2017).

Figure 23 Conservation status of assessed land taxa by taxonomic group



Source: Department of Conservation; Andrew et al (2012); de Lange et al (2012); Leschen et al (2012); Mahlfeld et al (2012); Sirvid et al (2012); Stringer et al (2012a); Stringer et al (2012b); de Lange et al (2013); Newman et al (2013); O'Donnell et al (2013); Buckley et al (2014); Buckley et al (2014b); Rolfe et al (2016); de Lange et al (2015); Heath et al (2015); Hitchmough et al (2015); Trewick et al (2016); Robertson et al (2017); Ward et al (2017)

Note: Numerous invertebrate taxa have not been assessed. We exclude taxa that do not breed in New Zealand, and groups for which a recent threat classification is not available (eg fungi). We also include both taxonomically determinate and indeterminate taxa (ie those with an unconfirmed taxonomy). In addition to the above, 76 taxa are confirmed extinct.

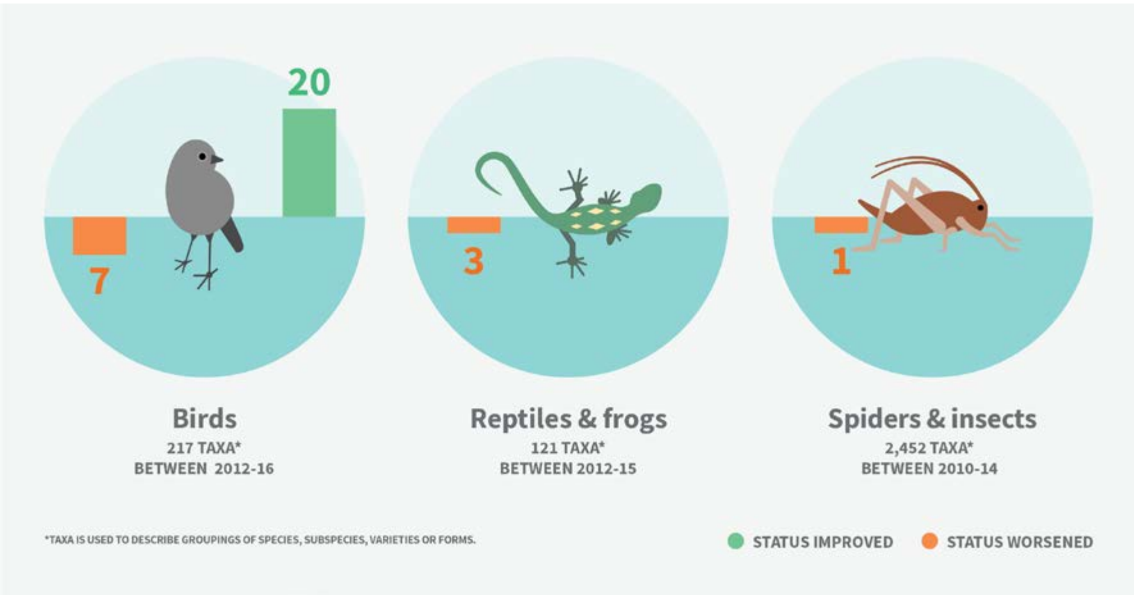
Within short timescales the extinction risk is worsening for some land species, although improving for some birds

For some species, the extinction risk worsened between 2010 and 2016 (figure 24). This applies to seven birds (the Australasian bittern (matuku), orange-fronted parakeet (kākāriki), yellow-eyed penguin (hoiho), whitehead (pōpokotea), North Island robin (toutouwai), South Island robin (toutouwai), and Campbell Island mollymawk; three geckos (Nelson green gecko, Central Otago gecko, and Cromwell gecko), and one terrestrial insect (one species of ground wētā). Three of the bird species, the whitehead and two robins, have moved from 'not threatened' status to 'at risk', due to ongoing decline of mainland populations. The increased risk of extinction is generally a result of predation and/or habitat loss and degradation (see earlier Pests, weeds, and diseases section).

In contrast, the risk of extinction reduced for 20 birds between 2012 and 2016. This improvement was dependent on intensive conservation management of these species, such as the efforts to eradicate rats from all of 11,300-hectare Campbell Island in 2001 and the Operation Nest Egg programme that kept kiwi eggs and chicks in captivity to increase their chances of survival. It is expected that more than half of the 20 species with improved status (the ones marked with an asterisk below) would return to a worse category if that conservation effort ceased. Of the 20 improved status bird species, one-quarter are still classified as threatened with extinction (Robertson et al, 2016).

The 20 improved status bird species were: the Campbell Island teal*, Auckland Island pipit (pīhoihoi)*, North Island brown kiwi*, rowi/ Ōkārito brown kiwi*, northern New Zealand dotterel*, Campbell Island snipe, Kermadec parakeet (kākāriki)*, Eastern rockhopper penguin, white-flippered blue penguin (kororā)*, New Zealand storm petrel*, North Island weka, Chatham Island warbler*, pied stilt (poaka), Otago shag*, northern giant petrel (pāngurunguru), mohua/yellowhead)*, North Island kākā*, sooty tern, red-tailed tropic bird, New Zealand dabchick (weweia).[18]

Figure 24 Number of assessed taxa with an actual change in conservation status, by taxonomic group, between 2010 and 2016



Source: Robertson et al (2013); Robertson et al (2017); Hitchmough et al (2013); Hitchmough et al (2015); Trewick et al (2012); Trewick et al (2016)

Note: There was no change in bats, snails, earthworms, plants, and lichens. An 'actual change' in conservation status is a result in a change in a species' population numbers or distribution, not a result of a change in available information, classification system, or taxonomy. The change is between different assessment periods: 2010–14 for terrestrial insects, 2012–15 for reptiles, and 2012–16 for birds.

[18] The asterix (*) denotes taxa that have a 'conservation dependent' qualifier, meaning they are likely to move to a worse conservation status if current conservation management ceases.

Box 12: The conservation status of the 'Tekapō ground wētā' worsened between 2012 and 2014

Wētā occupy much the same place in their ecosystems as mice do in other countries: they are nocturnal omnivores, and one of the few known insects that can pass seeds through their digestive tracts. The ground wētā is one of five types of wētā unique to New Zealand. It is very small and hides in burrows in the ground during the day and emerges at night to look for insects to eat. More than 30 species of ground wētā are found throughout New Zealand, but for many of them, we lack enough information on their ecology, distribution, and abundance to assess their conservation status.

Tekapō ground wētā. Photo: Tony Jewell

One species, *Hemandrus 'furoviarius'*, has no formal name but is sometimes referred to as the Tekapō ground wētā. It is only found in river margins of the Tekapō and nearby rivers of the Mackenzie Basin where it burrows in silty soils. Its habitat is vulnerable to disturbance and it has been recently reclassified from 'in some trouble' (at risk – naturally uncommon) to the most serious kind of trouble (threatened – nationally critical). Tekapō ground wētā is facing an immediate high risk of extinction due to observed declines between 2010 and 2014 (Trewick et al, 2016).

Wetlands: a case study of combined effects of multiple pressures

Habitat loss, habitat degradation, and species loss do not operate in isolation. These three pressures also interact, with compounding effect on indigenous biodiversity and ecosystem integrity

Many ecosystems are threatened by all three pressures of habitat loss, habitat degradation, and species loss. For example, habitat loss may result in habitat degradation through fragmentation of the habitat – increasing the proportion of 'edge' habitats vulnerable to pests, weeds, and disease. This fragmentation may also result in species isolation, making populations more vulnerable to chance events.

Box 13: All three pressures of habitat loss, habitat degradation, and species loss threaten our wetlands

Wetland ecosystems are permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals adapted to wet conditions (Resource Management Act 1991). Wetlands contain high proportions of threatened species, including 13 percent of nationally threatened plant species (Clarkson et al, 2013). Wetlands also provide ecological services including flood protection and water filtration. From a te ao Māori perspective, wetlands are considered taonga tuku iho. They provide habitat for species at the centre of a variety of important customary practices including mahinga kai (harvested food), raranga (weaving), and rongoā (medicines) and they support expression of cultural values.

New Zealand has lost an estimated 90 percent of wetland habitats since European settlement, mainly a result of drainage for farming and settlement. Most wetlands, particularly in lowland environments, are reduced to small remnants and surrounded by developed land (Myers et al, 2013). These losses are ongoing – see Habitat extent and diversity section.

At present, no coordinated national approach exists to monitor and report on the ecological condition of wetlands in New Zealand, except for recent developments in mapping changes in wetland extent (eg Belliss et al, 2017). However, available data indicates a strong connection between wetland loss and a decline in wetland condition (Clarkson et al, 2015). Evidence also suggests that wetlands are under continued pressure from surrounding land use, including drainage, nutrient enrichment and pollution, grazing, and the impact of invasive weeds (eg exotic willows) and animals (eg koi carp) (Ausseil et al, 2011; Myers et al, 2013).

Wetland loss and degradation can impact on many threatened species. The Australasian bittern (matuku), a bird specialised to wetland habitats, is a potential indicator of wetland health (O'Donnell, 2011). It has recently been reclassified during assessment periods between 2012 and 2016, as in the most serious kind of trouble (threatened – nationally critical), and faces an immediate high risk of extinction due to observed declines (Robertson et al, 2017).

Data gaps for biodiversity and ecosystems

Habitat extent and diversity

Ecosystem classification: We are lacking a nationally agreed, quantitative, and scalable ecosystem classification, and integrated national level monitoring system, to allow consistent assessment of state and risk at the ecosystem level.

Habitat quality

We have limited information on the condition of the full range of indigenous ecosystems, including rare and naturally uncommon ecosystems. Better information would enable us to assess ecosystem-level improvements, degradation, or stability, as well as changes in ecosystem processes such as carbon sequestration or water filtration.

Fragmentation: We do not have a measure of habitat fragmentation, or its impacts on various components of biodiversity.

Species threat status

Conservation status: We require more comprehensive information on the taxonomy, ecology, distribution, and abundance of some species (particularly invertebrates) to robustly assess their conservation status. We currently do not have information to assign a conservation status to 28 percent (2,440 taxa) of assessed terrestrial taxa.

Threat: We lack a clear understanding of the distribution, abundance, density, and impacts of pests and weeds, particularly at finer scales. We are also limited in our understanding of diseases and pathogens, their taxonomy and origins, and factors that determine their spread and impacts. Better information would support understanding of where the greatest pressures are on our ecosystems, and their relative risks.

Appendix: Data sources and specific gaps

Table 3 Environmental indicators Te taiao Aotearoa – Land

Chapter	Indicator	Dataset	Data supplying agency
2. Climate variability and change	Coastal sea-level rise	Six locations around New Zealand	National Institute of Water and Atmospheric Research (NIWA) and Emeritus Professor John Hannah (previously University of Otago)
	Rainfall intensity	30 regionally representative climate stations from National Climate Database (CLIDB)	NIWA
	Soil moisture and drought	Virtual Climate Station Network (VCSN)	NIWA
	National temperature time series	NIWA's 'seven-station' temperature series	NIWA
	Frost and warm days	30 regionally representative climate stations from the National Climate Database	NIWA
	Growing degree days	30 regionally representative climate stations from the National Climate Database	NIWA
	Annual glacier ice volumes	1978 New Zealand Glacier Inventory and the annual New Zealand glacier snowline survey programme	NIWA
3. How human activity affects the land	Predicted pre-human vegetation	Land Environments of New Zealand (LENZ)	Manaaki Whenua – Landcare Research
	Land cover (urban)	Land Cover Database (LCDB Version 4.1)	Manaaki Whenua – Landcare Research
	Use of public conservation land	Online bookings portal, concessions database	Department of Conservation
	Land cover (forestry)	Land Cover Database (LCDB Version 4.1)	Manaaki Whenua – Landcare Research
	Carbon stocks in forests	Land Use Carbon Analysis System (LUCAS)	Ministry for the Environment
	Agricultural and horticultural land use	Agricultural Production Censuses and Surveys	Stats NZ and Ministry for Primary Industries
	Change in farm numbers and farm size	Agricultural Production Censuses and Surveys	Stats NZ and Ministry for Primary Industries
	Change in livestock numbers	Agricultural Production Censuses and Surveys	Stats NZ and Ministry for Primary Industries
	Land use (urban)	Land Cover Database (LCDB Version 4.1)	Manaaki Whenua – Landcare Research

Chapter	Indicator	Dataset	Data supplying agency
	Irrigated land area	Spatial map from aerial photographs, multispectral satellite analysis and imagery, resource consent records, and property boundary extents (ie land ownership and title data)	Aqualinc, for Ministry for the Environment collated data, including data from Land Information New Zealand (LINZ)
	Change in use of Māori land for primary production	Agricultural Production Censuses and Surveys	Stats NZ and Ministry for Primary Industries
	Land cover (urban)	Land Cover database (LCDB Version 4.1)	Manaaki Whenua – Landcare Research
4. The state of New Zealand soils	Estimated long-term soil erosion	New Zealand Empirical Erosion Model and Land Cover database (LCDB Version 4.1)	Manaaki Whenua – Landcare Research
	Estimated highly erodible land in the North Island	Highly Erodible Land Model	Manaaki Whenua – Landcare Research
	Soil quality and land use	Regional and unitary council soil quality monitoring programmes	Data from Northland, Waikato, Bay of Plenty, Hawke's Bay, Manawatu-Wanganui, Wellington, Canterbury, Southland regional councils; Marlborough and Tasman district councils; and Auckland Council were collated by Manaaki Whenua – Landcare Research
5. The state of New Zealand's biodiversity and ecosystems	Predicted pre-human vegetation	Land Environments of New Zealand	Manaaki Whenua – Landcare Research
	Land cover (indigenous)	Land Cover database (LCDB Version 4.1))	Manaaki Whenua – Landcare Research
	Indigenous cover and protection	Threatened Environment Classification– a combination of Land environments of New Zealand, Land Cover Database (LCDB Version 4.0), and Protected Areas Network – New Zealand	Manaaki Whenua – Landcare Research
	Wetlands (contemporary loss)	Waters of National Significance and Sentinel -2 satellite imagery	Ministry for the Environment and Manaaki Whenua – Landcare Research
	Wetlands (historic extent)	Model using Fundamental Soil Layers database, and Geographic Information System	Manaaki Whenua – Landcare Research
	Active sand dune extent	Historic topographic maps, aerial photographs, and satellite imagery	Manaaki Whenua – Landcare Research and the Department of Conservation
	Rare ecosystems	Identified by experts and subjected to the International Union for the Conservation of Nature's (IUCN) Red List criteria	Manaaki Whenua – Landcare Research

Chapter	Indicator	Dataset	Data supplying agency
	Modelled rat and stoat population responses to mast seed events	Population models for rat and stoat responses	Massey University
	Pest impacts on indigenous trees	Tier 1 monitoring programme	Department of Conservation
	Bird species on public conservation land	Tier 1 monitoring programme	Department of Conservation
	Conservation status of indigenous terrestrial species	New Zealand Threat Classification System (NZTCS)	Department of Conservation

Table 4 Specific data gaps

Chapter	Section	Data gap	Explanation
1 – Physical processes	Natural forces	*Natural pressures and their impact*	We need to identify indicators for the incidence of earthquakes and fires, and other natural disasters that put pressure on the land environment and can have impacts on human well-being.
2 – Climate variability and change	Long-term climate change	*Biophysical characteristics*	In the case of climate change, the gaps are in people's understanding of what may happen in the future and how to model the impacts, rather than in data itself. These knowledge gaps (as they relate specifically to this report) are mostly about to biophysical characteristics of changing systems. Physical processes: there are still key uncertainties in understanding how global circulation models translate to the New Zealand context. Better downscaled models specific to New Zealand will help improve our understanding of key challenges such as future precipitation changes, sea-level rise, extreme events (droughts and floods), and tropical cyclone frequency and intensity. Quantifying vulnerability to climate change is another area where we lack knowledge. For instance, we do not yet have a detailed understanding of how a changing climate will add to the pressures of habitat loss and fragmentation, and pests, weeds, and diseases faced by already vulnerable indigenous flora and fauna. For productive systems, we need to understand how climate change would impact on productivity and on the environment (eg risks of sedimentation or nutrient loss). We also need to understand how changes in frequency of extreme events could affect both productive and natural systems, to enable New Zealand to anticipate, adapt, and prepare.

Chapter	Section	Data gap	Explanation
3 – How human activity affects the land	Land cover	*Land cover*	The report relies on the Land Cover Database Version 4.1 (LCDB 4.1), mapped from satellite imagery, to understand extent of and change in land cover. This LCDB has not been updated since 2012. Options are currently being investigated to fund the production of LCDB5 and LCDB6.
	Major land uses	*Land use (general)*	We do not have a single, comprehensive, robust nationally representative land use dataset that characterises New Zealand's land use, and how this is changing spatially and temporally. Current estimates are based on data from a variety of sources and proxies.
		Land ownership	We would benefit from greater detail on land ownership and protection status (across Crown and other public and private land including Māori land) including how these have changed over time (pre-colonial, post-colonial, 1950s, and today).
		Land use (primary sector)	The report relies on Agricultural Production Survey data from 2002 to map the location and extent of primary sector land uses. The data are not spatial, are limited to 'commercial scale' farms, and do not incorporate all forestry.
		Land use intensity (primary sector)	We do not have an accurate indication of the intensity of land use within land use classes. The indicators used are limited to a few input indicators (irrigation, stock density). We need better input indicators (improved dataset on stock density, fertiliser application, pesticides) and some indicators on agricultural performance such as nutrient use efficiency, to better understand the likely pressures from human activities.
		Land use (urban)	The report uses LCDB 4.1 to understand the extent of and change of urbanisation. Change since 2012 is therefore not captured.
		Visitor activities (conservation)	While we have good information about recent increases in international visitors, there is no national dataset that describes visitor activities (eg scenic drive, trekking, and camping) and the locations of those activities with enough detail to be used to signal particular environmental pressures.
	Extractive activities	*Legacy and current activities*	We do not have systematically collated data on environmental impacts from legacy and current mining activities, nor the impacts of oil and gas onshore production. The report relies on research studies, some which collate compliance monitoring reports and data from regional councils but these are of variable quality/use for assessing impact. We also lack information on environmental impacts (particularly on streams) of aggregate (and limestone) quarrying operations, and we do not have aggregated information on ironsand operations.
	Waste	*Waste (overall)*	We have limited data on waste (from 11 percent of the country's landfills, equating to about 30 percent of the total waste stream). Waste disposal facilities are spread across the private and public sectors, and there is no

Chapter	Section	Data gap	Explanation
			existing legislated requirement to collect more information about the remaining two-thirds of the country's waste, including about where it is going, how much of it there is, or what it is made up of.
		Rural waste	We have regional data to indicate rural waste volumes and disposal methods, but the full extent of disposal of waste to land outside managed facilities is unknown, as is the nature of materials disposed of and the related environmental risks.
		Recycling operations	We lack an integrated national dataset covering recycling and re-use operations, and the volumes redirected from the waste stream.
	Contaminated land	*Contamination (overall)*	We know the types of land contamination in New Zealand, and to a degree how these chemicals impact on human and environmental health, but we are unable to report on extent. There is some regional information (such as on the Specific Land Use Register), but there is no integrated national information about the extent of potential and known contaminated sites.
4 – The state of New Zealand soils	Soil	*Soil type*	We still rely on soil databases and maps that are patchy in scale, age and quality to describe what soils we have where. Many maps do not adequately describe the underlying properties of the soil types they represent. S-map integrates existing reports and digital information and updates soil maps where existing data are of low quality but currently only covers 30 percent of New Zealand.
	Soil erosion	*Soil erosion (actual and over time)*	We lack national information on erosion over time because there is no comprehensive national monitoring programme. Many of the most prominent types of erosion, such as landslides, are triggered by storms and earthquakes which vary significantly over time.
		Soil erosion (natural compared with human accelerated)	We lack a clear understanding of what proportion of eroded material is from natural and what portion is from human-accelerated erosion. This includes not only the effect of land use but the impacts (and uncertainties) of forecast climate change – in particular changes in rainfall and storm magnitude/frequency.
		Soil erosion (and carbon)	We have limited understanding of the relationship between erosion and the storage/release of carbon. This is important in considering the role of erosion in greenhouse gas sequestration and release.
		Sediment impacts	We still lack understanding of the impacts of large magnitude earthquakes on hill slope erosion, river response and sediment transfer. This includes the impact of sediment build-up in rivers and how this will affect flooding events and downstream infrastructure.

Chapter	Section	Data gap	Explanation
	Soil quality	*Soil quality*	We use the regional council soil quality monitoring programme to measure the state of soil quality. However, four councils do not contribute to this programme, limiting a national perspective on the long-term trends in soil quality. Some regions are under-represented (Southland, Northland, Taranaki) while regions with active soil quality monitoring programmes are over-represented (eg Waikato, Wellington, Auckland, Canterbury). Likewise, some soil types can be over-represented (eg brown soils) as some land uses (eg cropping and horticulture) (Cavanagh et al, 2017a; 2017b).
		Soil biological indicators	While the regional council soil quality monitoring programme has a comprehensive focus on physical and chemical indicators, it does not comprehensively assess soil biological factors. More data on soil biology and its role in ecosystem service provision would take us closer to understanding soil health (see next item).
	Soil biodiversity	*Soil biodiversity and health*	We lack data on soil biodiversity under different land uses, other than for specific sites. Without assessment of changes in soil communities and the services they provide, we are unable to form a more comprehensive picture of the state of soil biodiversity and ecosystem health in New Zealand.
		Soil fauna	We lack data for critical soil fauna, which limits our ability to use meta-barcoding data to confidently identify species. The functional role of some soil fauna is reasonably well understood. However, scientists do not yet have a strong understanding of how changes in the composition and size of bacterial and fungal communities affect ecosystem processes such as nutrient cycling and soil mitigation.
5 – The state of New Zealand's biodiversity and ecosystems	Habitat extent and diversity	*Ecosystem classification*	We are lacking a nationally agreed, quantitative and scalable ecosystem classification, and integrated national level monitoring system, to allow consistent assessment of state and risk at the ecosystem level.
	Habitat quality		We have limited information on the condition of the full range of indigenous ecosystems, including rare and naturally uncommon ecosystems. Better information would enable us to assess ecosystem level improvements, degradation, or stability, as well as changes in ecosystem processes such as carbon sequestration or water filtration. We don't have a measure of habitat fragmentation, or its impacts on various components of biodiversity.
	Species threat status	*Conservation status*	We require more comprehensive information on the taxonomy, ecology, distribution and abundance of some species (particularly invertebrates) to robustly assess their conservation status. We currently do not have information to assign a conservation status to 28 percent (2,440 taxa) of assessed terrestrial taxa.

Chapter	Section	Data gap	Explanation
		Threats	We lack clear understanding of the distribution, abundance, density and impacts of pests and weeds, particularly at finer scales. We are also limited in our understanding of diseases and pathogens, their taxonomy and origins, and factors that determine their spread and impacts. Better information would support understanding of where the greatest pressures are on our ecosystems, and their relative risks.
4 & 5 – Soil and Biodiversity and ecosystems	Impacts		We lack basic characterisation of the impacts of the change in state of soils and biodiversity on our economy, culture and recreation. In this report we rely heavily on additional sources or express these descriptively through case studies. A systematic approach and data to better quantify impact is required.
	Cultural impacts		We are limited in how best to use mātauranga Māori and tikanga Māori, to understand the cultural impacts of change in state particularly on kaitiakitanga, customary use, and mahinga kai.

Glossary – te reo Māori[19]

ahikāroa	Connection with place; traditionally relates to having title to land by occupation, signified by 'long-burning fires'
ahuwhenua	Land management trust – established under Te Ture Whenua Māori 1993
awa	River
hapū	Sub-tribe
heketara	Tree daisy, *Olearia rani*
hoiho	Yellow-eyed penguin, *Megadyptes antipodes*
iwi	Extended kinship group, tribe, nation, people, nationality, race – often refers to a large group of people descended from a common ancestor and associated with a distinct territory
kaitiaki	Agent or guardian carrying out the act of tiaki, of benefit to the resource or taonga, can be a human, animal, or spiritual being; for example, taniwha (a mythical or spiritual creature, can take many forms, for example, large tuna)
kaitiakitanga	Stewardship, guardianship
kākā	Forest parrot, *Nestor meridionalis*
kākāpō	Ground parrot, *Strigops habroptilus*
kākāriki	Parakeet, includes yellow-crowned parakeet, orange-fronted parakeet, red-crowned parakeet, Forbes' parakeet, Antipodes Island parakeet, Kermadec parakeet
kāmahi	*Weinmannia racemosa*
kānuka	White tea-tree, *Kunzea ericoides*
kārearea	New Zealand falcon, bush falcon, bush hawk, *Falco novaeseelandiae*
kauri	*Agathis australis*
kawa	Marae protocol – customs of the marae and wharenui (meeting house), particularly those related to formal activities
kāwanatanga	Governorship, government, rule, authority
kawenata	Covenant
kea	Mountain parrot, *Nestor notabilis*
kererū	New Zealand pigeon, *Hemiphaga novaeseelandiae*
kōkako	*Callaeas cinerea*

[19] Based on glossary in Scheele et al (2016), *Reporting environmental impacts on te ao Māori: A strategic scoping document*, prepared by Landcare Research for the Ministry for the Environment – with permission of Garth Harmsworth (one of authors). Supplemented with definitions from the Māori Dictionary.

korimako	Bellbird, *Anthornis melanura*
kororā	Little penguin, little blue penguin, blue penguin, fairy penguin, *Eudyptula minor*
mahinga kai	Food-gathering area
māhoe	Whiteywood, *Melicytus ramiflorus*
mana	Prestige, authority, control, power, influence, status, spiritual power, charisma
mana atua	Sacred spiritual power from the atua
mana ngahere	Authority over forest, bush
mana tangata	Power and status accrued through one's leadership talents, human rights, mana of people
mana whenua	People with tribal authority over a defined area of land, indigenous rights, status
mānuka	Tea-tree, *Leptospermum scoparium*
māoritanga	Māori culture, Māori practices and beliefs, Māoriness, Māori way of life
marae	Traditional gathering area, area for formal discourse at front of meeting house
marae tipuna	Ancestral marae
mātauranga Māori	Māori knowledge, Māori philosophy
matuku	A general name for various herons and the Australasian bittern
maunga	Mountain, mount, peak
mauri	The essential essence of all beings, the life force which is in everything
miro (also toromiro)	Brown pine, *Prumnopitys ferruginea*
moa	Large extinct flightless birds
mohua	Yellowhead, *Mohoua ochrocephala*
ngahere	Bush, forest
Ngā Whenua Rāhui	The Ngā Whenua Rāhui Fund is a contestable Ministerial Fund that exists to facilitate the voluntary protection of indigenous ecosystems on Māori land while honouring the rights guaranteed to Māori land owners under Te Tiriti o Waitangi
ngutukākā	Kākā beak, *Clianthus maximus*
pāngurunguru	Northern giant petrel, *Macronectes halli*
papakāinga	Original home, home base, village, communal Māori land
Papatūānuku	Earth Mother
patē	Seven finger, *Schefflera digitata*
Pīhoihoi	New Zealand pipit, *Anthus novaeseelandiae*

Pikirangi	Red mistletoe, *Peraxilla tetrapetala*
pīngao	Golden sand sedge, *Ficinia spiralis*
poaka	Pied stilt, *Himantopus himantopus leucocephalus*
pōhutukawa	New Zealand Christmas tree, *Metrosideros excelsa*, *Metrosideros kermadecensis*, *Metrosideros bartlettii*
ponga	Silver fern, *Cyathea dealbata*
pōpokotea	Whitehead, *Mohoua albicilla*
pounamu	Greenstone, nephrite, jade
pōwhiri	Invitation, rituals of encounter, welcome ceremony on a marae, welcome
pūriri	*Vitex lucens*
ramarama	*Lophomyrtus bullata*
rangatiratanga	Principle of authority
Ranginui	Sky Father
raranga	Weaving
rātā	*Metrosideros robusta* (Northern), *Metrosideros umbellata* (Southern)
rohe	Boundary, territory, geographic location, typically of iwi/hapū
rongoā	Remedy, medicine, treatment
rowi	Ōkārito brown kiwi, *Apteryx mantelli Okarito*
Tāne Mahuta	*Atua* of the forests and birds and one of the children of Ranginui and Papatūānuku
tangata whenua	Local people, people born of the whenua, people who have authority in a particular place
taonga	All things prized or treasured, tangible and intangible, treasured resource, possession or cultural item, including te reo, culturally significant species
taonga tuku iho	Those treasures that have been passed down, cultural property, heritage
taraire	*Beilschmiedia tarairi*
tawa	*Beilschmiedia tawa*
te ao Māori	The Māori world, Māori world view
Te ao Mārama	The world of life and light, Earth, physical world (a world of light and opening)
te Kore	The realm of potential being, The Void (the nothingness)
te Kupenga	Stats NZ’s first survey on Māori well-being
te mana o te whenua	The integrated and holistic well-being of the land
Te Pō	The darkness, night

te Tiriti o Waitangi	The Treaty of Waitangi
te reo Māori	The Māori language
tikanga	Custom, protocols, ethics
tītī	Muttonbird, sooty shearwater, *Puffinus griseus*
toromiro (also miro)	Brown pine, *Prumnopitys ferruginea*
toutouwai	New Zealand robin, *Petroica longipes, Petroica australis australis, Petroica australis rakiura*
tūī	Parson bird, *Prosthemadera novaeseelandiae*
tūrangawaewae	Place of being, origin, homeland
urupā	Burial ground
waka	Canoe
weka	Woodhen, *Gallirallus australis greyi*, *Gallirallus australis australis*
wētā	Large insects of various species found in trees and caves
weweia	New Zealand dabchick
whaikōrero	To make a formal speech
whakapapa	Genealogy, ancestry, interconnectedness
whatu	To weave (garments, baskets, etc.), knit
whenua	Land, homeland

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