Agriculture and Horticulture in New Zealand

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Foreword

We all enjoy eating high-quality food, wearing natural fibres, using timber products, seeing flowers on display and living in landscaped surroundings. This book will show you how agricultural and horticultural produce is grown, managed and harvested so that it can be sent around New Zealand and the world to provide naturally produced, premium-quality food and products that make life more enjoyable.

Most agricultural and horticultural production in New Zealand is exported and so must meet stringent health, biosecurity, animal welfare and environmental regulations. A useful way to understand the land-based systems used to produce food and other products is to work backwards from what the customer and regulators require, to how to grow and manage crops, trees and livestock that meet those requirements. This value chain, from customers to marketers to transport logistics to processing and packaging businesses to farmers and orchardists, is what New Zealand is a world leader in, and a key to our prosperity as a nation.

Over the approximately 800 years that people have been growing crops in New Zealand we have been learning how to get the best from our soil and climate to consistently grow high-yield crops and pastures in a sustainable way. Mistakes have been made along the way, but the information in this book will set you on the path to understanding the great challenge of sustainably using our natural environment while feeding people with fresh, healthy and safe food.

Most agricultural and horticultural production is land-based, although there is increased interest in indoor farming worldwide. While New Zealand is mainly a land-based producer, our use of land is dynamic — responding to market signals, new technologies and climate change. New Zealand has a total land area of 26.8 million hectares (ha), and approximately half is used for primary industry production, with approximately 45 per cent used for agricultural or horticultural production and 6 per cent for planted forestry. Livestock grazing on pasture and forage crops is our largest land use, with 92 per cent of the agricultural and horticultural land (11.1 million ha) growing pasture and forages. The major use of pastoral land is for sheep and beef production, but the area used for this has been declining over the past 20 years or so; until recently, there was strong growth in the area of land used for dairying. However, although the area of land used for horticulture and arable cropping is relatively small, it has been increasing and is predicted to continue to increase.

The area of land used for different agricultural and horticultural enterprises only tells part of the story. Productivity per hectare has greatly increased in all agricultural and horticultural enterprises over the decades and continues to do so. In the case of apples, kiwifruit and grain crops, both production and productivity have been increasing due to plant breeding, use of technologies such as irrigation, sensors and automation, and improved plant management based on scientific research.

Advances in apple production are a good example of research and innovation resulting in improvements along the value chain. Yields of apples have dramatically increased due to high-density plantings of apple trees trellised on wires so that the plants intercept more light. The apples produced on the rows of trees are more accessible for semi-automated picking, and ultimately full robotic picking. The apple varieties are bred to provide apples that different markets prefer, and they grow on trees kept short by the type of rootstock they are grafted on to. Pest and disease occurrences are predicted using software programs in computers connected to sensors in the orchard, and spraying is minimised through the use of integrated pest management. Picked apples are sorted by size, colour and blemishes using arrays of high-speed cameras feeding data into computer programs, and are then automatically packed into boxes the right size for each apple category. The cardboard boxes are designed to prevent bruising and to keep the apples fresh as they are transported around the world.

New Zealand's relatively small area of arable and horticultural crops produces world-leading yields per hectare, for example, in crops such as kiwifruit, apples, maize, wheat and barley. The total horticultural production and the economic value of those products has been on the rise over the past 20 years and there is much optimism that our horticultural export earnings will continue to rise due to high overseas demand for our high-quality and superbly marketed fruit, vegetables, seeds, grain, flowers and wine.

Given that agriculture and horticulture are major drivers of the New Zealand economy and are such dynamic and innovative industries, albeit with some environmental challenges, it is not surprising that the industry supports careers across the spectrum of growers, managers, agricultural and environmental consultants, agricultural service providers, engineers, agribusiness providers, and marketers. All these careers contribute to the challenge of feeding the people of the world high-quality food while sustaining our environment.

As you read through this book and marvel at the innovation and ingenuity behind agriculture and horticulture in New Zealand, consider how these industries contribute to the quality of your life.

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Chapter 1

Soils

Alan Palmer &
Dave Horne

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Introduction

Soils are a product of the environment in which they form — an environment that may evolve with time because of many factors, for example climate change. Soils, which vary from naturally occurring to heavily modified bodies, are where earth, climatic and biological processes intertwine. Our modern understanding of soil formation and classification has been influenced by two scientists: a Russian named Vasily Dokuchaiev, in the latter part of the nineteenth century; and an American, Hans Jenny, in the 1940s. Their thoughts have given us the famous equation:

$$S = f(cl, o, r, p, t)$$

This is called the 'soil-forming factors' or 'environment of soil formation' equation, where S = soil, cl = climate, o = flora and fauna, r = relief or topography, p = parent material and t = time available for formation of the soil. Some soil scientists now add an anthropogenic factor (a) to the list, while others accommodate the human impact on soils in the organisms (o) factor. What this means is that if we are blessed with a little knowledge of each of the soil-forming factors, we should be able to predict the type of soil present beneath our feet.

It quickly becomes apparent that specific soils occur on specific landscape units. We would expect to find different soils on a river plain that is subject to regular flooding than on a higher terrace where flooding no longer occurs. Similarly, in hill country a soil forming on a dry ridge is unlikely to resemble one forming in a moist swale at the foot of the slope. A knowledge of landscapes (geomorphology) is essential in understanding soil distribution.

We can learn a lot about New Zealand soils by considering each of the soil-forming factors

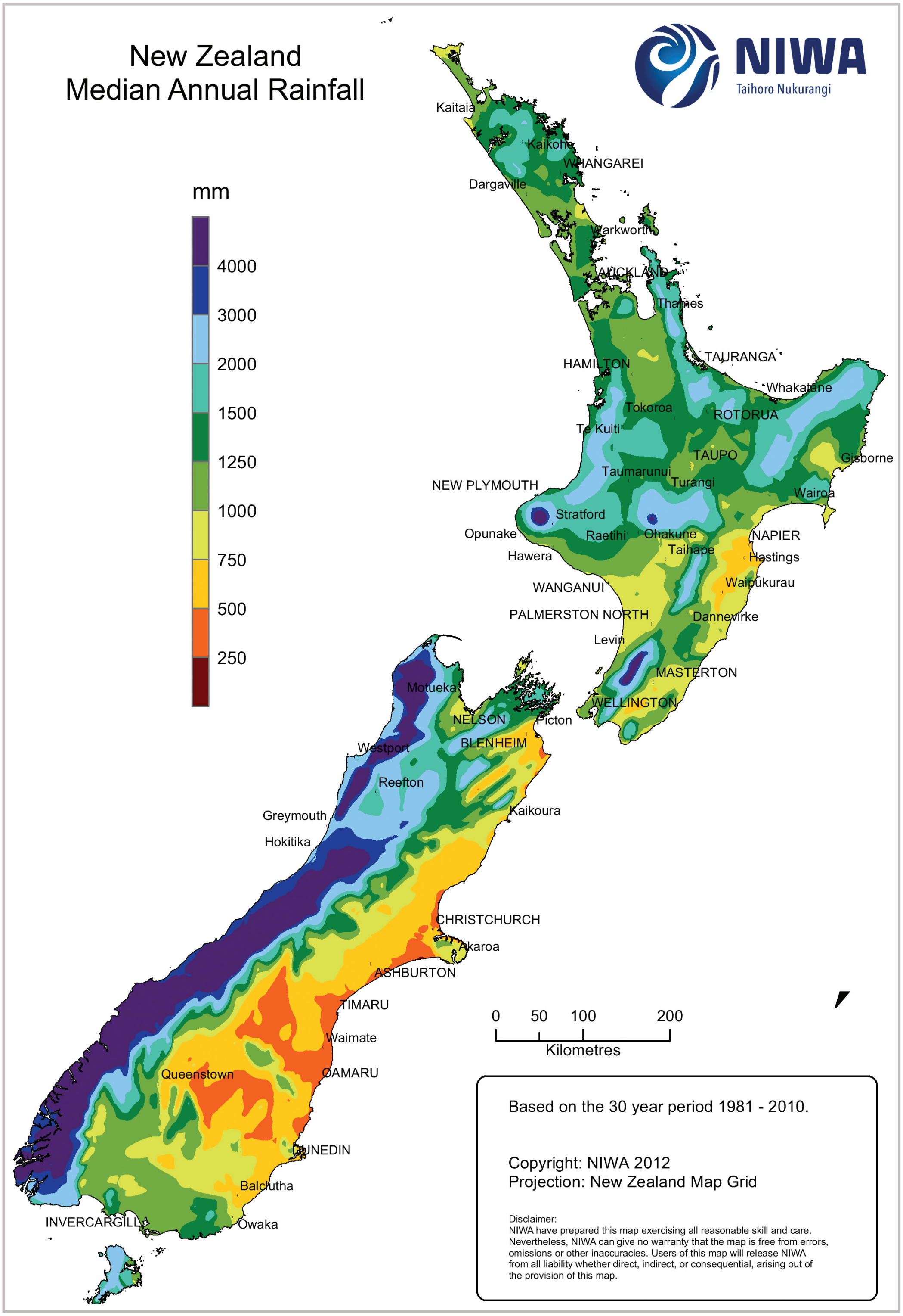


Figure 1.1 Median annual rainfall in New Zealand. (Source: Niwa)

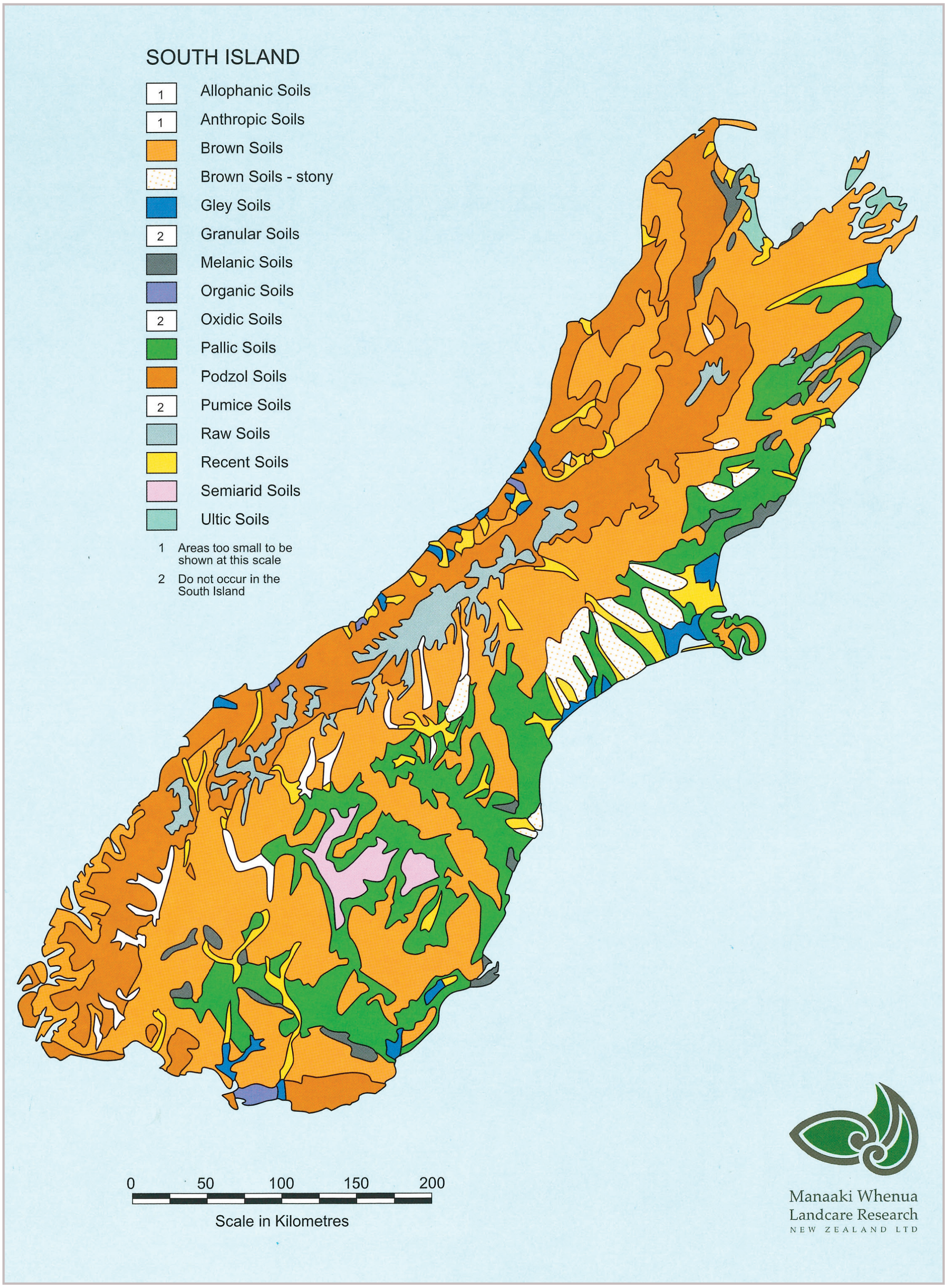


Figure 1.2 Soil map of the South Island. (Source: Manaaki Whenua Landcare Research)

in turn, while recognising that all of the factors interact to determine the type of soil present at any site in the landscape.

Climate

Due to its maritime setting in the middle latitudes and the dominant westerly flow of weather across the country, New Zealand has a temperate climate. Warm oceans surrounding the country ensure that incoming air is humid. The New Zealand landmass is also mountainous, particularly along its axial spine. Humid air is forced upwards by the elevated terrain, resulting in orographic rainfall (Figure 1.1). Nowhere is this more dramatically demonstrated than on the West Coast of the South Island. Moisture-laden winds coming in from the Tasman Sea drop 1500–3000 mm rainfall at the coast. Inland, 8000 to 14,000 mm per year can be recorded in the western foothills of the Southern Alps. It is interesting to note that the maximum rainfall is west of the highest parts of the Alps. A few tens of kilometres east of the main divide, the descending winds are dry and rainfall is commonly less than 1000 mm. The west coast of both islands is generally moister than the east coast, but local topography may superimpose an orographic effect on regional rainfall patterns.

The influence of rainfall on soil distribution is clearly demonstrated in the southern South Island (Figure 1.2). Central Otago is an area of basins and ranges in schist and greywacke–argillite bedrock. Being on the eastern side of the main divide, it is in a rain-shadow area and, on average, receives as little as 330 mm of precipitation per annum. Semiarid soils in New Zealand are soils formed on bedrock, slope materials, alluvium or loess, and where there has been sufficient time to weather the materials from which the soils form (soil parent materials) and where the annual rainfall is less than about 500 mm. Characteristically there is insufficient rainfall to carry all of the soluble weathering products, such as calcium carbonate, from the profile, resulting in whitish powdery coatings in the soil. Where annual rainfall is between approximately 500 and 1000 mm on the same parent material, pale-coloured soils called Pallic soils occur (Figure 1.3). Ironically, despite the rainfall still being low, these soils tend to have impeded drainage due to the way the soils are forming. Whereas Semiarid soils are seldom saturated, Pallic soils are often saturated in winter but dry in summer. At rainfalls higher than approximately 1000 mm on the same soil parent material, the soils stay moist for a longer time (due in part to the greater rainfall) but, counterintuitively, are often well drained.

This relationship between soils on the same parent material and in similar landscapes but under contrasting climate illustrates the importance of soil moisture in forming soils and developing soil properties.

Organisms

Organisms are flora and fauna that live on and within the soil. Pre-human New Zealand was unusual in being dominantly forested and having few soil-living animals other than birds and reptiles. Now a large proportion of our landscape is farmed, and humans and other animals living on the soil have modified it significantly. In pre-human New Zealand, the moister west

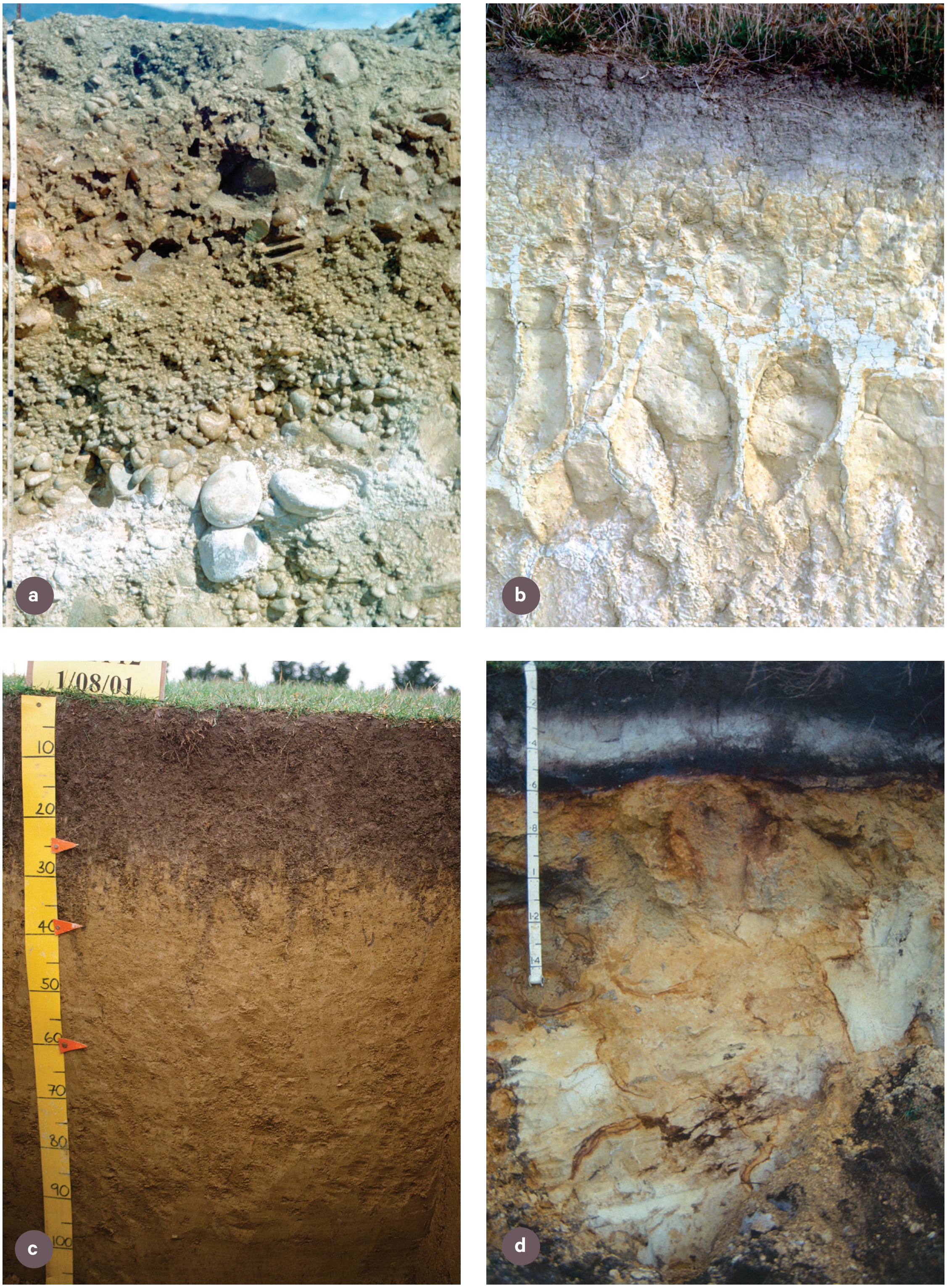
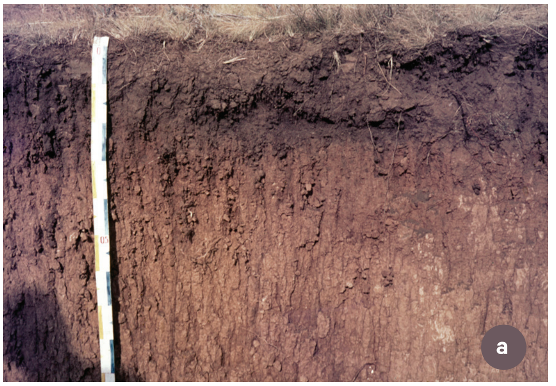


Figure 1.3 Southland soils: (a) semi-arid; (b) Pallic soil; (c) brown soil; (d) Podzol soil.

coast of both main islands, and much of the east, was cloaked with thick rainforest. Exceptions were the drier basins of Central Otago, Canterbury, Marlborough, Wairarapa and Hawke's Bay. In these areas, where rainfall was below approximately 1000 mm, the forest opened up progressively to more-scattered trees, shrubland and tussock-grassland. The vegetation present was closely related to rainfall and altitude, but landscape stability was also very important.

The type of forest that grew at any location has had a lasting legacy on the properties of some New Zealand soils. Areas once covered with podocarp (e.g. rimu, mataī, miro and kauri) and beech forests are often podzolised, resulting in Podzol soils. The word *podzol* has its roots in the Russian language, where it means ash. Villagers in the pine forests of northern Russia once collected pine needles for animal bedding. Underneath the thick layer of needles they would often uncover whitish material that they thought was ash from previous forest fires. We now know that pine trees, podocarps and other related families of vegetation produce certain chemicals in their leaves and bark. Rainwater carries these chemicals (among them polyphenols) into the soil, where they cause metal cations to move into solution and then down the soil profile. Iron and aluminium are particularly affected and their absence from the soil results in a bleached, whitish colour. The soil is also acidic and leached of other nutrient cations (such as calcium, potassium and magnesium) and anions (such as phosphate and nitrate). The plant is essentially removing competitors by being adapted to recycle nutrients through feeder roots in the plant litter that it, itself, has shed.

Even a hundred years after clearance, the legacy of podzolisation under the previous podocarp or beech forest cover can be seen in poorer soil fertility than in areas where other forest trees such as broadleaf species predominated (Figure 1.4). This concept is encapsulated by the following terms. *Mull* vegetation includes broadleaf tree species that dwell on more-fertile sites where leaf litter is broken down by an active soil flora and fauna, returning nutrients to the soil. Conversely, *Mor* vegetation favours and encourages less-fertile sites where acidity is



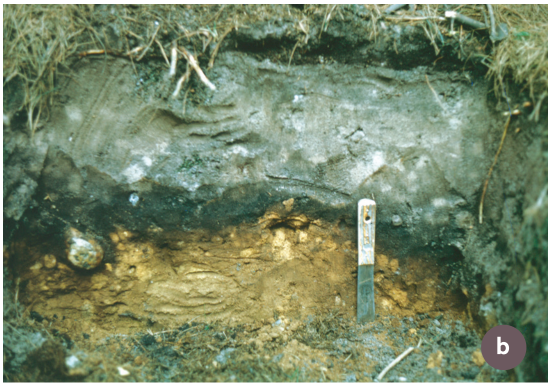


Figure 1.4 Mollisol soils (a) occur on natural grasslands such as this example from Russia. We do not have this type of natural grassland soils in New Zealand. Note that the topsoil is almost 1 metre thick. Most of the organic matter is in the soil. Podzol soils (b) occur in forests, for example, in this coniferous forest in Germany. Most of the organic matter is in the tree litter on the forest floor.

higher, flora and fauna are less active, and leaf litter accumulates at the soil surface. These species then recycle nutrients from this leaf litter.

The process of podzolisation can be faster or slower depending on the substrate (soil parent material) that the soil has formed from and the climate. For example, podzolisation has occurred in less than 2000 years on Taupō Pumice in higher-rainfall areas under podocarp forest. Taupō Pumice is both coarse-textured and siliceous, which hastens the podzolisation process.

Around the world, soils that form beneath forests are fundamentally different to those that form under natural grasslands. In both cases, photosynthesis allows plants to grow and take in carbon dioxide from the atmosphere to form organic matter. In the case of a forest this organic matter is the wood, leaves and roots. In a forest ecosystem a much larger proportion of the organic matter is stored in the actual plant and in litter that is dropped to the forest floor and not yet fully incorporated into the soil. Relatively little is found in soil horizons. In a grassland ecosystem, a relatively small proportion of organic matter is held in the above-ground plant or its roots. Plant residues, and dung from the animals grazing the grasses and herbs, are quickly returned to the soil, where incorporation is assisted by soil biota. A much larger proportion of the ecosystem's carbon is stored within the soil rather than in the plant. Ecosystems, from tundra in the Arctic to various types of forest and grasslands or wetlands, vary considerably in their biomass and the rate of turnover of that biomass. This difference is clearly expressed in the soils that form.

Everywhere in the world where humans have changed or adapted the natural vegetation, the soils have also changed. The soils we farm are different to how they were in their natural state, and have considerably different biota. It is debatable whether human use of soils has improved or degraded them; both answers can be true for different locations and circumstances. On the one hand, addition of fertilisers, lime, organic residues, irrigation water and artificial drainage has made many soils more productive. Conversely, human use has also resulted in accelerated erosion, compaction, loss of organic matter in cropped soils, structural degradation, the addition of potentially harmful waste products, over-fertilisation, and use of pesticides, fungicides and insecticides. The biodiversity and natural functioning of farmed soils has been affected. An example is the hill and steep-land soils of the North Island of New Zealand. When European farmers first settled the thickly forested hill and steep-land areas from the late 1800s to early 1900s, they logged and burned the forest cover to produce grassland for their animals. The soils they encountered had developed in unison with the forest after the Last Glacial Period. During the Last Glacial, from about 30,000 to 15,000 years ago it was too cold for extensive forests to grow except in the northern part of the island. Much of the hill and steep-land at this time had a shrub or grassland cover, soils were thin and erosion rates were extreme. As the climate warmed at the end of the Last Glacial, the forest grew and the roots of the trees held the developing soil to the slopes. Erosion rates under a forest cover are as little as 10 per cent of those under grass cover, although the local influence of the type of geology, tectonics and climate are also important in determining the rate of natural erosion. Therefore, 20–30 years after clearance, as the roots of the former indigenous forest trees decayed, the binding force that was holding the soil to the slope was removed. Introduced pasture grasses have relatively shallow and weak roots that are unable to hold soils in place when those soils are saturated by winter rain or tropical summer storms. There is a threshold of between 120 and 200 mm rainfall, depending on slope, aspect and geology, above which soil-slip erosion occurs in a concerted and destructive manner. Cycles of soil-slip erosion, in some cases occurring every 10–20 years, have stripped the soil cover back to the underlying bedrock in places. Some slopes have lost as much as 60 per cent of the spatial soil cover that they had at forest clearance. Work by Landcare Research has shown that not only does the soil re-form very slowly, perhaps over hundreds of years, but pasture productivity is permanently affected too (Figure 1.5). This is because the re-forming soils are thinner and less able to store moisture for summer pasture growth; they also contain less carbon, have lost the fertiliser nutrients and lime applied over preceding years, and the soil biology that aids in nutrient cycling has been disrupted.

Relief

There is a strong relationship between the landscape and the soil that forms upon it. Pedologists mapping soils are the first to understand the landscape around them. The words *topography* or *relief* are used to describe the shape of the land. Individual pieces of land with common formation and relief are called *landforms*. The shape of a landform can have a strong influ-

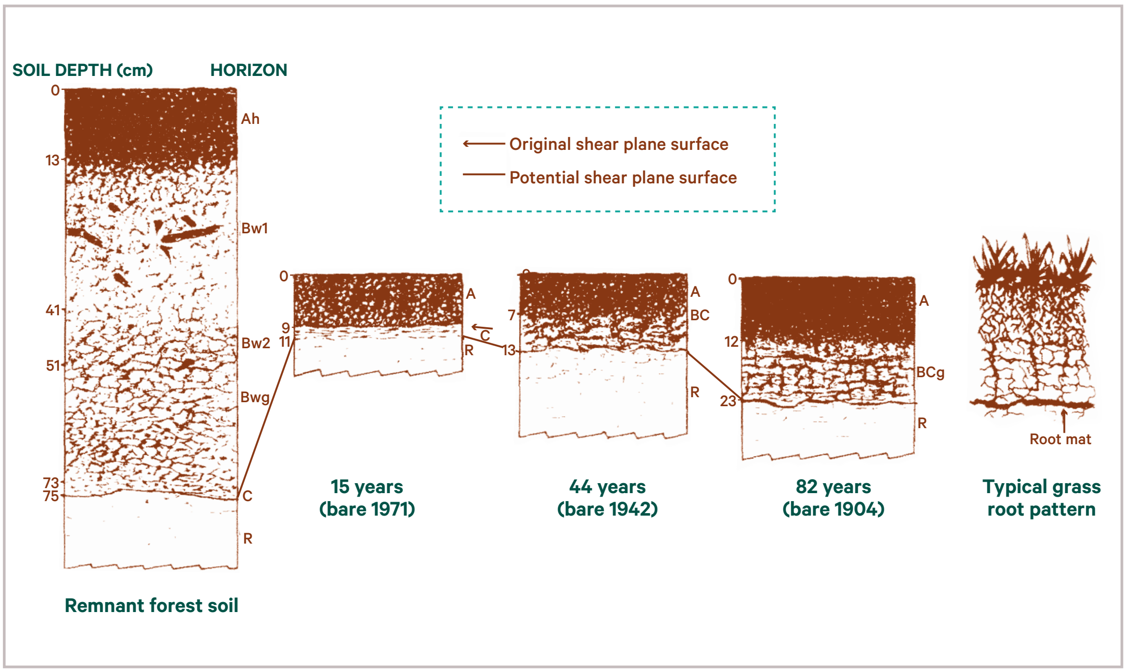


Figure 1.5 Erosion — mostly by soil slips — of steep-land soils removes the original soil that developed under forest. The soil reforms slowly and it takes thousands of years for it to fully reform. In many places the erosion of steep-land soils is unsustainable. Note: Ah is topsoil; Bw is well-drained brown subsoil; C is unweathered slope material. (After Trustrum and de Rose 1988)

ence on how surplus water from rainfall moves through or across the soil, where moisture is shed or percolates through the soil, where it is transmitted laterally, and where it accumulates. We usually see this manifest as soil drainage. For example, higher and convex parts of the landscape are often well drained, while concave and lower parts are more poorly drained.

Water in soil is a major determinant of how it forms. All soils retain a certain amount of rainfall within the soil (*storage*), allow some water to pass through laterally and horizontally (*drainage*), and have water leave the soil and move back into the atmosphere, mostly by transpiration through plant leaves. In most circumstances where plants cover the surface, relatively little water is directly evaporated from the soil surface. Transpiration and evaporation are collectively known as *evapotranspiration.* The proportion of storage, drainage and evapotranspiration varies greatly according to all of the soil-forming factors. Topography and soil texture (proportion of gravel, sand, silt or clay) strongly influence the drainage of the soil in any climatic regime.

Nowhere is the relationship between soil and topography better expressed than in areas of sand dunes, for example those on the south-west coast of the North Island, from Whanganui to Paekākāriki. Here, sand dunes have been accumulating since the Last Glacial Period, 30,000 years ago, and more particularly in the last 7000 years since the sea reached close to its current level after the glacial ice had melted. The sand is derived from soil and rock material eroded from the steep-lands and mountains of central North Island and transported to the coast by rivers, for example the Whanganui, Rangitīkei and Manawatū. The sand is then pushed south along the coast by wave action. For a variety of reasons the dune-building has waxed and waned in intensity and volume, resulting in phases of sand accumulation over time. (We will consider the age of the dunes in further discussion below.) The sandy soils of the dunes are porous and water passes through them readily, so much so that little is retained for plant growth and the dunes then appear droughty in dry summer months. However, the lower areas between the dunes, known as sand plains, are closer to the water-table and are often saturated, particularly in winter. These areas are low-lying, sometimes close to sea-level, and natural drainage pathways towards the coast can be blocked by younger dunes.

Even in low-rainfall areas, such as coastal Manawatū, the water-table can be close to the surface in wet seasons and when evapotranspiration is low in winter. Therefore, on any sand dune and adjacent sand plain, the soil that forms is dictated primarily by its position in the landscape (Figure 1.6). Soils on the upper parts of the dune drain freely, leach nutrients and are drought-prone in summer. Near the base of the dune the soils drain freely in summer, when the water-table is low, but come under the influence of a fluctuating water-table in their subsoil in winter. Soils on the sand flats have a fluctuating water-table that might rise close to the surface in winter. In particularly low-lying areas where the water-table remains close to the surface for most of the year, the soils are poorly drained, nutrients leach only slowly, and organic matter from plant residues in the topsoil do not oxidise and so may accumulate as peat.

Another dramatic New Zealand landscape where the influence of topographic position on soil formation is clearly seen is in western Taranaki. Here, in the shadow of Mt Taranaki,

Figure 1.6 A sequence of soils in 500–1800-year-old sand dunes in Manawatū: (a) the landscape in this area; (b) well-drained Motuiti soils that occur on the dune; (c) imperfectly drained Himatangi soils that occur on the higher parts of the sand plain between dunes; (d) Pukepuke soils — poorly drained soils on the sand plain that form where water-tables are high. This sequence of similar-aged soils with the same parent material but different properties is called a 'toposequence', in which the soils have formed due to their position in the landscape.

there is an unusual hummocky landscape of 5–20 m high, 1000–10,000 m2 rounded hummocks with flatter land between. The hummocks are composed of chaotic piles of rock derived from the collapse of former versions of the strato-volcano Mt Taranaki. In its approximately 130,000-year life, Mt Taranaki has built up through eruption and subsequently catastrophically collapsed as many as 13 times, or once every 10,000 years or so. Indeed, the major volcanic hazard of Mt Taranaki is not necessarily eruption but the collapse through debris avalanche during its partial destruction.

The hummocky remains of older debris avalanches are now more rounded and the landscape is softened by the volcanic ash deposited in subsequent eruptions. North and east of the volcano the ash is now metres deep, but to the west where younger collapses have been directed, the ash is thinner or even absent so the bouldery remains are often visible. Each of the debris avalanche hummocks has a sequence of soils depending on position on or between the mounds, and on the thickness of ash cover. One such sequence of soils is found on hummocks from debris avalanches that occurred 16,000–20,000 years ago. Since the collapse, 60–100 cm of ash has accumulated on the land surface, so the soils are formed in this ash rather than the underlying bouldery material.

On the top and sides of the mounds, the soils are well drained, signified by rich brown colours in the subsoil. Near the base of the mounds, the water-table again fluctuates between summer and winter, leaving a mottled appearance of grey and orange colours in the subsoil. These mottles are caused by the changes in the status of iron in the ash soil parent material. The poorly drained soils between the mounds, where water-tables are high, are almost unrecognisable as being formed in the same ash soil parent material. The ash is now grey, with some orange mottles due to the influence of iron-altering processes in saturated soil below the water-table (Figure 1.7).

On every hillside, no matter where in the world, there is some degree of relationship between the soil that is forming and its position in the landscape. On our hills and steep-lands discussed earlier, there is often a negative relationship between soil thickness and development (and presence even) versus increasing slope.

Parent material

Parent material is what the soil has formed from. In some cases this is the bedrock below; in other cases it is material that has been transported to the site, for example deposits from a river. Rock types vary in their geochemical composition, mineralogy, hardness and texture. Their hardness and erodibility may also be influenced by physical, chemical and biological weathering and tectonic forces such as uplift, faulting and folding. The mechanism by which rocks erode — whether it be mass wasting under the influence of gravity, ice or liquid, water or wind — also determine the types of parent material that a soil forms from.

New Zealand has excellent examples of the three main kinds of rock: igneous, metamorphic and sedimentary. Igneous rocks are either crystalline rocks that have cooled from magma within the Earth's crust (plutonic) or volcanic rocks that have erupted at or near the surface. Plutonic igneous rocks are common in the north-west and south-west of the South Island, and in smaller