Our land 2021

New Zealand's Environmental Reporting Series

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Cover: Takapu Valley, looking south to Wellington city.
Photo: Nature's Pic Images

Contents

Message to readers

Whenua – land – is the foundation of our environment and the connection between the atmosphere, climate, freshwater, and ocean. Its forms are diverse, complex, and in some places, highly modified. Choosing where to focus an environmental report such as this is therefore challenging.

A previous report, *Our land 2018*, documented what we know across a breadth of issues affecting the land resources, ecosystems, and species of Aotearoa New Zealand. This report is different. It zooms in on a single issue: how intensively we are using and managing our land. This issue emerged as the most pressing when the spatial extent and scale, magnitude of change, irreversibility, and impact on the things we value was considered.

Decisions about how we use and manage land start before we even step on the soil. Landowners, hapū, local communities, and councils have a role, but so do we. The choices we make about what to eat, what to buy and sell, and where to live are driving the type and intensity of land use in our country. Every generation leaves a legacy on the land according to the choices they make.

Our land is finite and in demand. Some land is particularly good for food production, but if that land is unavailable for agriculture (because we have built houses on it), other less productive land has to be used. This can involve the use of more fertiliser and irrigation to ensure good yields but risks damaging the quality and health of the soil as well as the wider environment.

Discerning the impacts of our land use and management is complex because of the connections and interactions that occur across multiple parts of the environment. While a set of new and updated indicators provide important information about the changes that are occurring to New Zealand's land and soil, significant gaps remain. Better and more targeted data is needed, particularly to understand the impact of intensive land use on native ecosystems.

We still have an incomplete picture of the effect of our land-based activities on the environment and our wellbeing. Building this picture is an urgent task as future New Zealanders are likely to face more uncertainty and greater pressure to make good decisions than we do. They will have to contend with a changing climate and a growing population to feed, both here and overseas.

Land is our tūrangawaewae, our place to stand. It is on loan to us for just a fraction of its ecological journey through time. Our collective challenge is to ensure our decisions today consider both the whole environment and the future generations into whose hands we will entrust this most precious asset.

Vicky Robertson
Secretary for the Environment

Mark Sowden
Government Statistician

Structure and content of this report

Our land 2021 is the latest in a series of environmental reports produced by the Ministry for the Environment and Stats NZ. It builds on *Our land 2018* and *Environment Aotearoa 2019* and is based on one of the five themes identified in *Environment Aotearoa 2019*: how we use our land.

In 2019, the Parliamentary Commissioner for the Environment suggested replacing domain reports with theme-based commentaries and including information about drivers and outlooks. To address this advice, *Our land 2021* has focussed on one issue in the land-use theme: land-use change and intensification. The report also explores land-use change and intensification as it presents across different parts of the environment.

The focus arose because of the significance of the issue in terms of the extent and magnitude of change, the irreversibility and lasting effects of change, and the effects on culture, recreation, health, and the economy. Some aspects of our land environment are consequently not presented in detail. These include biodiversity decline, pests and diseases, and pollution.

Our land 2021 discusses:

- the factors driving the ways we use land (chapter 2)
- how our activities affect land and the wider environment (chapters 3 and 4)
- the consequences of land use for wellbeing now and into the future (chapter 5)
- how climate change may affect land use in the future (chapter 6)
- the fundamentals for building a better understanding of this issue.

This report uses the best available indicator data to illustrate the changes in land use and intensification, and their consequences. Land fragmentation highlights the loss of highly productive land especially in rural areas, through the development of lifestyle blocks and rural subdivisions. The effects of agricultural intensification on our soils is shown in nearly 25 years of soil quality monitoring data. Questions about the effectiveness of environmental target ranges for freshwater quality are also highlighted.

New data related to New Zealand's land cover, soil quality, and land fragmentation is presented in chapter 3. The updated land-cover data has enabled more accurate estimates of current land cover and land use, as well as changes in land use, to be made.

Further supporting information is provided using a 'body of evidence' approach. This is defined as peer reviewed, published literature, and data from reputable sources. It includes mātauranga Māori and observational tools used to identify changes in an ecosystem.

Chapter	Indicator data reported
Chapter 1 **Our place to stand**	Rare ecosystems
Chapter 2 **The driving forces**	Exotic land cover Urban land cover
Chapter 3 **Activities and their effects**	Agricultural and horticultural land use Exotic land cover Farm numbers and size Fertilisers – nitrogen and phosphorus Indigenous land cover Irrigated land Land fragmentation Livestock numbers Urban land cover Soil quality and land use
Chapter 4 **Effects on the wider environment**	Consented freshwater takes Exotic land cover Indigenous land cover Irrigated land Livestock numbers
Chapter 6 **Land and a changing climate**	Growing degree days

CHAPTER 1

Our place to stand

Ashburton and the Ashburton River/Hakatere.

Photo: photonewzealand

Land is central to our identity as people of Aotearoa New Zealand – it is our tūrangawaewae, our place to stand. This country's unique landscapes connect us culturally and emotionally to the whenua (land) we call home.

As tangata whenua – people of the land – Māori have a distinct and special connection to land.

Land is valuable. It is a place for us to live, to make a living, and to grow the food and materials we need for ourselves and to export. From far north to deep south, huge variations in the landforms, soil, and climate influence how land across the country can best be used and managed.

The state of our land today is a legacy of the ways it was used by previous generations. Some former land uses limit how we can use it today. In the same way, our choices about land use today will affect future generations.

Māori are intimately connected to land

For Māori, the people of a place are related in personal terms to its mountains, land, and rivers, as well as the ecosystems and species present through whakapapa (ancestral lineage and connection). These are taonga tuku iho – treasures passed down through time under kaitiakitanga (guardianship).

Many Māori people reference their tribal boundaries and other landmarks when introducing themselves. Locating oneself with features of the land signifies a connection with a mountain, a lake, a river, or a coast, and the land within these boundaries.

A common Māori practice under tikanga (practice) and kawa (protocol) is to bury a baby's placenta in the soil. The word 'whenua' also means placenta, which references the direct connection between Papatūānuku (Earth mother) and the nourishment she provides to all her people. The connection is physical and spiritual, and integral to the survival and wellbeing of Māori. It is shown through whakataukī (sayings) like 'Ko au te whenua, ko te whenua, ko au' – 'I am the land and the land is me'.

Land, our provider

Land is central to all human life. Land ecosystems maintain liveable temperatures on Earth, clean water to drink, the air we breathe, and a place to live. Soil supports the plants we use for food and the materials we need to build shelter and clothe ourselves.

For many New Zealanders, time spent in nature is a powerful way to rest, recreate, and recharge. A healthy whenua also supports the economy and is the basis of an income for many New Zealanders. Te toto o te tangata he kai, te oranga o te tangata, he whenua, he oneone: while food provides the blood in our veins, our health is drawn from the land and soil.

Māori and Western world views value soil as a precious resource and a taonga (Hutchings & Smith, 2020). Keeping soil healthy and productive is important for maintaining its ability to produce food and materials like timber.

Ko te Pū – a Māori creation story

Ko te Pū	*The origin, the source*
Te More	*tap root*
Te Weu	*root, fibre*
Te Aka	*long, thin roots*
Te Rea	*growth*
Te Wao-nui	*primeval forest*
Te Kune	*pregnancy, conception*
Te Wheke	*a sound like creaking branches*
Te Kore	*the nothingness*
Te Pō	*the night and the darkness before light*
Ki ngā tāngata Māori nā Rangi rāua ko Papa	*the primordial beings (sky and Earth), the many atua (gods), and the creation of humans.*
Ko tēnei te tīmatanga o te ao	*We breathe life, the beginning of the world*
Tihei mauri ora!	

This karakia (chant, prayer) tells a Māori story of creation and describes the direct relationship Māori have with Papatūānuku and the natural world. All the myriad elements of creation – living, dead, animate, and inanimate – are seen as alive and interrelated. All are infused with mauri (a living essence or spirit) and all are related through whakapapa (ancestral lineage and connection).

Karakia remind us as Māori to uphold the mauri in every interaction we share with the environment, teaching whakapapa, Māoritanga (Māori culture), kawa, tikanga, and mātauranga (knowledge). Reciting karakia also strengthens an understanding of who we are and where we come from.

Ko au te whenua, te whenua ko au

For Māori, Papatūānuku is the source and sustainer of the land and all its life including humans. Our relationship with her has many facets.

Whakapapa

Our whenua is our identity. Through the whenua we whakapapa to our tūpuna/tipuna. We use the boundaries of our tribal land to introduce ourselves, referencing our mountain, river, land, and ocean.

Tūrangawaewae

The whenua is our home, our place to stand. The word whenua also means placenta. This demonstrates the lifelong connection formed when our placenta is buried after birth until we die and are returned to the whenua.

Hauora

A healthy whenua is fundamental to our health and physical, mental, spiritual, and social wellbeing. It provides resources to feed, shelter, and heal our whānau, opportunities to learn, and connects us to Papatūānuku.

Kaitiakitanga

When we act as kaitiaki and care for and protect our land, we uphold the mana of our ancestors and remember the struggles of those who came before us.

Tino rangatiratanga

Tino rangatiratanga is a way of living according to tikanga that safeguards the land and its resources for future generations.

Momotu

Different understandings and breaches of Te Tiriti o Waitangi led to conflict and the New Zealand land wars. Laws were also used to take away and alienate Māori from their whenua.

Signed in 1840, Te Tiriti o Waitangi formalised the partnership between mana whenua and Pākehā. Despite progress, considerable change is needed to honour the partnership and restore balance through utu and the rights of mana whenua.

Glossary

Ko au te whenua, te whenua ko au: I am the land, the land is me | **hauora:** health | **iwi:** extended kinship group **kaitiaki:** guardian | **kaitiakitanga:** guardianship/stewardship | **mana whenua:** customary authority exercised by iwi/hapū | **momotu:** separated | **Pākehā:** non-Māori New Zealander, generally European | **Papatūānuku:** Earth mother | **tikanga:** customs/protocols | **tino rangatiratanga:** sovereignty and self-determination | **tūpuna/tipuna:** ancestors | **tūrangawaewae:** place where one has the right to stand | **utu:** concept of reciprocation or balance **whakapapa:** genealogy/descent | **whenua:** land

Land and soil are varied and valuable

New Zealand's landscapes are spectacularly diverse – sand dunes, active volcanoes, braided rivers, alps, and fiords. These landscapes allowed a huge range of land ecosystems to develop – 152 major classes and 71 rare ecosystems – all with distinct plants and animals (Singers & Rogers, 2014). (See indicator: Rare ecosystems.)

The natural variations of climate, topography, and soil also shape how land is used and managed across the country. Most flat land has deeper fertile soils, can be irrigated and cultivated easily, and is primarily used for agriculture, including vegetable growing and horticulture. Dairy farming is most efficient on flat land, while sheep and beef can be farmed on hill country (Journeaux et al., 2017). Steep alpine land is generally set aside for conservation and enjoyed for recreation and tourism.

How we manage land can increase, decrease, or maintain the health, productivity, and mauri of the soil. People who live and work close to the land like farmers, foresters, and mana whenua (local people) usually have a good understanding of the characteristics of a place and its types of soil. This local knowledge brings an opportunity to tailor land use to the terrain and keep the soil healthy and productive.

Soil varies across our landscapes, with 15 major soil orders and thousands of mapped sub-types (Hewitt, 2010; Manaaki Whenua – Landcare Research, n.d.). Some types are more fertile or more susceptible to erosion than others. Many have naturally low levels of the nutrients that are essential for agricultural production, including phosphorus, nitrogen, and trace elements.

Te reo Māori (Māori language) has more than 60 words for different types of soil, which are distinguished by texture and colour using sight, smell, touch, and taste. The names indicate that some soil is better suited for particular cultural practises or for growing certain crops than others (Roskruge, 2007).

Hine-ahu-one was the first human created by Tāne-nui-a-Rangi from the red clay at Kurawaka. Her source (clay) highlights the importance of soil and the connection between soil and people. For Māori, soil health is reflected in its capacity as a living ecosystem to sustain and support all life, including microbes, plants, animals, and humans. Instead of viewing soil as a commodity, questions such as 'what can we do for the soil?' are encouraged (Hutchings et al., 2018) (see Framing a Māori view of soil). Enhancing the mauri of soil can be achieved by improving its fertility and structure and by supporting and enhancing soil biodiversity (Hutchings et al., 2018).

Sustainable management of soil and other resources on Māori land is a significant feature of Māori land management (Harmsworth & Mackay, 2010). Ki uta ki tai (from the mountains to the sea) is a whole-of-landscape Māori approach to managing the environment and its resources.

Land is our intergenerational asset

For hundreds of years, generations of people have modified New Zealand's original landscapes and soils to meet their need for food and shelter, and to make a living.

In the past 25 years, the use of land has intensified by increasing the number of livestock and the yields per hectare, and by adding more fertilisers and irrigation (Wynyard, 2016). Intensification has benefitted the economy but has also had negative effects on the environment. Those effects can last for a long time. Levels of nitrogen and phosphorus in groundwater and aquifers are likely to be the result of fertiliser applied to the land decades ago (Morgenstern & Daughney, 2012; Wynyard, 2016).

Land outside our expanding cities is sought after for housing, but is also valuable for growing crops and farming (Curran-Cournane et al., 2018). Making the most appropriate use of this productive land in both the short and long term is challenging and can require trade-offs between different uses.

The land under our feet today was inherited from our ancestors, and how they modified and used it affects how we can use the same land today. In the same way, the choices we make about how to use the land will have consequences for tomorrow's New Zealanders.

Framing a Māori view of soil

"When I hold soil or living compost in my hands, there's a feeling of intrigue, of mystery, about its creative potential for growth and for nurturing kākano into life", says Dr Jessica Hutchings (Ngāi Tahu, Gujarati). "I have reverence for soil because she is my tūpuna and there is no separation between me as a human being and the soil as my ancestor."

Māori food growing has a long history in Aotearoa New Zealand. Those who first voyaged from Polynesia encountered a cooler climate here and had to adapt their growing methods to suit crops like kūmara. Adding stones or mounding up soil were used to increase its temperature.

"The Ōtuataua Stonefields on the Ihumātao Peninsula are significant as the first cultivated gardens in this country and covered about 100 hectares. Māori were forced from that land in 1863, after which it was farmed by settlers and subdivided as part of the colonial project – as happened to much of our land. This place remains an example of the whakapapa and stories that attach people to soil and to place in Māori communities and need to be honoured, especially in land-use decisions."

To ensure a space for Māori ways of knowing and connections with Māori food systems, Jessica was part of a team with Te Waka Kai Ora (Māori Organics Authority) that undertook kaupapa Māori research to develop a framework called hua parakore. It is based on six principles or kaupapa drawn from mātauranga Māori: whakapapa, wairua, mana, māramatanga, mauri, and te ao tūroa. It is now being used across broader contexts, including soil, to support cultural and environmental wellbeing.

"Most Māori have an understanding of these terms. How they choose to apply the framework in relation to soil is up to different tribes, hapū, and whānau as they have their own specific kawa to do that."

Hua parakore is also the basis of the world's first indigenous verification system that has given Māori organic producers a pathway to tell a story about their food being grown according to these values.

"We should be looking to hua parakore farmers and growers because they are organic and have good soil practices that result in beautiful soil. They're also building knowledge by observation and trying things out over long periods of time, typically intergenerationally. This is the kaupapa of māramatanga – being gradually awakened to an intuitive sense of knowing about the soil.

Dr Jessica Hutchings (Ngāi Tahu, Gujarati) is an advocate for raising the mana of soil.

Photo: Ehsan Khanmohammadi Hazaveh

"Soil is the most precious thing we have. We come from soil and are the embodied form of Papatūānuku, so to assign personhood status and see soil as an ancestor would elevate her mana. Our soil is suffering and time is running out – we need an intervention as bold as giving soils personhood status to change the way we think about soils and to restore their immeasurable value."

Dr Jessica Hutchings has a PhD in environmental studies. She is co-editor of *Te Mahi Oneone Hua Parakore: A Māori Soil Sovereignty and Wellbeing Handbook*.

CHAPTER 2

The driving forces

▸ Mangahuia wetlands in Manawatū were created on private farmland in 1997.

Photo: Alexander Robertson

The basics of life – where we choose to live and the food we choose to eat – have an influence on the demand for land and how it is used in Aotearoa New Zealand. Our growing population will continue to drive this demand in the future.

A growing global population increases the demand for timber and food. More people, higher incomes, and changes in behaviour shift the demand for certain goods, causing changes in export markets.

Overseas markets are a significant driver in land use. Most of the products of agriculture and forestry are exported and these activities cover half of our land area.

The impacts of climate change are expected to force people to move from coastal locations and increase demand for housing inland.

Policies on trade, immigration, and housing can also affect how, and how intensively, we use land. The decisions we make today about how to use the land in this country will shape the ability of future generations to meet the demands of their time.

Consumer preferences

What we choose to eat and where we choose to live flows through to the ways we use land. The quality and price of food and housing, and the location of our housing are important for wellbeing. These essentials make up a large proportion of our expenditure. Housing and household utilities and food accounted for around 40 percent of the average weekly household expenditure for the year ended June 2019 (Stats NZ, 2020a).

Around the world, consumers are becoming more discerning about how the food they buy is produced. Food producers are expected to be transparent about their food growing methods and practices, and this influences industries to adapt their land-use practices to meet the demand (Driver et al., 2019; Journeaux et al., 2017). Land owners can be required to meet certain sustainability standards, including protecting biodiversity, but meeting standards may increase prices and access to markets (Norton et al., 2020).

Doing dairy differently: making a switch to organic farming

Dairy cows resting in shady areas on the Spooner's farm.

Photo: Mark Spooner

Passing an exhaustive document audit earlier this year was the last hurdle to full organic certification for Mark and Karen Spooner's dairy farm. It completes a three-year transition from conventional farming.

"We were thinking about organics, but on a family trip to America we were blown away that what the market over there was screaming out for was grass-fed, traceable, low input milk. It was exactly what we were doing but we weren't getting full recognition for it", says Mark. "When we got home we did the numbers and realised that organic production captured that and stacked up from a business perspective – it had to."

Researching the organic option involved visits to local organic dairy farms, which Mark confesses he imagined would be full of weeds and look unkempt.

"I didn't want to have a farm where it looked like the land was going backwards, but these were beautiful – I couldn't believe it. There were trees and shady areas, and the cows could eat everything that was growing, even the feijoa hedges. That was a game-changer for me."

The Spooner's farm comprises 110 hectares of prime dairying land near Te Aroha in Waikato. Mark grew up on the farm, which was bought by his grandparents in 1944. Today he and Karen milk 260 cows.

"Under a conventional system it was about trying to get the most out of the land. After we bought the farm from my parents we pushed the numbers up to 340 for financial reasons. That's what I thought stewardship was. Now I see myself more as a caretaker than an owner."

Mark says animal welfare and soil health are foundational to organic farming because backups like antibiotics are off-limits.

"As soon as something doesn't look quite right, you have to act on it. But we rarely have vets or lame cows on the property now. Our soils were compacted and anaerobic, but aerating them solved so many problems – it got rid of the buttercup and the mud, and lifted production exponentially. Nurturing the soil means it gives back to the animals and the end product."

Changing to organic milk production has reignited Mark's passion for farming and its "golden gift" has been retraining his thinking. It's also been a special connection point with his grandmother, who has taken a keen interest in the process.

"She's been really supportive of the organic road because that's how they farmed. Everyone was organic 50 years ago. It's about using what nature provides. I think organics can play a massive part in the turnaround for the environment that we all need to be part of."

A growing population

The number of consumers in New Zealand is projected to reach 6.8 million by 2073 having passed 5 million in June 2020 (Stats NZ, 2020b; 2020c). This will continue to drive the demand on land to supply food, housing, and opportunities for recreation.

A growing population also partly drives urban expansion and the development of rural residential areas. Urban areas currently cover only 1 percent of land in New Zealand but 87 percent of the population live in towns and cities. (See indicator: Urban land cover.) About 80 percent of our population growth for 2018–43 is expected to be in the main urban centres (Stats NZ, 2017).

Most urban expansion is outwards onto productive land rather than upwards in multi-story buildings because it is cheaper to develop flat land than build on less productive hilly sites (MPI & MfE, 2019). Fields on the fringes of urban areas are therefore in demand for residential developments, which creates tension between the use of land for housing and for agriculture (Curran-Cournane et al., 2018; Greenhalgh et al., 2017).

Domestic and overseas markets

Land use in New Zealand is strongly influenced by consumer demand here and overseas. Overseas markets are affected by global population growth and consumer preferences (Kelly, 2016; Spiess, 2016). The global population is projected to reach 10.9 billion by 2100 (UN DESA, Population Division, 2019). More people, higher incomes, and changes in behaviour can shift demand for certain goods – including food.

Overseas markets play a significant role in the relative profitability of different land uses. This is because half of our land is used for agriculture and forestry, with most of the products from these industries being exported. (See indicator: Exotic land cover.) In 2019, New Zealand's land-based primary industries generated $44 billion in export revenue (MPI, 2020c).

Fluctuations in these factors can cause an increase or decrease in the area of land used to produce certain goods. As an example, higher milk prices caused a change in land use from sheep and beef to dairy farming – from 1983 to 1993, the area of land used for sheep farming decreased by 32 percent while land used for dairy increased by 22 percent (Willis, 2001). Increased milk prices helped make dairy farming more economically viable on land that was previously considered unsuitable. Higher prices were able to overcome the relatively high cost of the fertiliser and irrigation required (Wynyard, 2016). Higher milk prices also supported the intensification of dairy farming from the early 1980s, resulting in more milk produced per hectare through the use of fertiliser, irrigation, and cattle feed.

The Māori economy

Māori freehold land (administered under Te Ture Whenua Act 1993) accounts for about 6 percent of New Zealand's total land area (RBNZ, 2021). Its uses are diverse and a significant proportion supports land-based primary industries.

A significant proportion of assets in the primary sectors are in Māori ownership: 40 percent of forestry; 30 percent of lamb production; 30 percent in sheep and beef production; 10 percent in dairy production; and 10 percent in kiwifruit production in 2017 (Chapman-Tripp, 2017; MFAT, 2019).

Māori values, mātauranga Māori and tikanga can promote healthy soil, and the sustainable use of soil and food production (Hutchings et al., 2018).

A changing climate

Climate change is already affecting New Zealand through increased temperatures and changing rainfall (MfE & Stats NZ, 2020a). As the climate continues to change in the future, the changes it brings to the environment will affect the ways we use and manage land.

Land owners are already recognising climate change as one of the main influences on the ways they use, plan, and manage land resources (Driver et al., 2019) (see chapter 6: Land and a changing climate). Threats from rising sea levels are also likely to encourage moves away from coastal residential areas (MfE, 2020; Resource Management Review Panel, 2020). To accommodate people, it may be necessary to develop new housing in existing urban and residential areas and create denser cities. The need may be greatest in places like Wellington, where suitable land for additional housing is naturally limited, or where there is competition between highly productive land and housing.

Policies and conventions

Policies on trade, immigration, and housing can affect how, and how intensively, we use land. A range of policies direct the type and intensity of activities that can take place on different land in New Zealand. These include zoning and planning regulations that dictate how land in specific areas can be used. Local governments (regional, district, and city councils) put these policies into action by creating and enforcing regulations about land use and management.

Policies also influence markets and through them, land use. For example, national and international policies to address climate change, like the New Zealand Emissions Trading Scheme, can make plantation forestry a more or less attractive investment (Cortés-Acosta et al., 2020).

Internationally, environmental crises and competing uses for land have triggered the development of policies and conventions to guide land management and regulate land use. International agreements such as the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity influence options and decisions around land use (CBD, 2020; UNFCCC, 2021).

Policies that address environmental, social, and economic issues will continue to affect how land is used and managed. Innovative legislation and ways of governing natural resources have been introduced in this country. Tikanga, mātauranga Māori, and co-governance are being included more and more in legislation and policies that govern land use (see Ngāi Tūhoe and the co-governance of Te Urewera) (MPI, 2020a; Resource Management Review Panel, 2020).

Ngāi Tūhoe and the co-governance of Te Urewera

Co-governance and co-management of land by indigenous people and government representatives is a unique way of managing natural resources. In a global first, Te Urewera (an area that was previously a national park) was given the same rights, powers, duties, and liabilities as a legal person.

The status of Te Urewera means that the land is not owned by anyone – this drives its use and management differently to land owned by the Crown, iwi, or individuals. Management of Te Urewera is based on tikanga and mātauranga, to preserve the mauri of the land and preserve it for future generations. This includes the obligations of kaitiakitanga. Decisions on what happens to the land are discussed by a board of representatives from Tūhoe and the Crown.

Te Urewera sets a precedent for recognising Māori rights and interests in our legal system. The recognition of natural features as legal persons may drive future Treaty settlements and co-management of land. The recognition could also provide a framework for natural resource management in other areas, both in New Zealand and internationally (Sanders, 2018).

This major legal shift is a direct reflection of the values underpinning te ao Māori (Māori world view) perspectives of the environment and opens up opportunities for wider understanding of the indivisible relationship between indigenous people, values, and landscapes. (Hutchings et al., 2018). It effectively gives the land itself a say in what it will be used for.

Healthy land, healthy soil, healthy people

Increasing population and incomes drive growth in overseas markets.

Domestic and overseas markets

Our exports and domestic food production rely on the small amount of highly productive land we have.

Policies

Government policies put rules and restrictions on how land can be used.

New Zealand's population passed 5 million in 2020.

New Zealand population growth

Our population is projected to reach 6.8 million by 2073. This will continue to drive the demand for food, housing, and recreation.

Change in land use

Changing demand and prices from domestic and overseas markets can cause changes in land use, like the dairy boom in the 1980s. Policies to address climate change may drive further changes in land use.

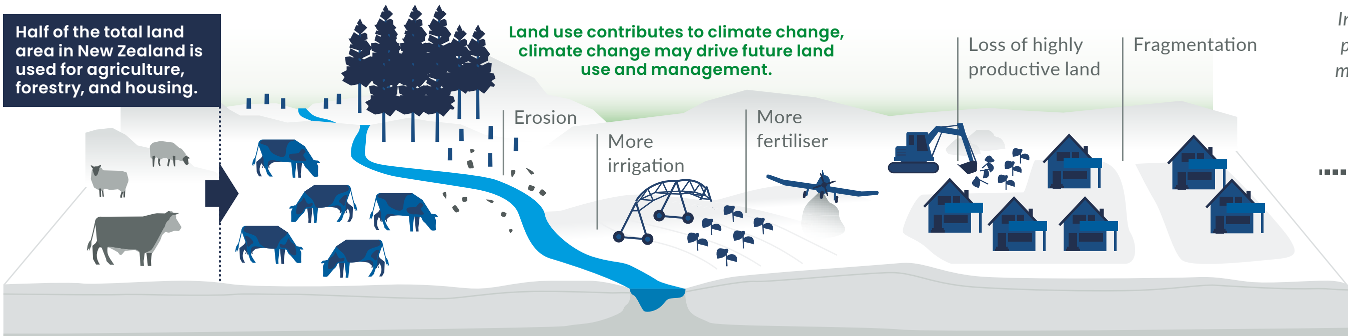
More intensive land use

Changes in overseas markets incentivise shifts in the area of land used to produce goods, and can make production more intensive.

Urban expansion and land fragmentation

Using highly productive land for housing developments and lifestyle blocks takes it out of commercial production.

Half of the total land area in New Zealand is used for agriculture, forestry, and housing.



Inform policy making

Soil quality

Soil availability

Healthy soil

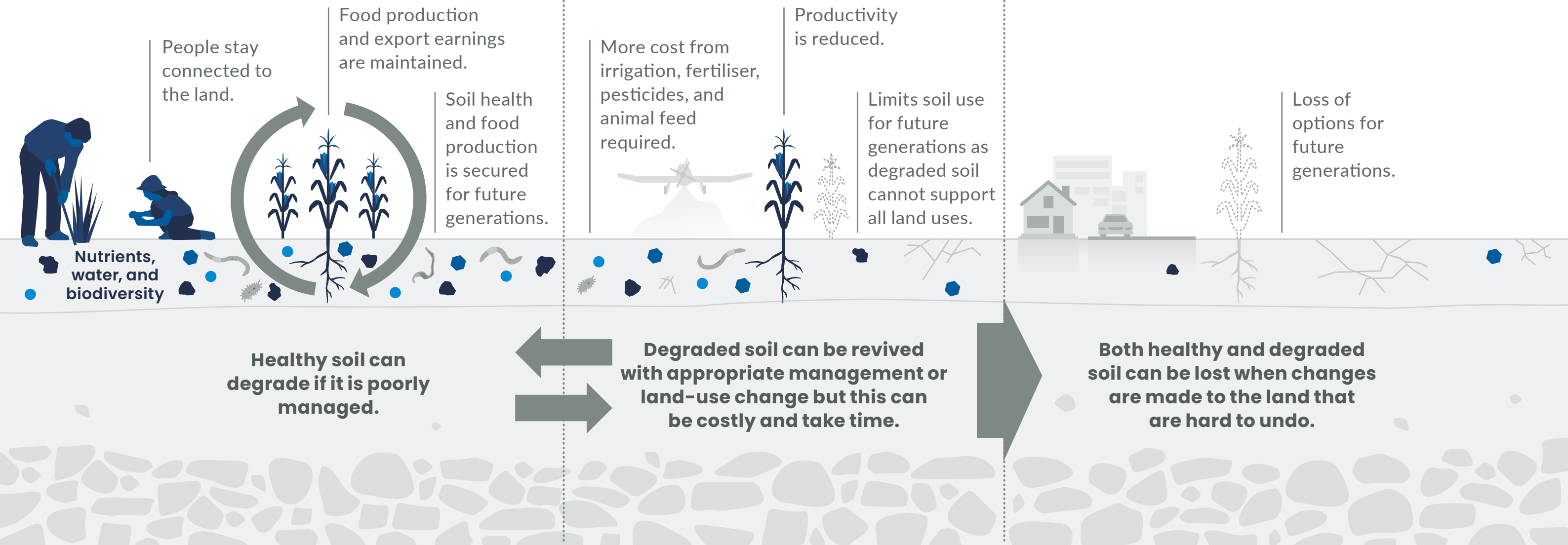
can be sustained for future generations with appropriate use and good management.

Degraded soil

can be the result of inappropriate use or poor management.

Lost soil

Once land has been built on or is surrounded by houses it can be almost impossible to use for farming in the future.



CHAPTER 3

Our activities and their effects

▸ Housing development on the outskirts of Blenheim.

Photo: Nature's Pic Images

Half of the total land area in Aotearoa New Zealand is now used for agriculture, forestry, and housing.

Some land (15 percent) is particularly good for food production by farming animals or growing crops. This highly productive land has a good climate, suitable soil, and is flat or gently sloping. Highly productive land is often on the fringes of our cities. The area of highly productive land that was unavailable for agriculture (because it had a house on it) increased by 54 percent from 2002 to 2019.

Our exports and domestic food production currently rely on the small amount of highly productive land we have. Using land that is not highly productive for food growing, especially horticulture, results in lower yields unless more intensive land management approaches are used.

Intensive land management is about getting the most from each hectare of land – maximising the yield of milk, meat, timber, fruit, vegetables, or crops. Intensive land management risks degrading the quality and health of the soil.

No declining or improving trend in soil quality was observed for 1994–2018. However, nationwide 80 percent of monitoring sites failed to meet the targets for at least one soil quality indicator. Soil in these areas can be less productive and may need more fertiliser and irrigation to keep up production.

Land use and changes in land use

HOW WE USE LAND

Land use is the modification of the natural environment for human use, such as clearing native vegetation for agriculture or forestry and building houses. Land-use change is a long-term change to the land, which can be irreversible.

Land cover is the main type of physical material covering a given area of land (Manaaki Whenua – Landcare Research, 2020). For this report, land cover is divided into three main classes: exotic land cover including agriculture and forestry, indigenous land cover including all native vegetation, and urban land cover including all built-up areas. (See indicators: Exotic land cover, Indigenous land cover, and Urban land cover.)

About half of New Zealand's total land area is used for agriculture and forestry:

- 40 percent exotic grassland (land covered with non-native grasses used for pasture including dairy and sheep and beef farming)
- 8 percent exotic forest (land covered by non-native forest including forestry)
- 2 percent cropping and horticulture (land covered by grain, seed, vegetable, fruit, or grape growing). (See indicator: Exotic land cover.)

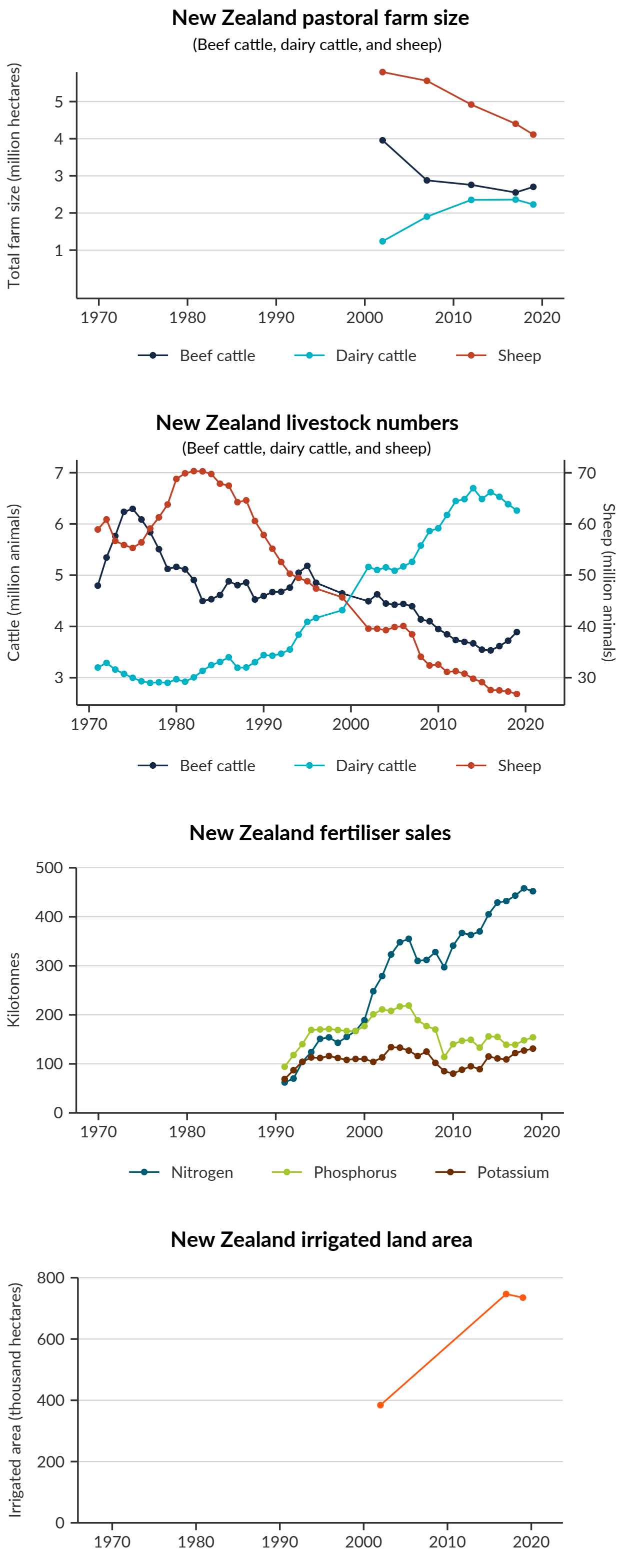
The total area of land used for agriculture and horticulture has been decreasing since 2002 and fell by 2 percent between 2017 and 2019. (See indicators: Agricultural and horticultural land use and Farm numbers and size and figure 1.) The number and size of farms has decreased since 2002 but the export income from farming products has increased during this time, suggesting that fewer farms are producing more on less land (MPI, 2012, 2015, 2020b). (See indicator: Farm numbers and size.) While part of the increase is due to higher prices for dairy products globally, higher prices also encouraged land to be used more intensively (Wynyard, 2016).

Dairy cattle numbers have more than doubled since the 1980s, rising from 3 million to almost 7 million in 2015, with more than 6 million in 2019. (See indicator: Livestock numbers and figure 1.)

Today, 40 percent of New Zealand's land area is exotic grassland – the total area has not changed since 2012 but regional changes have occurred. (See indicator: Exotic land cover.) From 1996 to 2018, the area of exotic grassland decreased in 14 of 17 regions. During the same period, the area of exotic forest increased by 12 percent (220,922 hectares), with three quarters of the increase coming from land that was previously exotic grassland. (See indicator: Exotic land cover.)

Cropping and horticulture land made up 2 percent of New Zealand's total area in 2018. The area of this land cover increased in 15 out of 17 regions for 1996–2018, with most of the increase coming from exotic grassland. (See indicator: Exotic land cover.)

Figure 1: Changes in pastoral farm size, number of livestock, fertiliser sales, and irrigated land, 1970–2019



Data source: Stats NZ and Fertiliser Association of New Zealand

NOT ALL LAND IS EQUALLY PRODUCTIVE

Some land is particularly good for food production (farming animals or growing crops). This highly productive land has a good climate, suitable soil, and is flat or gently sloping. Here, less irrigation and fertiliser is needed to grow food than in other areas. Highly productive land is often on the fringes of our cities.

Food production is most efficient on highly productive land because soil on this land needs the least fertiliser and cultivation (tilling or ploughing) to grow crops and livestock (Lynn et al., 2009). Highly productive land is also less prone to leaching fertiliser and contaminants into the environment than land with shallower or stony soil (Carrick et al., 2013; McLeod et al., 2014).

Highly productive land is important for growing food like potatoes, onions, and leafy green vegetables. Land in lower LUC classes is most suitable for grazing livestock (Lynn et al., 2009; Vogeler et al., 2014).

Using land that is not highly productive for growing food, especially horticulture, results in lower yields. Yields can be increased on some types of land by using more fertiliser and irrigation but this may affect the water quality in nearby waterways and can degrade the soil (Andrew & Dymond, 2013; MfE & Stats NZ, 2020b; Curran-Cournane, 2020; Sparling & Schipper, 2004). It also increases the cost of production.

Access to highly productive land is essential to continue food production for the domestic market and for export. Globally, the demand for dairy products is growing and the demand for horticultural and cropping products like kiwifruit remains high. In 2019, New Zealand's land-based primary industries generated $44 billion in export revenue (MPI, 2020c).

The Government has set a target for the primary industries to increase export earnings by a further $44 billion in the next decade to support economic recovery after the COVID-19 pandemic (MPI, 2020a).

Highly productive and highly versatile land

Land is classified into eight land-use capability (LUC) classes based on its potential for sustained production in the long term. The classes are based on soil properties, soil sensitivity to erosion, vegetation cover, and terrain (Lynn et al., 2009). The first four classes (LUC 1–4) are most suitable for cropping and most productive for pasture and forestry (Lynn et al., 2009; Vogeler et al., 2014). Land classified as LUC 8 is not used for agriculture and is often conservation land.

LUC class 1 land is the most versatile (it can grow the largest range of crops) and has few limitations on how it can be used. LUC class 2 is also versatile and has slight limitations. LUC class 3 land has moderate limitations. LUC classes 1–2 are known as highly versatile land and LUC classes 1–3 as highly productive land.

Highly versatile and highly productive land are scarce, finite resources – 5 percent of New Zealand's total land area is highly versatile and 15 percent is highly productive (Ewers et al., 2006; Lynn et al., 2009; Rutledge et al., 2010).

TOWNS, CITIES, AND HIGHLY PRODUCTIVE LAND

The area of urban land in New Zealand increased by 15 percent from 1996 to 2018, and 83 percent (25,248 hectares) of the increase came from the conversion of exotic grassland to urban use. Nine percent (2,602 hectares) was converted from cropping or horticultural land. (See indicator: Urban land cover.)

The area of highly productive land that was unavailable for agriculture (because it had a house on it) increased by 54 percent for 2002–19. (See indicator: Land fragmentation.) Urban land use increased by 31 percent on land that was potentially available for agriculture during this period. The area of residential land outside city boundaries (rural residential areas) also more than doubled in this time. (See indicator: Land fragmentation and figure 2). A large proportion of highly versatile land (LUC classes 1 and 2) nationally could be developed into urban zones in the next 50–100 years if current urbanisation trends continue (Rutledge et al., 2010).

Many of New Zealand's cities have developed on and around food producing land, with market gardens providing a local food supply for urban dwellers. In the 1950s, urban development of market-gardening land in and around Auckland was already a concern (Hunt, 1959). Urban expansion onto that land has continued in the past 60 years. Kumeu/Riverhead, Pukekohe, and a surrounding area in the Franklin district are the main remaining areas. (See indicators: **Exotic land cover** and **Urban land cover**.) The areas in and around Pukekohe and Kumeu/Riverhead have now been rezoned for various types of development and are largely fragmented (Auckland Council, 2021; Curran-Cournane et al., 2016). (See indicator: **Land fragmentation**.)

The current and future development of land in the Auckland region was calculated in 2019, where development includes planned zones for urban areas and lifestyle blocks. It was found that 34 percent of LUC class 1 land, 38 percent of LUC class 2 land, and 19 percent of LUC class 3 land has been or will be developed (Environment Court of New Zealand, 2019).

FRAGMENTATION OF LAND

Land fragmentation is the subdivision of land into smaller pieces (Hart et al., 2013; Rutledge et al., 2015). It includes subdividing agricultural land into smaller areas and building houses on agricultural land (Hart et al., 2013).

Fragmentation of highly productive land by subdivision can shift this land out of commercial production. This happens particularly with the development of lifestyle blocks, which were about 5 hectares on average in 2011 (Andrew & Dymond, 2013). These smaller blocks of land can produce food but it is generally for non-commercial consumption.

Highly productive land became more fragmented between 2002 and 2019, especially through residential development of land sized 2–8 hectares (Curran-Cournane et al., 2021). The largest increase in fragmentation (to 2–8 hectares of land with a house) occurred in Canterbury. (See indicator: **Land fragmentation** and figure 2.)

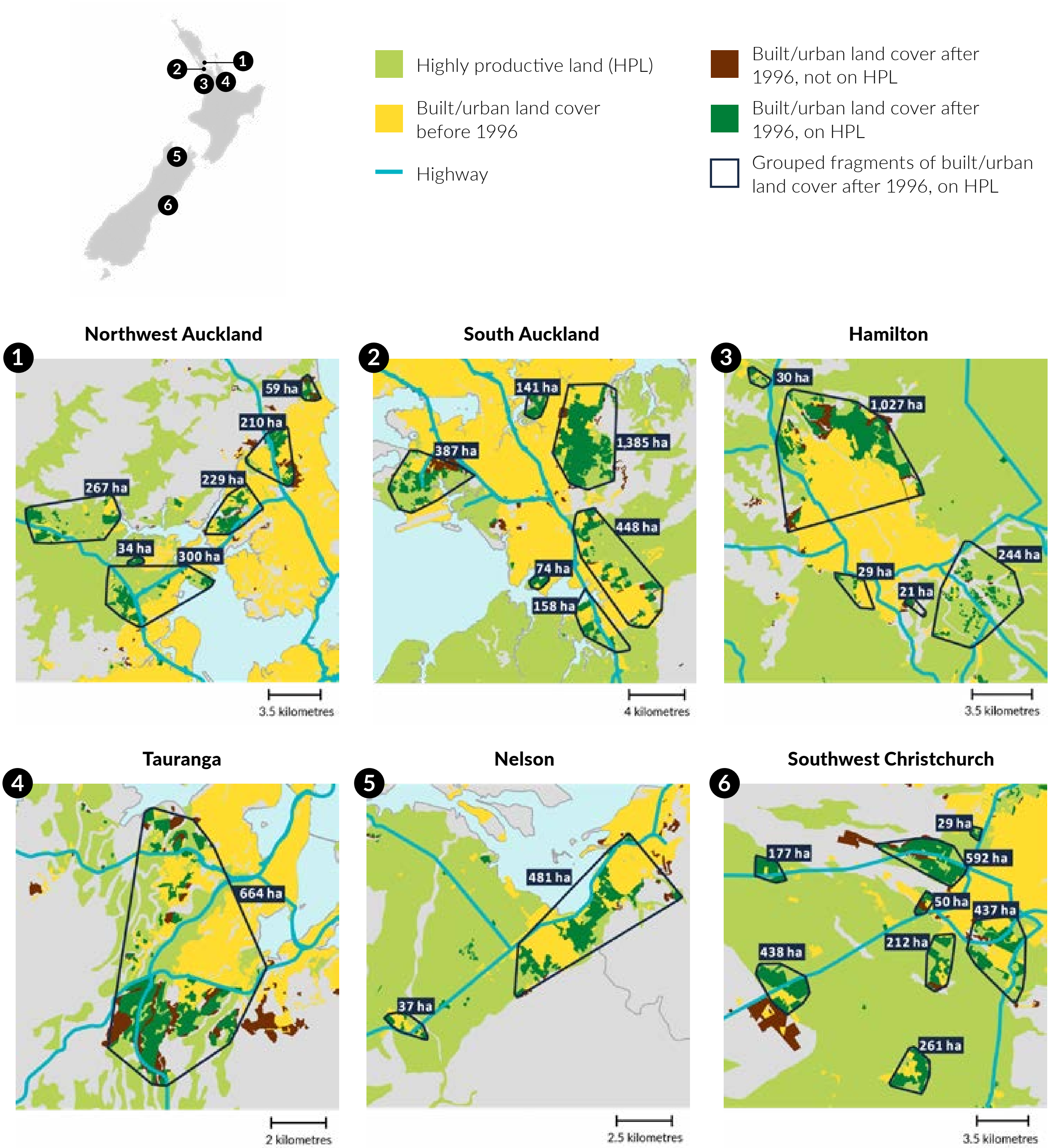
The way fragmentation happens can also increase the demand for further subdivision. If lifestyle blocks and rural subdivisions are scattered across an area, the agricultural land in between is also likely to become fragmented (Curran-Cournane et al., 2016; Hart et al., 2013). Land fragmentation can limit the options for land use today and in the future (Rutledge et al., 2015).

To address the demand for housing, there is a choice between building in existing residential areas (and creating denser urban areas) or building outwards onto productive land.

Our exports and domestic food production currently rely on the small amount of highly productive land we have. There are advantages to growing our food in New Zealand rather than importing it, such as being less vulnerable to disruptions in global trade. Ensuring everyone in New Zealand has access to affordable and nutritious food into the future is an important consideration in how we choose to use land today. (Fenwick Forum 2020, n.d.)

Figure 2: Residential expansion onto highly productive land

The growth of six residential areas around New Zealand shows where highly productive land in these areas was lost from 1996 to 2018.



The squares highlight where the highest proportion of highly productive land was converted to urban land cover for 1996–2018, shown in dark green. Black lines enclose fragments of converted highly productive land that are within 1 kilometre of each other, with the total area of converted fragments shown in hectares. Only areas totalling 20 hectares or more are outlined and labelled.

This graphic was created using Manaaki Whenua – Landcare Research LCDBv5.0 and NZLRI Land Use Capability layers. Built and urban areas are categorised as a built-up area (settlement) or urban parkland/open space in the LCDBv5.0. Highly productive land is in land use capability categories 1–3.

Data source: Manaaki Whenua – Landcare Research

Land management and the soil

SOIL IS VARIED AND HAS MANY FUNCTIONS

Soil is made up of minerals, organic material, living organisms, air, and water. Soils are not inherently good or bad, but vary through the landscape due to geology, time, and natural processes. Some naturally have higher fertility than others or are naturally more prone to erosion.

A well-functioning soil can drain excess water, retain water and important nutrients, and supply these to plants when they are needed. In these soils, processes such as carbon and nutrient cycling, structure development, biological activity, and disease suppression all take place. Reserves of carbon and nutrients are also built up (Herrick, 2000; Kibblewhite, 2018; Lilburne et al., 2020).

LAND MANAGEMENT AND INTENSIFICATION

Land management is how the land and soil are managed for a given use. It includes how many animals are on the land, the number and type of crop cycles per year, whether the soil is tilled, irrigated or fertilised, and how much and how often. Management varies with the seasons and conditions, the effects of a drought for example can be relieved with irrigation, and a new crop may need a different type of fertiliser.

In this report, intensification refers to the use of inputs like fertiliser and irrigation to increase or maintain productivity (FAO, 2004; Moller et al., 2008). The aim of intensive land management is to increase the production of meat, milk, or crops from a specific area of land. This can be achieved by farming more animals per hectare and increasing the number of harvests from crops.

Intensification is often associated with environmental damage and concerns about soil quality and health (Houlbrooke et al., 2011; MacLeod & Moller, 2006). Agricultural intensification, however, reduces the need to convert more land to agriculture to increase production.

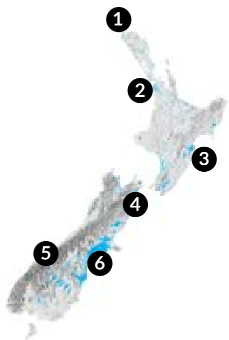
IRRIGATION OF LAND

The use of irrigation, especially on land used for dairy farming, has nearly doubled since 2002. In 2019, 5 percent (735,073 hectares) of agricultural land in New Zealand was irrigated, with dairy farming making up 58 percent of irrigated agricultural land. Sixty-four percent of irrigated agricultural land was in Canterbury. (See indicator: **Irrigated land** and figure 3.)

A study of irrigated and non-irrigated pasture sites across New Zealand found that irrigated pastures had significantly less soil carbon and nitrogen than non-irrigated pastures. This finding could be due to less root growth, more decomposition of organic matter, or more release of carbon dioxide by microorganisms. An increase in the area of irrigated land may also increase the loss of carbon dioxide to the atmosphere, the loss of soil carbon, and increase nitrogen leaching (Mudge et al., 2017). Overall in New Zealand, irrigation is not thought to change soil carbon stocks in humid climates. An increase in soil carbon stocks due to irrigation could be expected at more dry sites (Whitehead et al., 2018).

Figure 3: A landscape of irrigation

Land throughout New Zealand is irrigated, but how and where it occurs depends on the local climate, land use, and water supply. Irrigation benefits agriculture but can have negative environmental effects.



Irrigation type

Less efficient ← → More efficient

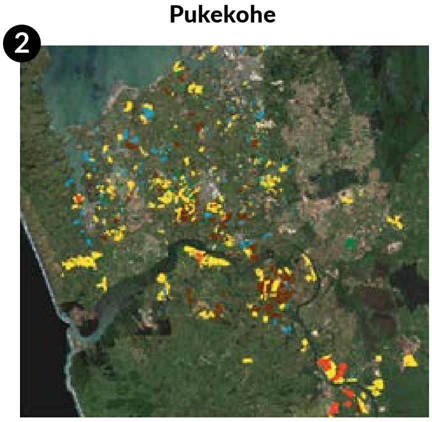
Surface methods	*Sprinkler methods*		*Drip methods*	
Borderdyke	K-line/long lateral	Pivot	Drip/micro	Unknown
Wild flooding	Linear boom	Lateral		
	Rotorainer	Solid-set		
	Gun	Side roll		

Northland

Drip irrigation is used in small areas by avocado growers and other producers to provide a reliable water supply throughout the year.

Most of the wetlands in Northland have been lost and those that remain are also at risk of being lost.

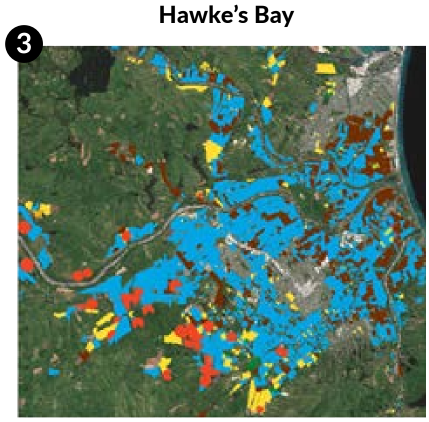
Pukekohe



Sprinkler and drip irrigation is used to grow vegetables (like onions, potatoes, capsicums, and tomatoes) that are supplied to Auckland residents and exported.

Concentrations of nitrogen in rivers and groundwater in this area are some of the highest in the country.

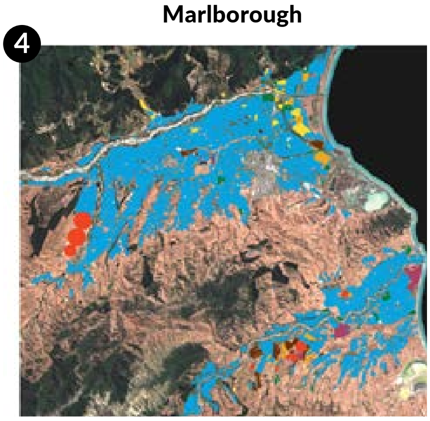
Hawke's Bay



Drip irrigation and some pivot or gun systems support one of the country's largest fruit and grape-growing areas.

Legal conflicts have arisen over new water storage schemes because of the effects they could have on the environment.

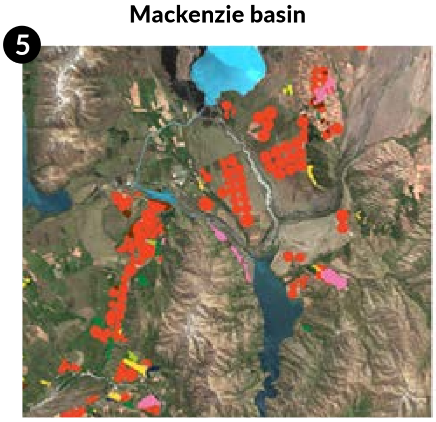
Marlborough



Micro and drip irrigation supplies water directly to the roots of grapevines.

This type of irrigation is very efficient but limited water reserves sometimes cause water restrictions.

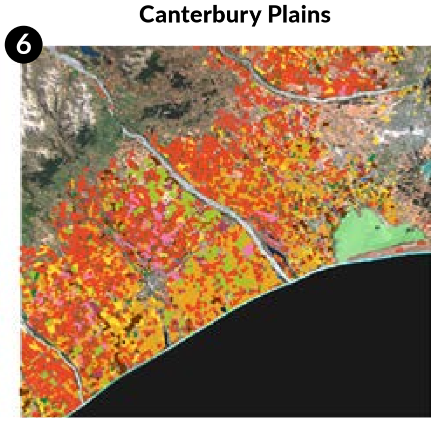
Mackenzie basin



Pivot irrigators enable this naturally dry area to be used for dairy farming.

Areas of native tussock and dryland habitat have been lost as irrigation enables pasture to be established in this harsh climate.

Canterbury Plains



Pivot, lateral, and rotorainer irrigation plus some older borderdyke systems support intensive dairy farming in paddocks that have few other types of vegetation besides exotic grasslands. Excess nitrogen degrades drinking water and freshwater ecosystems. The bright green colour of Lake Ellesmere (Te Waihora) is caused by algae that grow in the nutrient-rich water.

Data source: Aqualinc Research Limited; Land Information New Zealand

Ice, hydro, and irrigation: how water has changed the dry Mackenzie basin

Green irrigated land contrasts with naturally brown tussocks south of Twizel. Glacial outwash plains are visible in the foreground.

Photo: Steve Bicknell

GLACIERS AND CLIMATE SHAPED THE LAND, ITS PLANTS, AND ANIMALS

Glaciers were the first way that water shaped Te Manahuna/Mackenzie basin in the South Island. These great rivers of ice powered through the land, leaving behind lakes and outwash (deposited sediment and gravel). This is the only place in New Zealand where the full glacier sequence from mountain to outwash plain is intact.

Low rainfall, extreme temperatures, and stony and infertile soil influenced the range of plants that developed here. Many are found nowhere else, with special features to allow them to survive in these harsh conditions, like being low growing or leafless. The basin is also home to eight threatened bird species and rare native moths, butterflies, fish, and other animals.

MĀORI VISITORS AND THE FIRST SHEEP FARMERS

Early Māori visited Te Manahuna to harvest resources and food, particularly tuna and weka. Because the tall tussocks were hard to navigate, Māori lit fires to remove them from large areas.

From the 1850s, sheep were farmed in the Mackenzie basin on land that was leased perpetually from the Government. It was tough going and barely profitable.

HYDROPOWER AND IRRIGATION

Water drastically altered the Mackenzie landscape when this country's largest network of hydropower stations was built from the 1950s to the 1980s. Some lakes were increased in size and a new one, Benmore, was created. Leaseholders whose land was flooded were compensated by the promise of access to water for irrigation.

Irrigation began in the 1970s to produce feed for sheep. This 'sensitive' irrigation had the potential to double or triple the profitability of farms, because the basin is so naturally dry. More income did support some gains for the environment like wilding pine and rabbit control and enabled farmers to keep stock off delicate native vegetation during droughts.

TENURE REVIEW BROUGHT SIGNIFICANT CHANGES TO LAND OWNERSHIP

In the 1990s leaseholders were offered tenure review – the opportunity to buy portions of their land with the balance being set aside for conservation. Freehold land has fewer constraints on its management and can be farmed more intensively and profitably.

Large areas of land on the basin floor became freehold and by 2020, less than one tenth of the land below 800 metres had any form of protection. This, however, is where most of the threatened plants and animals are located.

IRRIGATION ENABLED MORE INTENSIVE FARMING

Water applied slowly to large areas of land has arguably had the most profound effect on the Mackenzie basin, particularly on freehold land. In less than 15 years (2003–18) the area of intensified land more than doubled. By 2018, only one third of the 25,000 hectares with active irrigation consents had been irrigated, so there is potential for further intensification.

Economic returns have driven intensification – the total gross high country farm revenue in 2018/19 was more than twice that of 2009/10. A change from sheep to more profitable dairy farming was also supported by access to water. The basin's first dairy farm opened near Twizel in 2003 using pivot irrigators. These machines require land to be flattened and seeded with grass, which removes all the native dry-loving plants.

In a highly controversial move, a 2009 proposal to farm 17,850 dairy cows at Ōhau Downs Station was granted separate consents from different governing agencies. This prevented all the effects being considered together, which was described by the Environment Minister at the time as "gaming" the resource consent process. The project did not go ahead – the discharge consent was called in by the Minister and the land-use consents were squashed after a legal challenge. Other landowners have since used the same tactics with more success.

WORKING TOGETHER TO SAFEGUARD LAND

The exposure of these regulatory loopholes led to changes in land management. In 2017, the Mackenzie District Plan tightened consenting requirements, which prevented land at its 56 sites of natural significance being further intensified or converted to agricultural use. In 2019, the Government ended tenure review.

Several joint initiatives to ensure landscape-scale protection have also been set up. The Mackenzie Agreement was signed in 2013 to protect and celebrate the biodiversity, landscapes, and cultural heritage of the basin. The Mackenzie Basin Agency Alignment Programme joined up the efforts of the five agencies that manage land and coordinate projects in the area. Tū Te Rakiwhānoa Drylands is an initiative between the Crown, mana whenua, and landholders to protect areas of lower altitude land in the Mackenzie and Waitaki Basins.

SOIL QUALITY

Measuring and monitoring soil quality

Soil quality is a measure of the condition of soil. Because different crops and animals have varying needs and interactions with the soil, soil quality is assessed according to its intended use.

Soil quality is monitored routinely by councils in New Zealand using a set of indicators. The programme began in the mid-1990s and sites are resampled every 4–5 years.

Soil quality indicators are based on the chemical and physical properties of the soil (see Monitoring soil quality) and biological indicators (like biodiversity) are not currently monitored directly (Sparling & Schipper, 2004).

Two of the indicators, mineralisable nitrogen and pH, were generally within target ranges at the tested sites and are not discussed here.

Monitoring soil quality

Soil quality is monitored to ensure soils can keep producing and to limit environmental damage. Seven soil indicators to monitor soil quality are commonly used.

Olsen phosphorus

measures the amount of phosphorus available to plants. This is a measure of soil fertility.

Total nitrogen

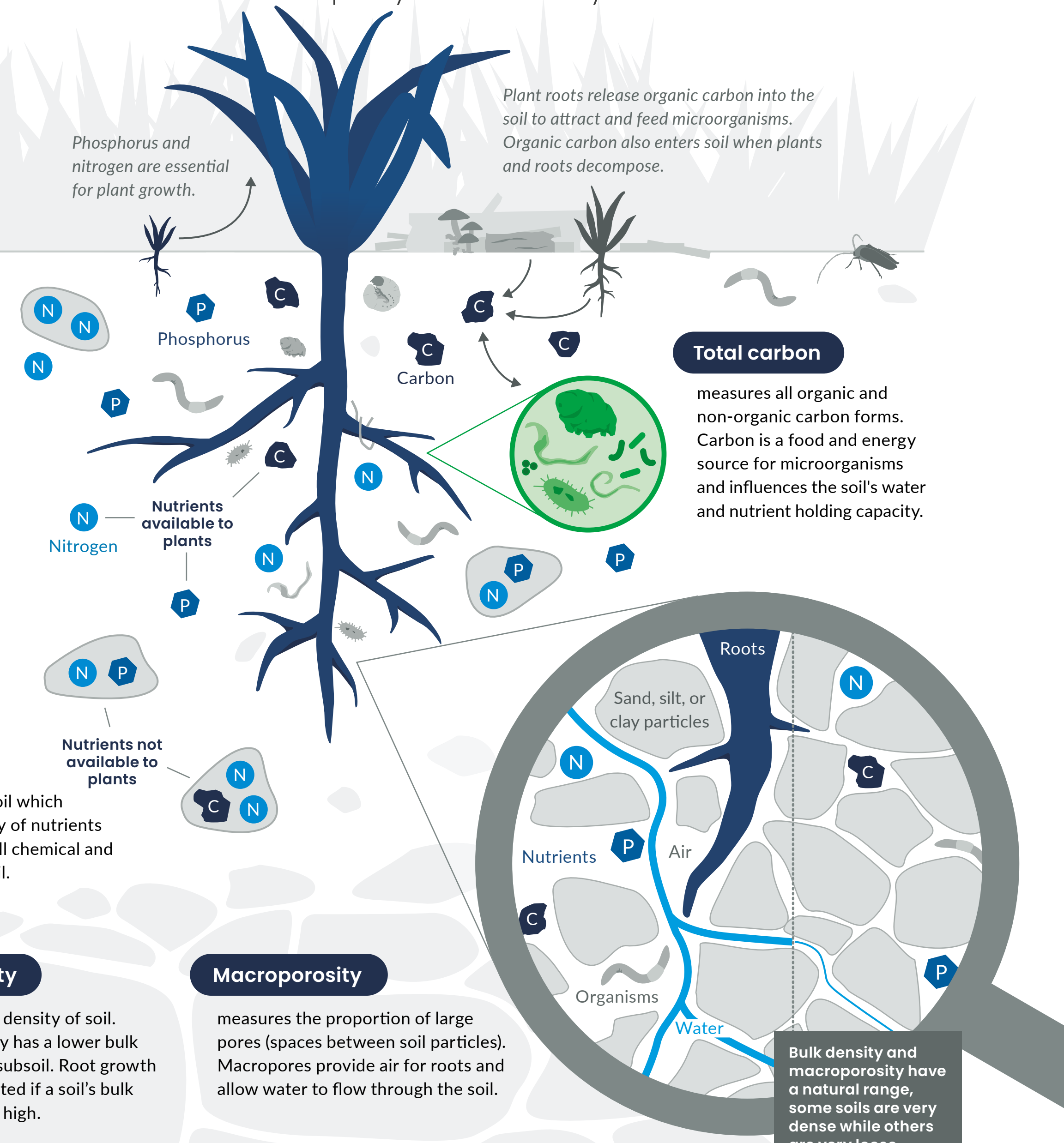
measures all the nitrogen in soil. Most soil nitrogen is in an organic form, but microorganisms change it to a mineral form that plants can take up.

Mineralisable nitrogen

measures the quantity of organic nitrogen that microorganisms can process and make available to plants. It also gives an estimate of the amount of microorganisms in the soil.

pH

measures the acidity of soil which determines the availability of nutrients to plants and influences all chemical and biological processes in soil.



Total carbon

measures all organic and non-organic carbon forms. Carbon is a food and energy source for microorganisms and influences the soil's water and nutrient holding capacity.

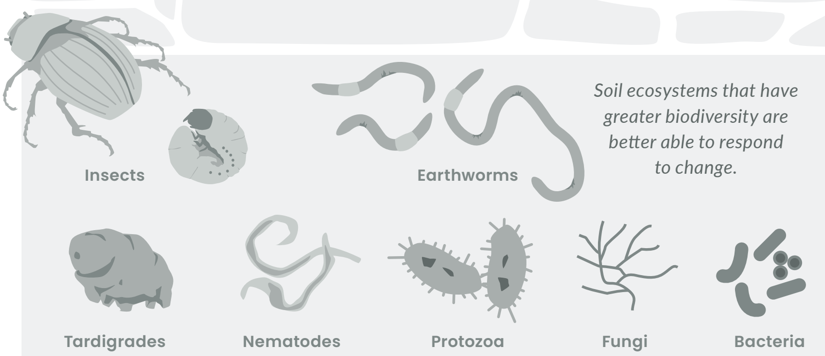
Bulk density

measures the density of soil. Topsoil usually has a lower bulk density than subsoil. Root growth can be restricted if a soil's bulk density is too high.

Macroporosity

measures the proportion of large pores (spaces between soil particles). Macropores provide air for roots and allow water to flow through the soil.

Bulk density and macroporosity have a natural range, some soils are very dense while others are very loose.



Soil ecosystems that have greater biodiversity are better able to respond to change.

SPOTLIGHT ON SOIL BIODIVERSITY

The biodiversity of soil is one aspect of soil quality that is not currently routinely monitored in New Zealand. Soil contains a multitude of insects, worms, fungi, and invisible microorganisms (like bacteria and protozoa), which together make up 25% of Earth's total biodiversity. Soil microorganisms can free up nutrients for plants to grow and can protect them from disease. Using land intensively can reduce the soil biodiversity (through the over use of fertiliser, pesticides, tilling, and compaction).

Target ranges for soil quality indicators

Each soil quality indicator has set target ranges to ensure the best crop yields and the least environmental damage (Sparling et al., 2008). Values that fall above or below a target range can limit production from the soil or indicate negative effects on the wider environment (Sparling et al., 2008; Stevenson et al., 2020).

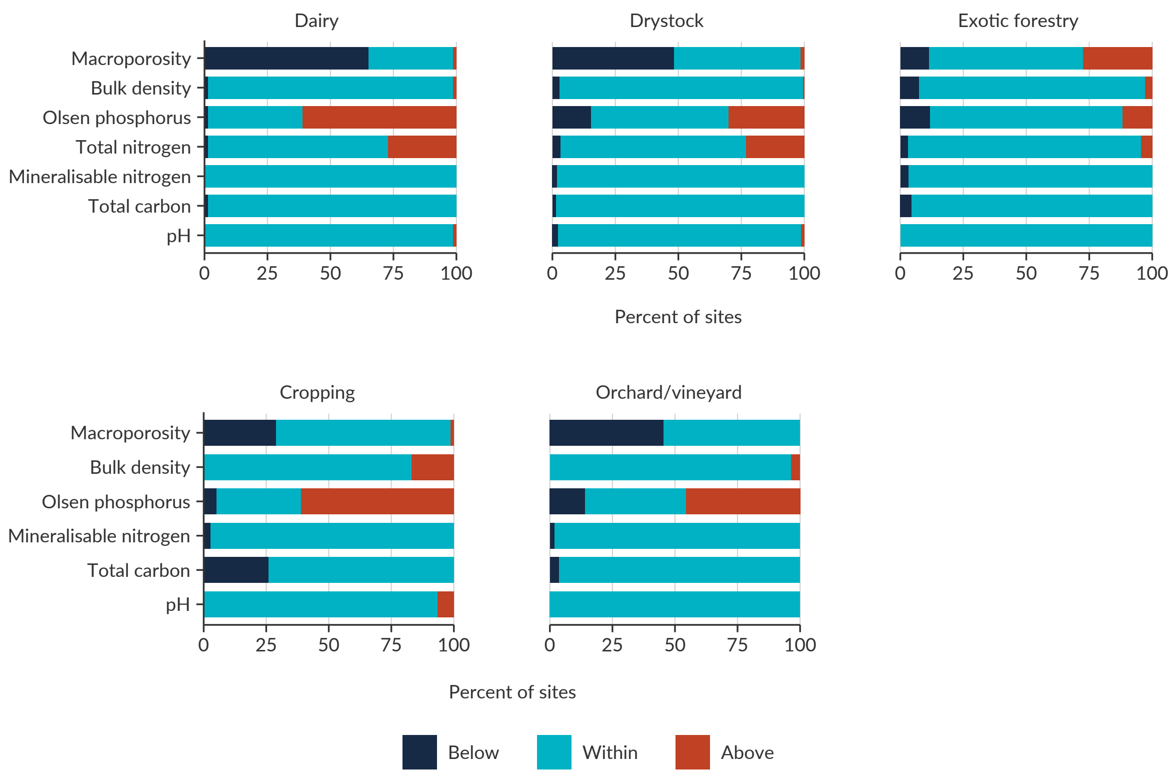
Soil quality target ranges are established for the combination of each indicator, land use, and soil order (Sparling et al., 2008; Stevenson et al., 2020). Not all soil quality indicators have target ranges for every land use. Total nitrogen target ranges are not available for cropping and orchard/vineyard. Total carbon does not have an upper limit as more carbon is considered better (Sparling et al., 2008).

Target ranges have been established for the following land uses:

- pastoral: dairy and drystock (sheep, beef, and deer) farming
- cropping and horticulture: cropping and orchard/vineyard
- forestry: exotic plantation forestry.

Soil quality target ranges are provisional and incomplete, and are updated as new research on production requirements or environmental effects becomes available.

Figure 4: Sites within target range of soil quality indicators by land use, 2014–18



Data source: Manaaki Whenua – Landcare Research

Macroporosity

Macroporosity (the number of pore spaces in the soil) was below the target range in 65 percent of dairy farming sites, 48 percent of drystock farming sites, and 46 percent of orchard/vineyard sites sampled between 2014 and 2018. No decreasing trend or improvement in macroporosity was found in drystock farming or in dairy farming from 1995 to 2018 (Stevenson & McNeill, 2020).

Low macroporosity can indicate that soil is compacted, with few large pores and a restricted flow of water and air. This can reduce the growth of plants and the yield from pastures, especially in wet conditions (Drewry et al., 2004, 2008; Mackay et al., 1996). Also, water can pond on the surface then run off, which causes erosion and moves topsoil and nutrients into waterways.

Soil compaction can be caused by heavy machinery (like tractors), high animal stocking rates, or stock damaging the soil when it is wet. Low macroporosity in orchards and vineyards can be caused by the use of heavy machinery for harvesting, pruning, and applying fertilisers and pesticides. The expansion of dairy farming since the 1980s is likely to have contributed to low macroporosity and increased compaction of soils with this land use (Drewry et al., 2008; Wynyard, 2016). (See indicator: Livestock numbers.)

Soil carbon

Levels of total carbon at most sites were within the target range, but soil carbon was below the target range at 26 percent of cropping sites. (See indicator: Soil quality and land use.)

Cropping – growing cereals, seeds, and vegetables – requires soil to be used intensively. This often involves several crop cycles per year, preparing the soil with tilling, adding fertiliser, pesticides, and irrigation, and harvesting with heavy machinery. The frequent tilling in cropping systems can cause soil carbon to decrease (Whitehead et al., 2018).

Olsen phosphorus

Levels of Olsen phosphorus were above the recommended target range for 61 percent of the dairy farming and cropping sites, and 46 percent of orchard/vineyard sites sampled between 2014 and 2018. (See indicator: Soil quality and land use and figure 4.) Olsen phosphorus levels provide an indication of soil fertility.

The top of the target range for Olsen phosphorous is 50 milligrammes per kilogramme for volcanic soils used for dairy farming, and the average concentration for monitored dairy sites was 67 milligrammes per kilogramme. (See indicator: Soil quality and land use.) Olsen phosphorus was also above the target range at 30 percent of drystock sites. (See indicator: Soil quality and land use and figure 4.) Also, a trend of increasing Olsen phosphorus was observed at cropping and drystock sites for 1996–2018 (Stevenson & McNeill, 2020).

Phosphorus becomes chemically unavailable soon after it is applied and only 15–30 percent of phosphorus fertiliser is taken up by crops (Cordell et al., 2009; Roy et al., 2006). High levels of Olsen phosphorus in the soil therefore indicate that too much has been applied. Also, phosphorus fertiliser is costly, so its overuse is an unnecessary expense.

Phosphorus – an essential but limited nutrient

Phosphorus fertiliser is produced from rock phosphate, a type of rock that contains high levels of phosphorus. It is only found in a few places worldwide and its supply is becoming increasingly scarce (Cordell & White, 2014).

Until the 1960s, New Zealand sourced rock phosphate from Nauru, where phosphate mining devastated the Pacific Island's environment (Wynyard, 2016). Today, approximately 70 percent of our rock phosphate comes from Western Sahara (Fertiliser Association of New Zealand, 2021). Geopolitics in this region may threaten a sustainable supply, which is a cause for concern (Cordell & White, 2014; Powers et al., 2019).

Recycling phosphorus from waste streams can be part of a circular economy. Manure, wastewater sludge, and waste from fisheries and the food industry are all possible sources (Ahuja et al., 2020; Powers et al., 2019). Fish waste has been used traditionally as a fertiliser and fertiliser made from fish waste can be commercially viable (Ahuja et al., 2020).

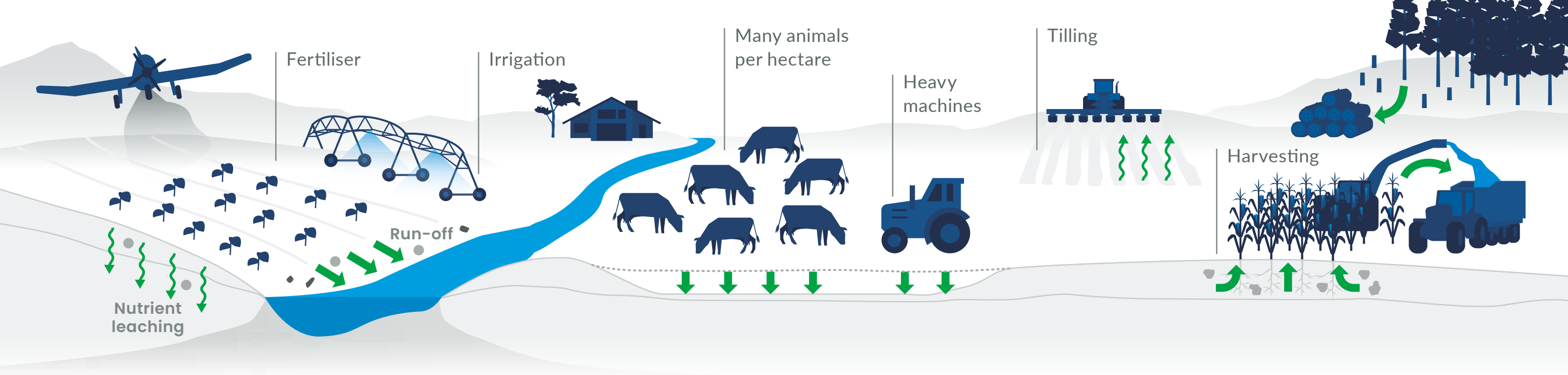
The phosphorus exceedance footprint (PEF) calculates the use of phosphorus from a consumption perspective. It takes into account a country's imports and exports of phosphorus as fertiliser and in goods that used this fertiliser in their production. PEF also takes the global environmental risk of phosphorus to freshwater and oceans into account (Li et al., 2019; Steffen et al., 2015).

In New Zealand, the use of phosphorus fertiliser peaked in 2005 and has reduced since then but the PEF per capita of this country is the largest in the world. (See indicator: Fertilisers – nitrogen and phosphorus.) New Zealand is a net exporter of phosphorus because of the exports of agricultural products that required phosphorus in their production (Li et al., 2019).

Land-use effects on soil quality

The ways we use and manage land affect the health and productivity of the soil.

PRESSURES AND IMPACTS ON SOIL



Nutrient leaching and erosion

Using too much fertiliser can cause nutrients (nitrogen and phosphorus) to move into groundwater or run off into freshwater. Too high levels of nutrients in the soil can also reduce its biodiversity.

Soil compaction

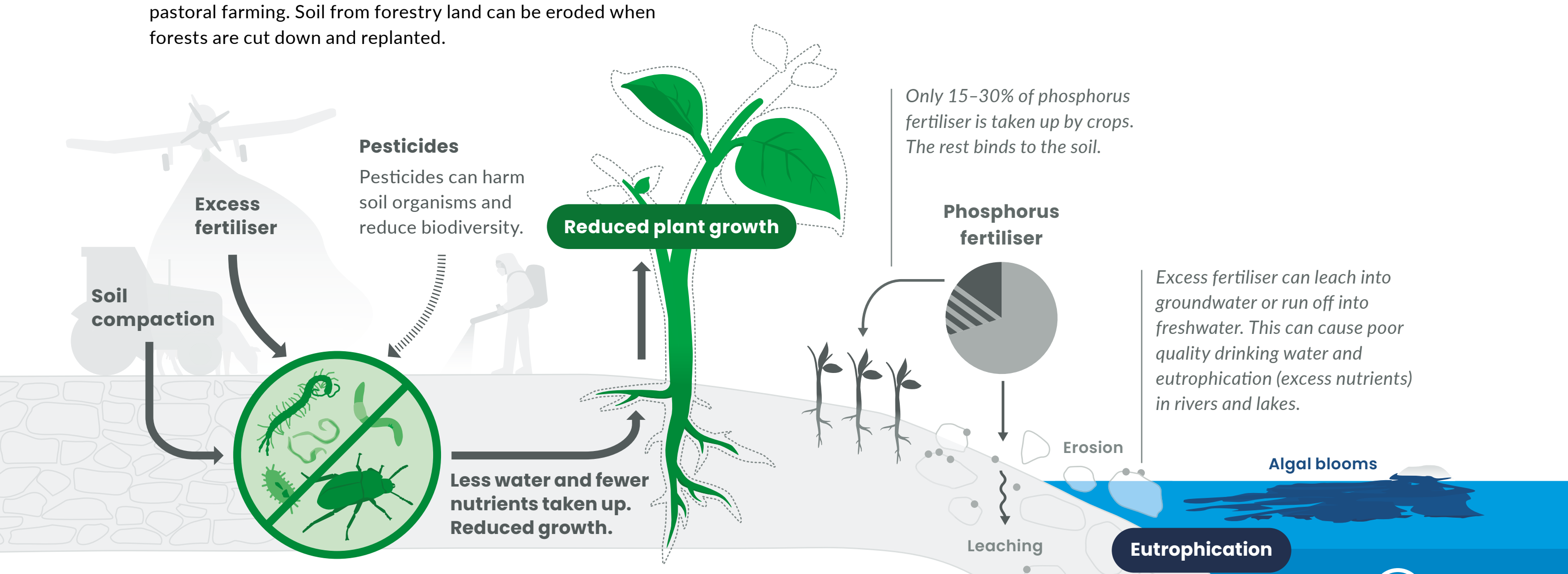
Compaction happens when the soil is compressed and air is pressed out. It can be caused by heavy machines and by having a large number of animals per hectare. Compacted soil has less air and water for soil organisms and fewer pores to let water and fertiliser into the soil.

Loss of soil carbon

Turning soil over disturbs its structure and the microorganisms in the soil. It leads to soil carbon being released as carbon dioxide. Harvesting crops also removes carbon and nutrients from the soil. Soil that is turned over and left bare is also at greater risk of being blown or washed away.

IMPACTS OF INTENSIVE LAND USE

Most human-caused erosion comes from land that is used for pastoral farming. Soil from forestry land can be eroded when forests are cut down and replanted.



Intensive land use threatens soil biodiversity

Mismanagement of fertilisers and pesticides, compaction, erosion, and the loss of soil carbon all can reduce the biodiversity of soil, and its health and productivity.

Excess nutrients reduce the quality of freshwater

When nutrients enter waterways they can lead to algal blooms that degrade rivers and lakes. Low levels of dissolved oxygen also reduce the health of freshwater and can contribute to environmental degradation such as eutrophication and algal blooms, affecting health and the diversity and function in those environments.

Total nitrogen

Total nitrogen levels were within the target range for more than 72 percent of sites for dairy, drystock, and forestry. (See indicator: Soil quality and land use and figure 4.)

Cropping and orchard/vineyards sites do not currently have target ranges for total nitrogen because of the large variations in the amount of nitrogen required by different crops. Concern about nutrients leaching from land with these uses has been raised, particularly where vegetables are grown intensively (Drewry et al., 2015).

Despite most sites being within the target range, many rivers are polluted with excess nitrogen (MfE & Stats NZ, 2020b). The total nitrogen target range therefore does not appear to adequately capture the issues around its use and environmental impacts. While more nitrogen is considered to be better for agriculture (to enhance plant growth, crop yield, and production), less nitrogen is better for environmental outcomes like freshwater quality (Sparling et al., 2008).

Trace elements

Some dairy and drystock sites have relatively high levels of cadmium and zinc compared to natural soil background concentrations. A decrease in cadmium at these sites has been observed since 1995. Some cropping and horticulture soils have relatively high levels of arsenic and cadmium compared to natural soil background concentrations (see figure 5).

While there is no soil quality target range for trace elements, heavy metals such as arsenic, cadmium, copper, lead, and zinc can be toxic for soil organisms, plants, and animals if their concentrations become too high. Levels of trace elements in New Zealand soils are generally within the provisional ecological soil guideline values that have been established to protect soil life, plants, and animals from toxicity (see figure 5) (Cavanagh & Munir, 2019).

Cadmium can be present in some types of phosphorus fertiliser. Rock phosphate from Nauru was high in cadmium and as a result, soil cadmium concentrations have increased on most land used for agriculture, particularly dairy farms in Waikato and Taranaki (Longhurst et al., 2004; Taylor et al., 2010; Wynyard, 2016; Cavanagh et al., 2015; Drewry et al., 2021; Fertiliser Association of New Zealand, 2019; Abraham, 2020).

Cadmium levels in agricultural soils are managed through the tiered fertiliser management system that ensures they remain within acceptable limits for human health, soil health, and agricultural production (Abraham, 2020; Fertiliser Association of New Zealand, 2019).

SOIL HEALTH, MICROORGANISMS, AND BIODIVERSITY

The concept of soil health is more holistic than soil quality. Soil health is a soil's ongoing capacity to function as a living ecosystem that sustains plant, animal, and human health (Lehmann et al., 2020).

A healthy soil supports high biodiversity, with myriads of microorganisms forming complex, intricate networks and interacting to process carbon and nutrients. Soils contain more than 25 percent of the world's total biodiversity mostly as microorganisms (FAO et al., 2020). These microorganisms contribute to nutrient cycling, plant growth, and defending plants against pathogens (disease-causing organisms) (Bardgett & Van Der Putten, 2014).

Soil biodiversity is essential for a functioning and resilient soil ecosystem (FAO et al., 2020). Many different organisms in the soil have similar functions so if some are attacked by a pathogen or cannot tolerate a drought, other organisms will be able to carry on the same processes.

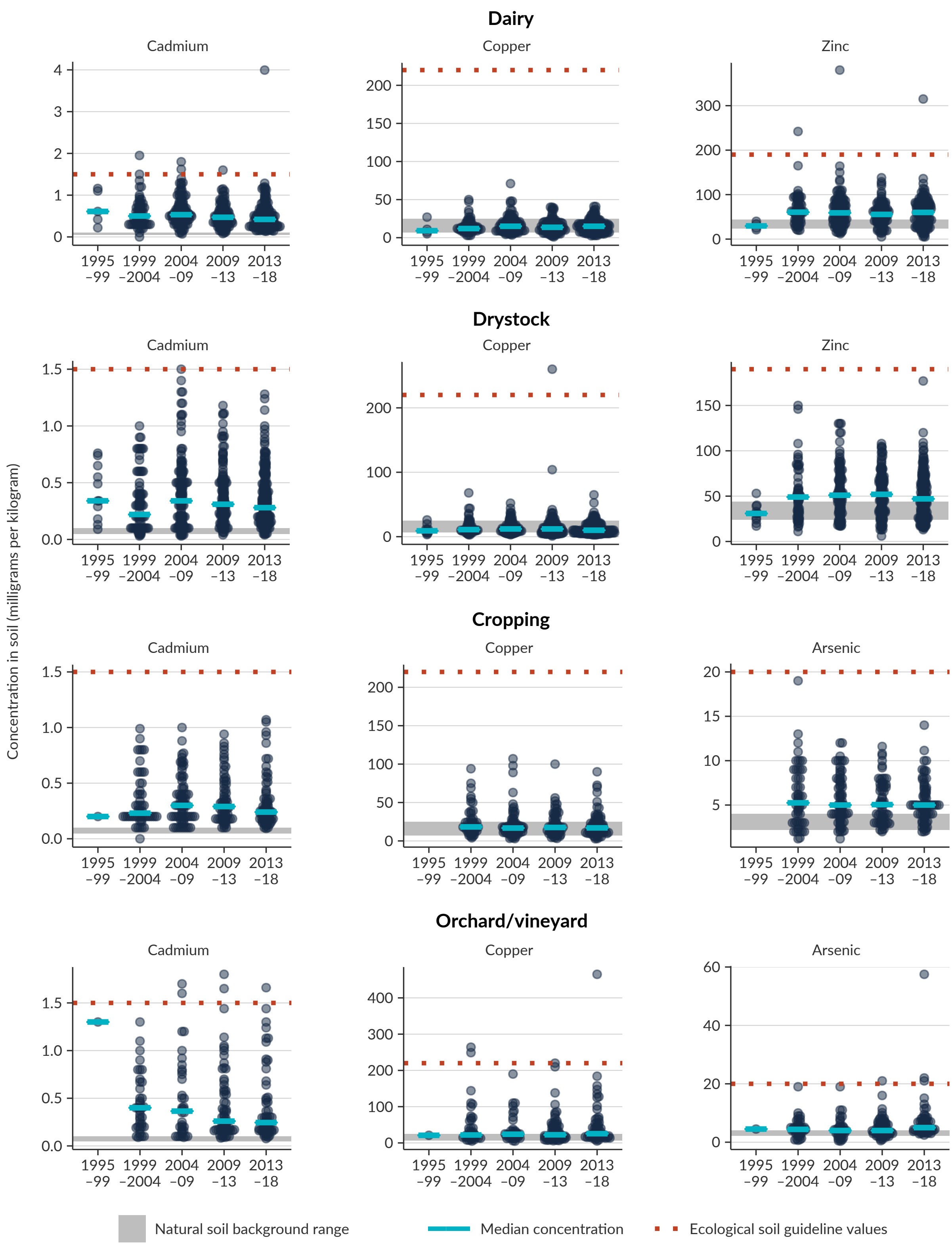
Intensive management – tilling, fertiliser use, pesticides, and compaction – has negative effects on soil biodiversity (Bardgett & Van Der Putten, 2014; Leahy et al., 2019; Tamburini et al., 2020; Wakelin et al., 2021). In degraded soil, soil organisms cannot process carbon and nutrients sufficiently and it is harder for plant roots to access the water, air, and nutrients needed for growth.

Adding fertilisers affects which microorganisms live in the soil and the functions they perform (Hermans et al., 2017; Wakelin et al., 2021). Using land for pasture can affect soil biodiversity for decades. It can also have ongoing effects on how soil ecosystems are able to respond to further changes in land use (Addison et al., 2019).

At 50 pasture sites across New Zealand, the complexity of networks and interactions in groups of microorganisms with different functions were compared. Pastures that were managed less intensively had more soil complexity than those managed as highly intensive dairy pastures. The higher complexity may indicate that the soil processes are more resilient and better able to tolerate disturbance (Dignam et al., 2018; Bardgett & Van Der Putten, 2014).

Despite some progress to identify suitable indicators of soil biodiversity in New Zealand, regular sampling and measurement of soil biodiversity is yet to be established as part of long-term soil quality monitoring (Hermans et al., 2020).

Figure 5: Trace elements in monitoring sites, 1995–2018



Data source: Manaaki Whenua – Landcare Research

Note: The background soil concentrations reported here (shaded grey) are for guidance only since these vary considerably depending on geology. Values below the given ecological soil guideline values (Eco-SGVs, shown as red dotted lines) are generally considered safe for soil microorganisms, invertebrates, plants, wildlife, and livestock for agricultural land use. Eco-SGVs reported here are provisional guidelines based on current best estimates of ecotoxicity. The concentrations of trace elements at a site should be assessed using site-specific background concentrations. Eco-SGVs for copper and zinc are reported for typical reference soils (Cavanagh & Munir, 2019; Stevenson et al., 2020).

CHAPTER 4

Effects on the wider environment

▸ Plumes of sediment from the Kahutara River discolour the sea at Peketa, south of Kaikoura.

Photo: Nature's Pic Images

Land connects every part of the complex system that is te taiao, the environment. How we use land can therefore affect the many interactions between land, lakes, rivers, oceans, air, climate, and native species.

Native vegetation and wetlands continue to be removed in some regions, including the West Coast and Southland. From 1990 to 2012, 157 hectares of wetland were lost per year in Southland – mainly through conversion to pasture. Areas of native vegetation offer many benefits to farms.

More intensive agriculture and urban expansion can increase pollution in the freshwater and marine environments. This degrades the environment and has a negative influence on the native species living there. People can be affected when their drinking water is polluted and sources of wild food are contaminated.

Animals and fertiliser contribute to our greenhouse gas emissions – 53 percent of our emissions by volume in 2018 were methane and nitrous oxide, with most coming from agriculture. Emissions from livestock made up 86 percent of methane emissions.

All these impacts – loss of native vegetation, water pollution, and climate change – affect each other through feedback and cascading effects, and can cause further negative effects on the environment.

Land use and the loss of native vegetation

In 2018, about half (49 percent) of New Zealand was covered with native ecosystems and the other half (51 percent) with farms, pasture, and plantation (exotic) forests. (See indicators: Indigenous land cover and Exotic land cover.) In New Zealand, land covered with original or regenerating native vegetation ranges from vast areas of conservation land to small, isolated stands of regenerating bush on farms and in cities.

The area of land covered with native ecosystems continues to shrink, mainly through conversion to agriculture or forestry. (See indicator: Indigenous land cover.) Some types of native land cover are more at risk. Scrub tussocks, wetlands, and lowland forests are particularly vulnerable because they are often located in accessible areas that are suitable for agriculture and housing (see Ice, hydro, and irrigation: how water has changed the dry Mackenzie basin) (Cieraad et al., 2015).

Scrub, shrubland, and tussock grassland have seen the greatest losses in recent decades but native forest continues to be removed in some regions including the West Coast and Southland. (See indicator: Indigenous land cover.) In 2010, 10 percent of wetlands remained compared to their original extent (Ausseil et al., 2011). In Southland 157 hectares of wetland were lost per year between 1990 and 2012, mainly through conversion to pasture (Robertson et al., 2019).

Farms benefit from the presence of native vegetation. It can prevent erosion, filter nutrients out of water, and reduce the damage caused by floods – all of which increase a farm's sustainability and ability to adapt to change (Dominati et al., 2019). Also, farmland that is used less intensively loses fewer nutrients from the soil to freshwater (PCE, 2013). Farms and landscapes that have more diverse agriculture and vegetation types receive a greater range of environmental benefits (Gómez-Creutzberg et al., 2020).

Land that is used for more intensive agriculture like dairy farming and cropping (market gardens and grain and seed growing), usually has less native vegetation and lower native biodiversity than land used for less intensive agriculture such as sheep farming (Pannell et al., 2021). Trees are often removed from intensively used land to maximise production and the reach of irrigation systems (Welsch et al., 2014).

About 25 percent of the total area of native vegetation cover in New Zealand is on land used for sheep and beef farming, compared with 1 percent of total area of native vegetation cover on land used for dairy farming (Dominati et al., 2019; Norton & Pannell, 2018). Only about 3 percent of the native vegetation on sheep and beef farms is permanently protected by covenants (Pannell et al., 2021).

Land use affects freshwater

NITROGEN, PHOSPHORUS, AND SEDIMENT IN FRESHWATER

Excess sediment, pollutants, and unnatural water flows cause pollution and poor ecological health in most of the rivers and lakes in catchments where the dominant land cover is urban, farming, or forestry (MfE & Stats NZ, 2020b). Nutrient and sediment run-off from land that is used intensively can cause native freshwater biodiversity to decrease (MfE & Stats NZ, 2020b).

Applying nitrogen fertiliser and animal effluent to the soil increases the risk of nitrogen moving into freshwater and its leaching into groundwater (Di & Cameron, 2002). The type of land use, soil nutrient levels and inputs, weather, and vegetation influence how increases in nitrogen applied to the land affects the amount of nitrogen in freshwater (Abell et al., 2011; Monaghan et al., 2007).

Phosphorus can accumulate in the soil when phosphorus fertiliser is applied continuously. It enters freshwater mainly when soil with high levels of phosphorus is eroded (McDowell et al., 2019). New Zealand's large lakes and rivers have naturally low levels of phosphorus (McDowell et al., 2020b). Most of the rivers and lakes in catchments with land in the urban, pastoral, and exotic land cover classes have a higher risk of algal blooms, based on calculated nutrient concentrations (MfE & Stats NZ, 2020b).

Nitrogen and phosphorus can cause algal blooms in rivers and lakes, reducing the amount of oxygen in the water for plants and for fish to breathe. Too much nitrate-nitrogen (one form of nitrogen) in groundwater used for drinking water is also a potential human health concern (Schullehner et al., 2018). A preliminary study of nitrate contamination of drinking water in New Zealand found nitrate concentrations above potentially harmful levels in areas with high cattle density (Richards, 2021). The leaching of nitrogen and other nutrients into groundwater can take a long time. In groundwater that was dated using tracers, a sharp increase in nitrogen and other agrochemicals was observed after 1955, corresponding to the start of intensified agriculture (Morgenstern & Daughney, 2012).

Management was estimated to be effective in reducing the loss of nitrogen from pastoral land between 1995 and 2015. Methods included fencing streams, and timing irrigation and effluent to minimise run-off. However, the overall national nitrogen losses for this period increased because more land was converted to dairy farming and land use became more intensive (Monaghan et al., 2021).

Similar methods can be used to reduce the amount of phosphorus-rich soil being washed into freshwater – streams can be fenced off from livestock, and irrigation and effluent disposal adjusted so the risk of erosion is low. If these measures were taken nationally, the amounts of nitrogen, phosphorus, and sediment from pastoral land could be reduced by 34, 39, and 66 percent respectively by 2035 (McDowell et al., 2020a).

URBAN AND AGRICULTURAL WASTE

Urban and agricultural land uses produce waste, which can also pollute waterways. A large proportion of rural waste – such as scrap metal, agricultural plastics, and agrichemicals and their containers – is disposed of directly on land. This waste also risks polluting freshwater when waste blows away or when contaminants in the waste wash into freshwater or soak into groundwater (Hepburn & Keeling, 2013; Waikato Regional Council, 2014).

Pollutants from cities and towns like heavy metals from vehicles, plastic litter, and nutrients from garden fertiliser, can enter rivers, lakes, estuaries, and beaches through stormwater networks. Wastewater also pollutes waterways and coastal water with nutrients and pathogens (disease-causing microorganisms) (MfE & Stats NZ, 2019b, 2020b).

EFFECTS OF TAKING WATER

More water is being used as New Zealand's urban areas expand and agriculture becomes more intensive. To meet this need, a larger volume of water is taken out of rivers, lakes, and groundwater. This affects how much water is stored in aquifers, and the quantity, timing, and intensity of flows in rivers and streams. Taking water from rivers alters the volume and flow of water, which can degrade freshwater ecosystems and reduce the quality of freshwater for recreational and cultural uses (MfE & Stats NZ, 2020b).

While a small proportion (5 percent) of agricultural land is irrigated, this area is increasing especially land used for dairy farming. (See indicator: Irrigated land.) Irrigation uses large amounts of water and irrigation had the largest consented water allocation by volume (58 percent) for 2017–18. (See indicator: Consented freshwater takes.) Computer models predicted that taking water for irrigation had the greatest potential to reduce river flows across the country when compared with other uses (Booker & Henderson, 2019).

Land use affects the marine environment

Coastal areas that receive large volumes of freshwater from rivers have correspondingly large amounts of sediment and high concentrations of nitrogen (Dudley et al., 2017; MfE & Stats NZ, 2019a, 2020b). How far these effects extend into the marine environment is not well understood.

People can become sick from contact with harmful bacteria, for example, from sewage in contaminated seawater. Kaimoana (seafood) can also be affected (MfE & Stats NZ, 2019a). From a Māori perspective, sewage systems and food gathering should occur in completely separate domains, with land-based treatment of sewage preferred (Harmsworth, 2002; MfE & Stats NZ, 2019a).

Land use contributes to climate change

Emissions of greenhouse gases in New Zealand are contributing to global climate change. The way we use land has the largest impact on our emissions. More than half (53 percent) of our gross emissions in 2018 were methane and nitrous oxide, with most coming from agriculture. Emissions from livestock made up 86 percent of methane emissions, while 93 percent of nitrous oxide emissions came from agricultural soils (mainly due to dung and urine from livestock) (MfE & Stats NZ, 2020a).

The manufacture and transport of fertiliser in this country and overseas causes high emissions from the greenhouse gas nitrous oxide. After those from animals, fertilisers made the largest contribution to greenhouse gas emissions from New Zealand dairy farms at 15 percent of their carbon footprint. Emissions from nitrogen fertiliser were the highest across all types of fertiliser (Ledgard et al., 2011).

Greenhouse gas emissions are increasing, and in New Zealand the increase is linked to more intensive agriculture. The shift from sheep and beef farms to dairy farms increased the number of dairy cattle between 1971 and 2019, and dairy cattle emit more methane and excrete more nitrogen per animal than sheep and non-dairy cattle (MfE & Stats NZ, 2019a). (See indicator: Livestock numbers.) Urine from dairy cows that is deposited onto wet compacted soil can increase nitrous oxide emissions (van der Weerden et al., 2017).

Finding a way through disaster to environmental and economic sustainability

Taylah and the Mitchell family. From left, Dana, Shaun, Taylah, Kenzie, and Dana's father Walter Brady.

Photo: Stuff

"I woke up in darkness to the sound of a waterfall, which didn't seem right," says Taylah Mitchell (Te Aitanga-a-Hauiti) of that morning in October 2018. "When I stood up, my feet went into a foot of water. In the 10 minutes it took for everyone to wake up, the water had reached 1 metre. It was scary."

A large volume of timber debris from forestry operations (slash – woody debris) in the hills behind her home had been washed downstream by heavy rain. The logs formed a dam behind Wigan Bridge, which then burst, causing flooding and damage to the bridge as well as homes.

"There was no way of getting out of our house until the water subsided because all the cars were floating. We ended up calling my dad who drove a log truck out to get us out – and he only just made it. We lost everything and our house couldn't be repaired."

The family has had to move into different accommodation – Taylah with a sister and her parents to another house.

"My grandparents had just moved in with us and it was really traumatising for them. Their new house is also close to a river so it took a bit of time for Nan to feel safe when it rained.

"Even talking about it now, I still find it hard to believe what happened to me. Sometimes I don't know how to feel because my dad is in forestry. But I don't sit here and put a lot of blame on them. It's in the past and I'm more about how we're going to move forward."

Victor Walker is dwarfed by a pile of forestry slash on Tolaga Bay beach.

Photo: Nori Parata

Victor Walker (Te Aitanga-a-Hauiti), trustee of the Ūawanui Sustainability Project, has lived in Ūawa Tolaga Bay all his life and has seen local industries come and go. His father and many of the whānau were employed to cut and clear mānuka and kānuka for sheep farming in the steep, erosion-prone hills behind the small east coast settlement.

But back in 1988, Cyclone Bola devastated the area with slips and flooding and took the lives of three local people. Concern about damage from similar events in the future led the Ūawa community to embrace forestry as a better way to use their land, despite warnings about potential issues due to the steep terrain.

"We bought into forestry as a better way to use the land than farming. For us it was an economic decision and seemed the right way to go. But 30 years later with harvesting at its peak, we are on the back foot because the mitigations to protect us and our waterways were not in place."

A heavy rain event in 2011 brought thousands and thousands of cubic metres of forestry slash down the river. There have been several more since.

"It was terrible, really ugly. You could follow the trail of devastation from the streams to the tributaries to the main artery which is the Ūawa River, with debris and rubbish that destroyed kilometres of fences and covered most of the paddocks with silt. Some of the streams were pristine with beautiful native flora and fauna – we used to get our drinking water from them.

"We were 10 years into a 100-year environmental sustainability strategy, and we got smashed. Our vision is for a restored freshwater habitat with all the native species including fish that indicate good health. But our rivers are seriously contaminated and not in good health.

"Our coastline has also been impacted. There's evidence that our kaimoana (seafood) like kina is relocating and in some places, becoming bitter and sour. The pāua are becoming choked because of the sediment and they're moving to a new home away from here. As iwi, we're concerned that we might not be able to manaaki and host manuhiri with our local foods in the way we always have."

Massive amounts of slash ended up on the beach – it was littered with logs. Floating rafts circled the bay with the tide and were hazardous for swimmers and boaties. A hugely popular training programme at the surf lifesaving club had to be put on hold with the beach closure. As part of a clean up, there were 90 bonfires on the beach in November 2020.

"Even the fires caused some angst in the community because of the potential for smoke to drift inland. Ours is one of the greatest beaches in the world but anyone younger than eight has not been able to experience that."

In the aftermath of the flooding, all work associated with forestry stopped. This had severe effects on the household income for many of the forestry contractors and the retailers in Ūawa. Victor acknowledges the tremendous support for the community that was shown with gifts and donations from locals as well as charities, iwi authorities, and people across the country in a time of great adversity.

"It's really hard for the community – families like Taylah's have lost so much. Some people want to get rid of forestry altogether while others are focussed on the benefits. There wouldn't be one household here that isn't touched directly or indirectly by forestry. Many of us are concerned that if we didn't have forestry at the current level, we would be faced with higher unemployment, a proliferation of issues associated with unwellness, and the anti-social behaviour that comes with a loss of purpose, income, and positive busyness."

For now, keeping people safe is the most important thing.

"If we see a hurricane in the South Pacific tracking our way, our Civil Defence goes on high alert and if heavy inundations of rain begin, the message to clear out goes to people near the most vulnerable streams.

"We're looking to the Gisborne District Council and the forestry industry to assure us that in the next heavy rain we're not going to have logs coming down our river, smashing into our bridges and houses and ending up as dangerous debris along our beaches and coast. I would have confidence for the future if they could do that in a credible way. Now, with the greatest respect, I think there's still work to do."

The Ūawanui Sustainability Project is a community-led initiative that aims to achieve long-term economic, environmental, and social benefits. Many agencies have contributed to and supported the project since it began in 2010.

CHAPTER 5

Land and our wellbeing

▸ View of Mt Taranaki from the Pouakai Range.

Photo: Sarah Wilcox, Descipher

Food, shelter, health, connections to other people, and the ability to provide for ourselves and our families contribute significantly to our wellbeing. All depend on having access to good quality land.

Land provides places and spaces to live, work, play, and socialise. It also generates benefits and goods to ensure good health and material gain. Benefits include food, energy, health, recreation, and identity (Ausseil et al., 2021). Wellbeing frameworks help us understand these links between nature and people.

Living in urban centres can reduce our exposure to nature, along with its benefits to physical and mental health. Māori in urban centres are at risk of losing the connection to their whenua. Intensive land use can affect human health in rural areas through infectious diseases transmitted by livestock.

Losing access to mahinga kai (food gathering) is significant for Māori. It is not just the loss of a food source – it also reduces the ability to exercise tikanga (customs), pass on mātauranga (knowledge), and manaaki (show hospitality). This all affects the mana (prestige) of people and the whenua (land).

Land provides jobs and income, and local changes in land use can cause unemployment or new opportunities.

Many coastal settlements are at risk from sea-level rise and exposure to storms and coastal erosion. This can affect personal safety as well as the investment made in the property. Neighbourhoods and lifestyle blocks that are close to pine forest or land with highly flammable plants (like grass) have a greater risk of damage from wildfires.

When land changes hands or is used for different purposes, it can disrupt the strong social connections that people have with their land or where they live.

Wellbeing frameworks

WELLBEING IN TE AO MĀORI

In te ao Māori (a Māori worldview), the health of animals, humans, and the environment is intimately connected (Harrison et al., 2020). If the whenua is not healthy, every dimension of whānau wellbeing suffers.

If the ecosystems and biodiversity where mahinga kai (food gathering) is practiced are lost, it means more than not being able to collect food to eat. These losses reduce taha wairua (spiritual wellbeing), hinengaro (emotional wellbeing), tinana (physical wellbeing), and whānau (family wellbeing) because the ability to exercise tikanga (customs) and mātauranga (knowledge) that has been passed down through generations is also lost. Not being able to manaaki (show hospitality) and share that kai (food) with whānau (family) and manuhiri (guests) also affects the mana (prestige) of the people and the whenua (land).

Te whare tapa whā is a Māori model of wellbeing that is used widely in the health sector. It provides a holistic understanding of how Māori view wellbeing and how it relates to culture, place, and nature (McIntosh et al., 2021). It uses a whare (house) and its four walls (tapa whā) to represent different components of wellbeing: taha wairua (spiritual), taha hinengaro (emotional), taha tinana (physical), and taha whānau (family interconnections). The foundation connects the whare to the whenua (land). To be strong, the whare must balance and connect all the dimensions.

THE LIVING STANDARDS FRAMEWORK

The Living Standards Framework represents the Treasury's perspective on what matters for New Zealanders' wellbeing, now and into the future. It is based on the OECD better life index that measures wellbeing in a way that is internationally comparable (OECD Better Life Index, 2020). Through the Framework, wellbeing can be assessed across 12 domains (New Zealand Treasury – Te Tai Ōhanga, 2019).

Living Standards Framework domains	Wellbeing component and section title
▸ Health ▸ Time use	Land and health
▸ Income and consumption ▸ Jobs and earnings ▸ Housing	Land and material wellbeing
▸ Safety and security	Land and personal safety
▸ Social connections ▸ Subjective wellbeing ▸ Cultural identity ▸ Knowledge and skills	Land, culture, and social connection
▸ Civic engagement and governance	Land, governance, and engagement
▸ Environment	See chapter 4: Effects on the wider environment

Land and health

ACCESS TO NATURE

Easy access to nature improves the connection we have with nature. It also benefits our physical and mental health through exercise and a stronger immune system (Kuo, 2010). The value of being able to spend time in nature can help us during difficult times.

While our cities generally have good access to green spaces, people who live in urban areas often have less connection to nature than those in other areas (Blaschke et al., 2019; Duron-Ramos et al., 2020; Ma & Haarhoff, 2015). Access to nature has benefits for people living with mental illness (Kuo, 2010). A UK study found that people who lived in neighbourhoods with more vegetation and birdlife were less depressed, anxious, and stressed (Cox et al., 2017). Because of these benefits to health and wellbeing, the Mental Health Foundation of New Zealand and the Department of Conservation partnered to encourage New Zealanders to spend time in nature (DOC, n.d.).

Green spaces with many different species (high biodiversity) are particularly beneficial. These areas can bring health benefits by introducing new and diverse microorganisms to our microbiome (the collection of microorganisms that are naturally present in our bodies) (Flies et al., 2017). Urban green spaces can also reduce exposure to air pollution and balance extreme temperatures (Zupancic et al., 2015).

Holding on to rongoā and mātauranga

Many native plants are treasured by Māori. Kūmarahou, mānuka, and kawakawa have been used by generations of Māori for rongoā (the practice of medicine and healing) and continue to sustain and restore Māori health and wellbeing.

Rongoā practitioners, however, are finding it more difficult to access the plants they need. Kūmarahou (*Pomaderris kumeraho*) used to grow abundantly in the far north, but has slowly disappeared as introduced weeds have taken over. Many native plants species are currently under threat from changes in land use and introduced species, and increased pressure from climate change (DOC, 2020).

If rongoā plants are not available, the rongoā the plants produce is lost, as well as the mātauranga (knowledge) and tikanga (practices) associated with the species (McGowan, 2011). A loss of mātauranga in the past 100 years has meant there are now very few Māori who can identify rongoā plants in the ngahere (forest). A 2018 survey of approximately 8,500 Māori people found that only 18 percent had gathered materials for use in traditional practices. The highest rates of gathering were in the far north and eastern regions of the North Island (Stats NZ, 2018). This loss is compounded because about 82 percent of Māori live in urban areas (Stats NZ, 2021a), which can limit access to whenua and ngahere.

Robert McGowan, expert rongoā practitioner says, "Rongoā is about the living connection between ourselves and the living world of the forest. That can only be gained by going into the forest and getting to know it as a friend, with all of its changes and moods, in all of the seasons. It can't be done quickly, but it is the right place to learn." (McGowan, 2011).

RISKS FROM AGRICULTURE

Infectious diseases that jump from wildlife, such as COVID-19, are a risk to human health. When land is converted for agriculture or used more intensively, more livestock are in contact with wild animals and humans. This increases the risk that these infectious diseases will affect livestock and people (IPBES, 2020).

New Zealand's native animals are not known to spread human diseases, but there is a high risk of introduced farm animals spreading diseases to humans in this country, particularly in rural communities (Crump et al., 2001). Diseases caused by bacteria such as *Campylobacter*, *Leptospira*, and *Salmonella* can be spread via animals, and some have been linked to intensive animal farming. The amount of farm animals in New Zealand per capita is high. The hazards of animal-spread diseases are also higher among agricultural workers here than in other countries where the ratio of humans to farm animals is lower (Crump et al., 2001; Green, 2014; ESR, 2020). Campylobacteriosis is the most frequently notified disease in New Zealand and in Canterbury, this disease was diagnosed more often in areas with more intensive animal farming (Ball, 2007; Green, 2014).

LAND AND MATERIAL WELLBEING

Material wellbeing is about having adequate food, shelter, and income. Some jobs are related to the land. In the year ended March 2020, 384,186 people were employed directly and indirectly in the tourism sector (Stats NZ, 2020d). In December 2020, 110,791 people were employed in land-based primary industries including agriculture, forestry, and related support services. In December 2020, there were 2,253,444 filled jobs in New Zealand (Stats NZ, 2021b).

Changes in land use can affect employment locally. In Southland for example, the change from sheep and beef to dairy farming from the mid-1980s led to a fall in employment in meat processing and an increase in dairy product processing. These transitions can be difficult, particularly for small towns like Mataura that was dependent on meat processing and where unemployment subsequently rose (Taylor, 2019).

Other land-use changes may bring new job opportunities. In the Bay of Plenty, changing from dairy farming to kiwifruit growing created new jobs for thinning, spraying, and mowing contractors and for seasonal pickers and packers. This surge in seasonal jobs, coupled with low unemployment rates in the region, has kept the demand for migrant workers high (Taylor, 2019).

Reclaiming land helps to reconnect people

Te Kaikaitāhuna stream.

Photo: William Anaru

The worst weeds – blackberry, gorse, willow, and honeysuckle – were as high and impenetrable as walls on either side of Te Kaikaitāhuna stream only a few months ago. They smothered an area that was used traditionally for food gardens and isolated the Ngāti Rangiwewehi people from their awa (river).

The beautiful Te Kaikaitāhuna stream begins at Hamurana Springs and carries cold, clear water to the northern end of Lake Rotorua. The area is culturally significant to Ngāti Rangiwewehi and Te Arawa and was used by tūpuna for healing and for performing karakia and spiritual ceremonies.

"There were no major conflicts at Hamurana Springs in the 1800s. It is known as a place of peace and it's still peaceful – that's one of the reasons I love going up there," says Junette Putaranui, Ngāti Rangiwewehi.

In the kōrero (stories) of Ngāti Rangiwewehi, two taniwha, Hinerua and Pekehāua, are kaitiaki (guardians) of the waterway and the treasured kōaro (a native fish) are their children. Having access to the awa is essential for being able to continue cultural activities and traditions like mahinga kai (food gathering).

"Because of the weeds, you couldn't see the water from the track and there was no way we could get to some parts of the awa. That affected the wairua of Te Kaikaitāhuna, the pest trapping work, and the monitoring for kōaro."

About 30 percent of the Te Arawa people have had their employment affected by the fall in tourists visiting Rotorua because of the COVID-19 pandemic. Jobs for Nature funding through Te Arawa Lakes Trust, however, has provided help for both problems by providing employment for workers to clear the weeds.

Project manager William Anaru reports, "Ten te hunga tiaki (caretakers) started work in December and have already put in more than 1,500 hours' work, with at least 30 trailer loads of weeds removed. It was a massive job. This has tidied up the site significantly, increased access, and enabled kōaro monitoring to re-start. People have also been able to connect with the awa again."

Native tree planting is scheduled for later in the year and a regular weed spraying programme is in place.

Michael Hancock, Te Arawa, says he didn't realise how significant Hamurana was to his iwi when he was growing up. "We're now trying to help more people learn about the significance of the springs and the awa and bring the old stories back. People are staying here a lot longer to enjoy what we haven't seen in a very long time. The visitors I talk to are amazed."

In the future Michael would like to see the gardens around the springs re-established and watercress reintroduced.

"My parents and kaumātua (elders) said there used to be lots of watercress there but there isn't any now. We'd like to try and re-establish it somewhere – it tastes so much better when you get it from the wild."

Te Arawa Lakes Trust is using funding from Jobs for Nature to restore a number of wetlands in their region, including Te Kaikaitāhuna, through the Mauri Tū, Mauri Ora programme. The programme is designed to reinvigorate the economy, environment, and the community of Te Arawa. Its kaupapa is to create jobs and support skills initiatives that are aligned with national environmental projects. Thanks to Junette Putaranui (Ngāti Rangiwewehi, Te Arawa), William Anaru (Te Arawa), Michael Hancock (Te Arawa), and Deliah Balle (Te Arawa) for their contributions to this story. The mahi (work) of Pest Free Hamurana is also acknowledged.

Land and personal safety

Approximately 7 percent of our population lived within 3 metres of the height of the average spring high tide in 2015, and more than 43,000 houses were within 1.5 metres of this level (Bell et al., 2015). These coastal settlements are at risk from sea-level rise and exposure to storms and coastal erosion (Glavovic et al., 2010). This can affect personal safety as well as the investment made in property.

Choices about how we use land can bring risks in other areas. When neighbourhoods and lifestyle properties are close to areas of pine forest or highly flammable plants, it increases the risk that wildfires pose to people and homes. The 2017 Port Hills fires near Christchurch posed more risk to people and property because of the multiple land uses in the area and the proximity of houses to flammable vegetation (Kraberger et al., 2018). In 2020, fires caused property damage in Lake Ōhau Alpine Village.

While some risks to personal safety cannot be avoided, effective planning can help reduce the risk that natural and human-caused events pose to wellbeing. Floods can cause significant damage to homes and people in vulnerable low-lying areas like floodplains. Protecting and restoring natural areas upstream (like wetlands) that slow the flow of run-off water can reduce the risks of flooding in low-lying areas. This approach may be cheaper in the long term than building costly flood-protection infrastructure like stopbanks, which also require more ongoing maintenance (Clarkson et al., 2013; Van den Belt et al., 2013).

A strategy for managing eroding coastal areas in Hawke's Bay used two approaches to reduce the risks to people – building sea walls and other structures, and supporting communities to leave the most at-risk areas (Bendall, 2018). After the Christchurch earthquakes in 2011, green and red zoning was used to keep people safe from the resulting unstable land and liquefaction (Saunders & Becker, 2015).

Land, culture and social connection

People in farming communities have a strong connection to their land or the place where they live (Curran-Cournane et al., 2016). When land changes hands or is used for different purposes, it can cause social changes in a community through a loss of traditions and shared cultural values (Taylor, 2019). These changes can also cause people to take up new opportunities like tourism (Mackay et al., 2009).

The resilience of Māori communities can depend on the cultural background, history, identity, and availability of Māori land. Māori people, however, have lived through extreme social and economic shocks because of land confiscation, resource alienation, racism, and loss of employment (Pomeroy & Tapuke, 2016). These shocks have ongoing social and cultural effects. Urban Māori are particularly at risk of losing a connection to their ancestral land, as well as associated mātauranga, tikanga, and all the dimensions of te whare tapa whā (see Wellbeing in te ao Māori section) (Walker et al., 2019).

Local iwi retain a close connection to the environment and have noticed declines in biodiversity and ecosystem health using cultural indicators. A decline in the number of kererū in Te Urewera has been observed by Tūhoe in the past 50 years. They attributed the decline to the removal of Tūhoe's mana over kererū by Crown authorities outlawing the harvest of kererū, as well as Tāne Mahuta reclaiming the mauri of the kererū because fewer birds were being harvested and people had less respect for the birds (Lyver et al., 2008).

Land, governance, and engagement

The wellbeing of a society is more than the sum of its members' individual wellbeing. It relates to the trust in, and perceived quality of institutions (such as government) and their processes and procedures, as well as the ability to engage and participate (Smith, 2018).

Participating in discussions about values and outcomes as individuals and communities is one way to influence decisions around land use and have a voice in related environmental issues. Examples of strategies to bring communities into governance and decision-making include Te Mana o te Wai and Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020 (DOC, 2020; MfE, 2017). Engagement with Māori, individuals, and communities throughout the preparation of the strategies was promoted as a way to ensure sustainable and equitable development and enhance societal wellbeing (Barrett et al., 2020).

CHAPTER 6

Land and a changing climate

▸ Checking the rain gauge at Mill Creek, Ohariu Valley near Wellington.

Photo: Greater Wellington Regional Council

How our ancestors modified and used land has affected how we can use it today. The choices we make about how to use land will in turn affect future generations. But added to the mix is climate change – our generation's environmental challenge. Its effects could cause agriculture, native ecosystems, infrastructure, and health to look very different in the future.

The impacts of climate change are expected to become more intense in the coming years. They will challenge the way we manage land and more powerfully influence how land in some areas can be used.

A longer growing season and warmer temperatures may bring new opportunities but more extreme weather events (like droughts) are likely to seriously affect agricultural production and forestry.

The measures we take to reduce greenhouse gas emissions and adapt to a changing climate are also likely to influence land use. The effects can be direct, such as changes in management to reduce emissions from livestock or increase native trees. Indirect changes can also influence land use, like policy changes that shift markets and lead to more trees being planted.

A climate-driven future

The push and pull of global markets is currently the main driver of land use in New Zealand. Climate change, however, will play an increasingly important role as its impacts intensify. By the end of this century, the average global temperature is likely to be three degrees warmer than the pre-industrial temperature even if all current emission reduction commitments and goals are met by the international community (IPCC, 2018).

How quickly the climate changes depends on many factors, particularly the speed of the transition to net zero carbon dioxide emissions. The more the transition is delayed, the greater the changes to the climate and the magnitude of the impacts are likely to be (MfE & Stats NZ, 2020a).

Rising temperatures on land and in the ocean will translate into effects on land and how it can be used (IPCC, 2019). The climate has always shaped the types of ecosystems and land use that are possible in a given place, but it will increasingly influence the range of possible land uses in a particular area (Mendelsohn & Dinar, 2009). This will be felt most acutely where sea-level rise eliminates the possibility of certain land uses due to flooding, inundation, and salt water intrusion (MfE, 2020).

Higher temperatures, changes to rainfall, and more frequent and intense storms are likely to increasingly affect large areas of New Zealand's landscape (MfE, 2018). This may narrow the areas where certain land uses are viable, or may make conditions suitable for other, new land uses.

Climate change is likely to affect land indirectly though policies and changes to land management that are designed to mitigate or adapt to the effects of climate change. These policies will shape land use by making some land uses more or less economically or socially attractive.

Extreme events

Changes in the magnitude and frequency of extreme weather events (like floods, droughts, and heatwaves) are projected to increase across much of the country. This will require us to adapt and make innovative responses (Ausseil et al., 2019a; Cradock-Henry et al., 2020; MfE, 2018). In many places, however, the changes will cause a threshold to be crossed where the current land use is no longer compatible with the new climate.

Drought can have significant impacts on land and the people who derive a living from it. Between 2007 and 2017 it is estimated that drought driven by climate change cost New Zealanders $720 million in insured damages and economic losses. This is six times the figure estimated for insured damages from increasing floods (Frame et al., 2018).

Changes to the frequency and intensity of droughts have been observed across New Zealand, and along with heatwaves, are expected to become more common and more extreme in many places as the climate continues to warm (MfE & Stats NZ, 2020a). The greatest increase in the frequency of droughts is expected to be in the North Island (MfE & Stats NZ, 2020a).

Irrigation allows farmers to grow crops that might not be viable under natural climatic conditions, and to alleviate the effects of a drought when it occurs. Increasing irrigation may solve the problem of drought in the short term, but extracting more water from rivers, lakes, and aquifers during droughts risks depleting these sources of water (MfE & Stats NZ, 2020b).

Considerable irrigation infrastructure is already available in inland Canterbury and Otago but much less so in the North Island (see figure 3). Models predict that in some parts of Canterbury, Otago, and Hawke's Bay, rivers and streams would run dry if water users took out the full volumes they have been allocated (MfE & Stats NZ, 2020b).

At the other end of the spectrum, climate change is projected to increase the frequency and magnitude of intense rainfall, which can cause floods (MfE, 2018). In places where floods occur more often, changes in land management or even land use, may be needed as certain activities become unworkable.

Changing land use

We have changed and adapted the ways we use land in response to various driving forces. Climate change will challenge the sustainability of our production systems, and provide opportunities to adapt to, and even capitalise on some of the potential benefits.

Some climate impacts may be beneficial for farmers. Higher concentrations of carbon dioxide in the atmosphere may have a positive effect on plant growth and crop productivity in some cases (Rutledge et al., 2017). This is likely to lead to better plant growth and higher pasture yields (Ausseil et al., 2019b). The positive effects are also likely to be at least partially counteracted by losses from increased extreme weather events (Rutledge et al., 2017), drought, and a higher risk of heat stress for animals (Ausseil et al., 2019b).

Changes in management practices are anticipated as climate patterns shift. Fewer frosts and increased temperatures in the northern North Island for example may expand subtropical and tropical climates where a range of new crops could be grown commercially (Northland Regional Council, 2017). Wine growers could respond to a new climate by changing the varieties of grapes they grow, and farmers may alter the breed or species of their livestock. Some drought-tolerant grape varieties and pasture species are already being investigated and grown (Booth et al., 2020; Cradock-Henry et al., 2020).

Climate change is also projected to lengthen the growing season in New Zealand. (See indicator: Growing degree days.) This could increase overall productivity by increasing the growth of some crops and allowing for more crop cycles per year (Clothier et al., 2012).

A different land use or changing to a new crop may not align with a landowner's previous experience, expertise, or personal preference – farming and forestry for example require very different skills (Cradock-Henry et al., 2020). Support and advice to deal with the challenges of climate change will become increasingly important as farmers are on the front line in tackling and responding to climate change (He Pou a Rangi Climate Change Commission, 2021).

Land use to reduce emissions

Changes in the way we use land are underway to reduce emissions as well as the greenhouse gases that are already in the atmosphere. These include converting marginal farmland to native and plantation forest in the One billion Trees programme (MPI, 2020d). Options to reduce greenhouse gas emissions include lowering the density of dairy cows, sheep, and other livestock; improving animal performance; using less fertiliser; and breeding sheep that produce fewer emissions (BERG, 2018).

Policies to mitigate or adapt to climate change will also affect how land is used in the future. In many places local governments have created plans to reduce emissions, and manage the risks from sea-level rise and flooding. Most plans aim to reduce greenhouse gas emissions to zero by 2050, following the Paris Agreement and Zero Carbon Act timeline (Auckland Council, n.d.). Some have a longer timeframe like the 100-year plan to address coastal erosion in Hawke's Bay (Bendall, 2018). These plans may force changes in land use or affect economic markets that cause changes in land use. Incentives to plant more native trees to store carbon, for example, could cause shifts in land use from agriculture to native forestry (Norton et al., 2020).

Towards a better understanding of our land

Researchers measure water movement in the soil at Tihoi, near Lake Taupō.

Photo: Manaaki Whenua – Landcare Research

Untangling current and future drivers of land use

Despite our daily interactions with land, we have an incomplete picture of the processes that shape the landscape and the consequences of our activities on land. This limits our ability to achieve the best outcomes for ourselves and the environment.

The ways we use and manage land are shaped by a complex interaction of demands and drivers, which can be economic, demographic, governance (local and global), technological, and cultural. Drivers do not operate in isolation but can influence and be influenced by each other (Nelson et al., 2006).

The world is on the threshold of the era of committed climate change. This is when the impacts of climate change have become irreversible within our lifetimes, regardless of any actions we may take.

We already have a good knowledge of the main drivers of land-use change in Aotearoa New Zealand. This includes climate change as an outcome of other drivers, and a driver in its own right.

More work is needed to quantify the relative contributions of drivers and how they interact with each other to shape land use. This includes understanding whether certain drivers are more or less important and if the importance of different drivers is changing over time. Climate change will amplify existing risks and create new risks for natural and human systems, so untangling the importance of different drivers as they affect land is paramount.

Models and scenarios can provide useful information about how a future climate may influence New Zealand's land-based economy. Their analysis can reveal the likely directions of change and the implications of different options to adapt to the impacts of climate change. One example is how pasture productivity and commodity prices would be affected by different climate and economic scenarios (Ausseil et al., 2019a). Having tools to explore probable changes will become more and more important given accelerating complexity, interacting drivers, and an uncertain future (Banuri et al., 2019; Wu et al., 2017).

Understanding cause and effect in a complex system

To manage land resources effectively, we need a good understanding of how actions translate to effects on the environment. Some aspects of this understanding are well developed. However, the environmental system is complex, and work is needed to understand the connections between the many processes that affect the land.

How intensive land use affects native land ecosystems has not been widely studied. We do not understand its impacts beyond the destruction of habitats when native vegetation is cleared. Monitoring for maintaining ecosystem processes, whether the ecosystem as a whole functions well, can help understand interactions between native and productive systems and drivers of biodiversity better (Bellingham et al., 2020; McGlone et al., 2020). Monitoring the environment on farms, including the biodiversity, could enhance nationwide monitoring and improve an understanding of the interactions between modified and native ecosystems.

Interactions between land, freshwater, the marine environment, air, atmosphere, and climate occur on different spatial and time scales. Where and when these interactions occur, and how they affect other domains is not well understood. For example, while the effects of intensive land use on water quality are known, the interactions between land, groundwater, rivers, lakes, and the ocean are not well understood.

Some major gaps remain including in what chemical form, and through which pathways nutrients like nitrogen and phosphorus travel through different types of soil into groundwater.

As reported in chapter 3 there are still indicators, crops, and land uses that do not have target ranges for soil quality (especially for cropping and horticultural land uses). We still cannot adequately correlate soil nitrogen target ranges to understand the impacts on freshwater quality. The soil quality indicators may not fully capture the environmental impacts of intensive land use on the wider environment. Also, the concept of soil quality focuses on its intended use rather than the broader concept of soil health. Soil health is a soil's ongoing capacity to function as a living ecosystem that sustains plant, animal, and human health.

We also lack a full understanding of how soil health and biodiversity are affected by land use and intensification. A major knowledge gap in New Zealand and globally is understanding soil biodiversity, how it affects the quality of soil, and how ecosystems function (FAO et al., 2020; Hermans et al., 2020).

Building a long-term perspective

Demands on land, drivers of land use, management interventions, soil processes, and other factors influence land and the environment over different time scales. There is however, limited time series data to explore change over time.

How fast or slowly environmental processes change or react is often not well understood or taken into account. The legacy of previous land uses (like soil compaction or contamination) can have long-term effects on the ways we manage and use land today. Lag effects that show up several years or decades later, such as high levels of nitrate-nitrogen in groundwater, can be an unwelcome surprise.

Long-term monitoring can help to understand the effect of time on environmental processes, and enable us to track issues (PCE, 2019). Long-term studies can show how effects from outside (like climate change and socio-economic drivers) affect the environmental system. These studies provide a better understanding of the system and how it adapts to change. Overseas, long-term ecological studies and trials have contributed to knowledge about how agricultural and natural ecosystems function, and how our actions affect the environment (Lindenmayer et al., 2012; Macdonald et al., 2020). More work on New Zealand-specific environments is needed.

Māori see the environmental system as indivisible from themselves and their culture. For hundreds of years, Māori have been kaitiaki (caretakers) of te taiao (the environment), building on generations of mātauranga (knowledge). The use of a te ao Māori (Māori world view) framework and mātauranga Māori is particularly helpful for understanding and addressing issues that affect several different parts of the environmental system.

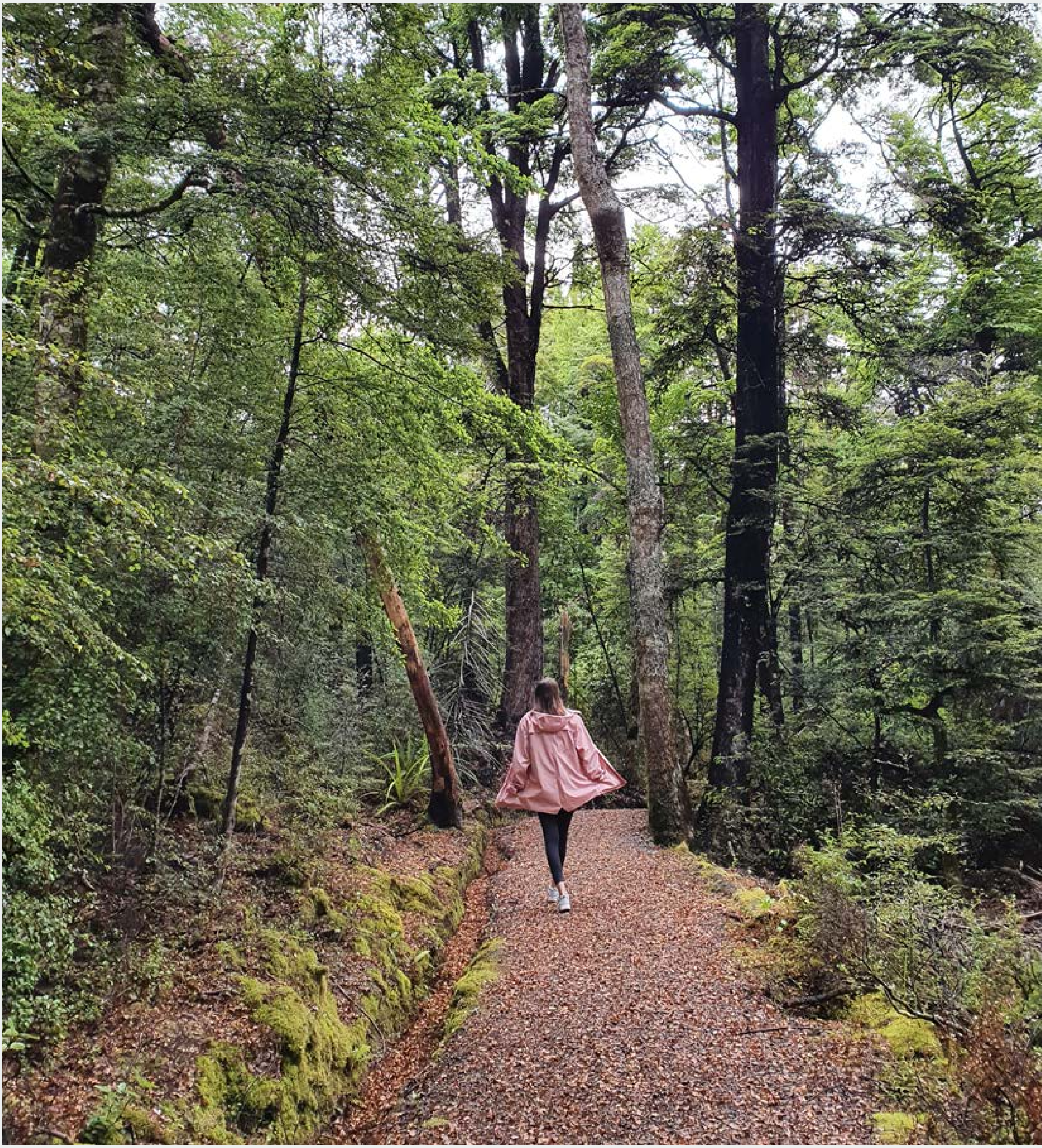
Connecting land to wellbeing

We recognise the importance of land as a place to live and as a source of food, income, culture, and recreation, but knowledge gaps around how it contributes to our wellbeing remain. The health of the land and our wellbeing go hand-in-hand, so a better understanding of all the ways they are connected is critical for navigating the future.

Maintaining land for our wellbeing today is fundamental but at the same time, we must ensure it can provide for the wellbeing of future generations. According to the Parliamentary Commissioner for the Environment, "empirical research is required to provide evidence of the links between environmental quality and wellbeing" because "the extent to which natural resources can be safely depleted in pursuit of building up other desirable assets is at the heart of a long-standing debate about what sustainable development entails" (PCE, 2019).

Different aspects of our wellbeing are affected by the different ways we use land, but this also varies over space and through time. Understanding this complexity is essential for improved decision-making about how land is managed today and in the future.

Additional information



Honeydew walk, Lake Rotoiti, Nelson Lakes National Park.

Photo: Ministry for the Environment, Kelsi Loader

About Our land 2021

REPORTING UNDER THE ENVIRONMENTAL REPORTING ACT 2015

Under the Environmental Reporting Act 2015 (the Act), the Secretary for the Environment and the Government Statistician must produce regular reports on the state of our environment.

Under the Act, a report on a domain (marine, freshwater, land, air, and atmosphere and climate) must be produced every 6 months and a whole-of-environment (or synthesis) report every 3 years. Each domain report has now been published once (see the Environmental reporting section on the Ministry for the Environment website for the full list). The most recent synthesis report, *Environment Aotearoa 2019*, was published in April 2019. The previous land report was *Our Land 2018*.

Our land 2021 continues the second cycle of domain reporting. It updates *Environment Aotearoa 2019* and *Our land 2018* by presenting new data and insights.

As required by the Act, state, pressure, and impact are used to report on the environment. The logic of the framework is that **pressures** cause changes to the **state** of the environment and these changes have **impacts**. The reports describe impacts on ecological integrity, public health, economy, te ao Māori, culture, and recreation to the extent that is possible with the available data.

Suggesting or evaluating any responses to environmental impacts is out of scope under the Act. Therefore, this report does not cover the work that organisations and communities are doing to mitigate the issue. It does provide an update on the most recent data about the state of our land. The evidence in this report is a basis for an open and informed conversation about what we have, what we are at risk of losing, and where we can make changes.

INFORMATION FOR THIS REPORT COMES FROM MANY SOURCES

Data, upon which this report is based, came from many sources including Crown research institutes and central government. Further supporting information was provided using a 'body of evidence' approach. This is defined as peer reviewed, published literature, and data from reputable sources. This also includes mātauranga Māori and observational tools used to identify changes in an ecosystem.

All the data used in this report, including references to scientific literature, was corroborated and checked for consistency. The report was reviewed by a panel of independent scientists.

SUPPORTING INFORMATION IS AVAILABLE

This report is supported by other products that are published by the Ministry for the Environment and Stats NZ:

- Environmental indicators: Land – summaries, graphs, interactive maps, and data that are relevant to the state, pressures, and impacts on land.
- Data tables are available on the Ministry for the Environment's data service, and technical reports on the Ministry for the Environment's website.

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