Soils and Land Use

THE land-use pattern of New Zealand today is dramatically different from that of 1200 years ago at the beginning of Polynesian settlement of Aotearoa, or even from that of 150 years ago, just prior to European colonisation. The indigenous character of the primitive landscape has been changed irrevocably. Indigenous forests still cover the mountain lands of the South Island and the wetter hill country of the North Island, but in most of the lowlands and drier hill country the transformation to introduced plants and animals is almost complete. Only on the wet West Coast of the South Island has the impact of agriculture been relatively minor in the lowlands, and the regional economy of indigenous forestry, mining and tourism in this remote region still remains very different from the rest of New Zealand. Elsewhere, the landscape is now dominated by 9 million ha of pastureland and cropland and 1 million ha of exotic forest plantations – a remarkable tribute to the skills of the rural population of New Zealand.

With the benefit of hindsight it is easy to criticise many historical land developments from a modern scientific viewpoint. But any criticism should be tempered with an appreciation that our pioneering rural community had only a fraction of the scientific and technological information available to land-use decision-makers of today. The responsibility for soundly based land-use decisions is, therefore, much greater now, precisely because we have a clearer idea of the likely ecological consequences of our actions. It is this more ecological appraisal of how New Zealand’s soils can be better used, by attempting to match their end uses with their inherent properties, that this chapter addresses.

Arable Land - Our Most Important Soil Resource

Despite New Zealand’s traditional emphasis upon pastoral land uses, the cropping of arable land for cereals, vegetables, fruits and animal fodder has always been important for domestic consumption. Arable land is regarded as land capable of being cultivated by machines, accepted as slopes of less than 12 degrees. Because of our mountainous and hilly topography the potentially arable land is restricted to 8 million ha (30 percent of the total land area). If the 1.5 million ha of stony terrace soils are excluded because they are difficult to plough, the area is reduced to 6.5 million ha. These potentially arable soils are, however, not all of equal value for food production: some are poorly drained, others droughty; some have layers which prevent roots penetrating any deeper, others are excessively leached; and some occur at higher altitudes where the growing season for most crops is too short. Because of these limitations, only 2.6 million ha (or 10 percent of New Zealand’s land area) are regarded as having high value for food production.

The regional distribution of these high-value soils is shown in Fig. 14.1a. Most occur in the North Island (particularly in the Waikato, Bay of Plenty and Taranaki); Southland is the only South Island region with a significant proportion of such soils. In terms of the national soil groups mapped in Fig. 1.6, the volcanic loams, lowland brown earths, recent alluvial soils and better-drained dense grey soils make up most of the 2.6 million ha (Fig. 14.1b). Currently only 0.6 million ha are actually cropped for cereals and fodder crops, or are used as market gardens (Plate 14.1), orchards, and vineyards; the remaining 2 million ha are devoted mainly to intensive dairy and sheep farming. Clearly there is considerable potential for using more of our arable soils for crops.

Plate 14.1 (opposite)
The arable soils of the Pukekohe area produce nearly 30 percent of New Zealand’s fresh vegetable crop. Over 5000 ha of these volcanic loamy soils are devoted to market gardening, producing 20 percent of the country’s potato crop and 70 percent of the onion crop. Other important crops are cabbage, cauliflower, carrots, lettuce and pumpkin (see also Plates 3.15 and 3.16).
Soil versatility and crop suitability

A highly versatile soil is one that is capable of growing a wide range of crops suited to its particular climate. In terms of its physical characteristics a highly versatile soil is one which:

- occurs on flat land or very gentle slopes (< 5°);  
- has a potential rooting depth of at least 0.75 m;  
- offers little resistance to root penetration;  
- suffers very few days of soil-water deficit;  
- suffers very few days of waterlogging;  
- has enough large, interconnected pores to ensure good drainage and aeration;  
- has a low content of stones;  
- is capable of being cultivated by machines throughout most of the spring period;  
- has high structural stability; and  
- is not likely to suffer from erosion, flooding or salt contamination.

Modern soil surveys are now placing much more emphasis upon interpreting the soil pattern of a region in such a way that both the versatility and crop-specific suitability of particular soils are more apparent to the potential user. Some of this information can be obtained from detailed soil survey reports and maps published by the New Zealand Soil Bureau of the Department of Scientific and Industrial Research (Private Bag, Lower Hutt), or the land inventory maps and reports of the Water and Soil Division of the Ministry of Works and Development (Private Bag, Wellington). Some of the more important regional soil survey and land-use publications are listed in the bibliography.
Soil and Climatic Factors in Land Use

Within this broad category of high-value soils there are very different potentials for the growth of a range of crops. Some crops need specific soil conditions. Blueberries like peaty, acidic soils; asparagus needs deep, free-draining soils; and kumara tubers seem to develop best in a friable soil above a firmer base. The influence of climate is very important; the Bay of Plenty is highly suitable for subtropical crops such as avocados, citrus and kiwifruit, whereas the Southland Plains are more suited to cool climate vegetable and cereal crops.

This raises the question of whether climate is of overriding importance or whether intrinsic differences between the volcanic loams of the Bay of Plenty and the lowland brown earths of Southland make some of these soils more suitable for particular crops. The concept of climate/soil/crop suitability and the associated concept of soil versatility (see p. 206) is critical when planning the future pattern of agricultural land use in New Zealand, at farm, district, and national level.

Historically, crop/climate suitability determined the different pathways of Maori and European agriculture. When Polynesian voyagers first stepped ashore in Aotearoa, their relief must have been tempered by apprehension and uncertainty as to whether this sombre land of temperate forest could sustain them. Not only were they faced with the impossibility of acclimatising staple tropical plants like the coconut and breadfruit to the cooler climate, but they also had to adapt their neolithic skills of root-crop culture to very different soils. Only in the north could they find pockets of familiar, well-structured volcanic soils from basaltic and andesitic volcanoes. Consequently the early Maori had to rely heavily on other indigenous foods, such as fish, forest berries and birds, and the ubiquitous fern root (aruhē). In contrast, the Europeans were able to introduce pastures, cereals, vegetables and fruits from the temperate parts of the Northern Hemisphere.

In simple terms the land-use challenge now, as in the past, is the matching of the crop with a suitable climate and soil. Yet we have perhaps become rather blasé about any climatic or soil limits to land use in New Zealand because of the remarkably wide ecological tolerance of our two main ‘crops’—ryegrass/clover pasture, and *Pinus radiata* trees.

But crop tolerance does not mean optimum crop production. If we note ryegrass/clover pasture production at the three different locations shown in Fig. 14.2, the influence of climate and soil becomes apparent. Even though the Southland lowlands are much cooler (growth all but stops during the winter months and is slow to begin again in spring) the climate is sufficiently benign to maintain rapid pasture growth for the six months from October to March. In contrast, although the temperature and annual rainfall in Northland are much higher, annual pasture production is significantly lower, even though growth continues all year. The reason is a sharp drop in summer production, probably caused by the combination of low summer rainfalls and the lower moisture-holding capacity of the coastal sand soil. This summer moisture stress is even more pronounced at the Hawke’s Bay site where the combination of lower annual rainfall and a soil with low moisture-holding capacity severely limits pasture production.

Clearly then, high temperatures alone are not sufficient to guarantee high production—at least for pastures. An adequate, well-distributed rainfall, plus a soil which is capable of storing this rainfall (or irrigation water), are equally, if not more, important. It is this storage property that makes soil such a valuable medium for plant growth for it can act as a ‘heat sink’, a ‘water sponge’ and a ‘nutrient bank’.

### Table 14.2

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil name</th>
<th>Soil group</th>
<th>Mean annual temperature (°C)</th>
<th>Annual rainfall (mm)</th>
<th>Days of soil moisture deficit</th>
<th>Annual dry matter production (T/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northland</td>
<td>Red Hill</td>
<td>coastal sand</td>
<td>14.5</td>
<td>1336</td>
<td>20</td>
<td>12.8</td>
</tr>
<tr>
<td>Hawke’s Bay</td>
<td>Takapau</td>
<td>Stony terrace soil</td>
<td>14.0</td>
<td>851</td>
<td>71</td>
<td>6.7</td>
</tr>
<tr>
<td>Southland</td>
<td>Waikiwi</td>
<td>Lowland brown earth</td>
<td>9.7</td>
<td>1073</td>
<td>4</td>
<td>14.6</td>
</tr>
</tbody>
</table>

Fig. 14.2

Growth curves for pasture production on three arable soils in contrasting climates. The graphs are based on production averaged over 6–10 years to minimise annual climatic variation. Soil and climatic data for the sites are given in the accompanying table.
Soils and plant growth

Soil is a remarkable natural product because it is able to integrate many of the environmental elements which have a bearing on plant growth:

- soil acts as a heat sink, gradually storing up the heat which the sun gives to the atmosphere.
- Whereas air temperatures can fluctuate sharply between day and night, or between fine and bad weather, soil temperatures are much more stable;
- soil can also act as a water sponge, storing up much of the moisture it receives from rainfall or irrigation. Some of this water is only loosely held and is freely available to the plant, while some is more tightly held and the plant has to make greater efforts to absorb it from the soil;
- soil is a nutrient bank, holding nutrients until they are required by plants.

Soil as a ‘heat sink’

By using the heat sink attribute, New Zealand can be subdivided into seven soil temperature zones (Fig. 14.3). These zones express regional differences in the length of the growing season (Table 14.1). Consequently the zones can be useful as broad indicators of the suitability of regional climates for certain crops. The warmest zone (thermic) covers Northland, Auckland, Waikato, Bay of Plenty and narrow coastal strips extending down the west coast to New Plymouth and around East Cape to Gisborne. This thermic zone coincides with the main location of our so-called subtropical horticultural crops such as tamarillos, avocados, passionfruit, kiwifruit, as well as potential new crops such as babaco, persimmons, macadamia nuts and lychees. Some of these (e.g. kiwifruit, citrus and feijoas) can also produce well in the warm zone. Others such as grapes (Plate 14.2) and boysenberries can grow well in the thermic, warm and mild zones but quality varies and they are less susceptible to disease in the less humid areas. Our traditional pip fruit (apples, pears) and most stone fruit (peaches, nectarines, plums, apricots, and cherries) require winter chilling to stimulate spring flowering. They do not thrive in the thermic zone where frosts rarely occur; instead they are suited to the warm, mild, and continental zones. Blackcurrants and gooseberries thrive in the cool zone of Otago and Southland.

As with the fruit crops, some generalisations can be made about the ideal locations for various temperature-sensitive vegetables. Sweetcorn and maize (Plate 14.3), capsicum, courgettes and melons are suited to the thermic zone; kumara, onion, tomato and asparagus extend into the warm zone; garlic prefers the less humid warm zone, while artichokes and brussels sprouts prefer the mild and cool zones.

### Table 14.1

Characteristics of soil temperature zones of Fig. 14.3

<table>
<thead>
<tr>
<th>Soil temperature zone</th>
<th>Mean soil temperature* (°C)</th>
<th>Growing season (number of days above a base soil temperature)</th>
<th>Dates in spring when soil temperature expected to reach 10°C†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer</td>
<td>Winter</td>
<td>≥ 5°C</td>
</tr>
<tr>
<td>Thermic</td>
<td>≥ 20</td>
<td>≥ 10</td>
<td>whole year</td>
</tr>
<tr>
<td>Warm</td>
<td>≥ 19</td>
<td>≥ 7</td>
<td>whole year</td>
</tr>
<tr>
<td>Mild</td>
<td>&lt; 19</td>
<td>≥ 5</td>
<td>300-365</td>
</tr>
<tr>
<td>Cool</td>
<td>&lt; 17</td>
<td>≥ 4</td>
<td>300-365</td>
</tr>
<tr>
<td>Continental</td>
<td>≥ 17</td>
<td>&lt; 4</td>
<td>&lt; 300</td>
</tr>
<tr>
<td>Cold</td>
<td>&lt; 17</td>
<td>&lt; 4</td>
<td>&lt; 300</td>
</tr>
<tr>
<td>Frigid</td>
<td>&lt; 15</td>
<td>&lt; 2</td>
<td>&lt; 250</td>
</tr>
</tbody>
</table>

* All data for 30-cm soil depth
* Less than; > greater than; ≥ greater than or equal to
† Note that the surface temperatures of soil beds for seed germination will not be the same as these temperatures at 30 cm depth; consequently, the dates must only be treated as approximate for seed germination.

Zones based on data of R. Aldridge.
Fig. 14.3
Soil temperature zones of New Zealand. The temperature characteristics of the zones are given in Table 14.1.
The regional land-use impact of the establishment, since the mid-1970s, of nearly 1000 ha of vineyards in the Wairau valley in Marlborough almost rivals that of kiwifruit in the Te Puke district during the late 1960s (see Plate 3.3). In contrast to the traditional commercial vineyards of Auckland and Gisborne, this Marlborough district was chosen only after considerable scientific investigation, in order to match classical grape varieties with a climate and soils which were more likely to ensure the production of quality wines. Most of the varieties are Muller Thurgau, with lesser areas of Cabernet Sauvignon, Sauvignon Blanc and Chardonnay.

Plate 14.3
The Waikato produces 50 percent of New Zealand’s maize crop, with yields of 8–9 tonnes/ha being produced on about 9000 ha. The region lies at the cooler end of the thermic soil-temperature zone (Fig. 14.3) and the critical spring soil temperature of 12°C will generally be reached by mid-to-late August.

Soil as a ‘water sponge’
The water sponge properties of the soil depend upon a number of factors: the depth of the soil and its chemical and physical properties; the amount of water which has percolated into the soil; and the amount of water which is taken up by plants or evaporates from the soil surface. The weather primarily dictates how much moisture will be in the soil but in areas of low rainfall the moisture-retaining properties of the soil assume greater importance. Fig. 14.4 shows that the areas of most severe water deficit (and hence most likely to benefit from irrigation if their soils are suitable) are generally those with lower rainfall (Central Otago and Waitaki basins, Canterbury Plains, Marlborough, Wairarapa, Manawatu and Hawke’s Bay) or higher temperatures (Poverty Bay, Bay of Plenty and the eastern coastal parts of Northland). The large number of days of soil-moisture deficit suffered by the Takapau soil at the Hawke’s Bay site in Fig. 14.2 is typical of these areas; the soil has only a moderate water-holding capacity and the local weather pattern produces hot, dry summers. Irrigation of such soils is worthwhile, however, if crop returns outweigh the cost of installation and operation.

In the past, insufficient attention has generally been paid to selecting the most appropriate soils for irrigation — ideally free of salt and subsoil pans, free draining and with a moderate-to-high water-holding capacity. Many of the irrigation schemes of Canterbury and Central Otago are on unsuitable shallow and stony soils (Plate 12.2 and 12.4), very often the soils which could most easily be reached by water races from the nearest river. Consequently, although irrigation may have increased production, the overall economics remain a matter of debate. Irrigation is particularly important for high value, shallow-rooting crops (such as blueberries, capsicums, and tomatoes) that are more susceptible to moisture stress because their roots cannot tap water stored deeper in the profile.
Annual water-deficit zones. Each zone is based on an average figure (since annual deficits can deviate by up to 30 percent from the average). At this small scale it is not possible to show the wide site variation in soil water-holding capacity, so the data are based on the assumption of a standard soil which can store 760 mm of water. The range of figures shown is the likely shortfall between the evaporative demand of the plant (and soil) and what can be supplied by rainfall and soil storage. Generally, the regions with the lowest rainfall are those with the highest water deficit.
Soil as a ‘nutrient bank’

Generally, the greater the depth of soil capable of penetration by roots the greater the availability of moisture and nutrients to the plant. The roots of pastures and cereal crops will exploit the entire upper metre of friable, well-drained soils (Plate 12.5), and crops such as lucerne can send roots down as far as 2 m. Apple and pear trees and grape vines can root as deeply as 2.5 m and this probably accounts for much of their drought tolerance. The outstanding production performance of Pinus radiata plantations in the pumice lands of the North Island is largely due to the great depth of some of the pumice soils; tree roots are often found at depths of more than 5 m.

Sometimes a dense layer, a gleyed horizon or a stony subsoil is sufficient to act as a barrier to roots. Some plants, however, have adapted to such conditions; for example, overturned beech trees on morainic till and stony outwash terraces (Plate 9.8) often exhibit a surprisingly shallow root pad in relation to the large size of the tree. In such a wet climate, the roots may not need to penetrate deeply for water and nutrients – even if they could. The fragipan of dense grey soils and the iron/humus pan of podzols can also act as barriers to roots. Plate 14.4 shows the difficulty experienced by the roots of young Pinus radiata trees in penetrating compact layers in some of the soils on flow tephra on the Kaingaroa Plateau of the pumice country (Chapter 2; also Plate 2.8).

The pasture-production levels in Fig. 14.2, the soil temperature boundaries of Fig. 14.3, and the regional water deficit categories of Fig. 14.4 are averages of data measured over many years; averages, however, tend to disguise the variability of weather conditions from year to year. Just as horticulturists need to plan for the possibility of weather catastrophes (such as unseasonal frosts, hail, or gale-force winds), so too, arable or pastoral farmers need to understand the year-to-year variation in crop production and quality brought about by differences in the soil temperature and moisture levels. A range of conservative management practices can then be adopted to iron out the effects of the extreme years.

Soil Rehabilitation and Recontouring

The stripping of topsoil from the landscape, for re-use by homeowners and local authorities, is a major example of soil disturbance, particularly around expanding metropolitan areas. Appropriate soils can be ‘farmed’ for their topsoils but careful management is essential to restore the productivity of the subsoils of the stripped area. It is not simply a matter of adding fertilisers and resowing the bare surface to new pasture. Five years after the topsoil was removed from experimental plots, pasture production on exposed subsoils has been found to be still only 30–70 percent of that on the original soil – even with the optimum addition of fertilisers. Obviously, factors such as changes in soil structure, aeration, organisms and water-holding capacity are also involved.
In a few situations the overall productivity of the landscape can be improved by removing a topsoil to a more favourable environment. One such example is in the Wellington-Hutt Valley area where significant areas of Belmont soils (Plate 8.4) have been stripped from the cooler, windy uplands (such as the foreground of Plate 8.3) and transported down to the milder, more sheltered urban areas. Another example was the attempt to strip some of the Cromwell Gorge soils threatened with inundation by the Clyde dam and relocate them in the Earnscleugh locality with its new irrigation scheme and intensive horticulture.

Soil recontouring has been carried out by many landowners in Tauranga County in the Bay of Plenty to increase their area of potential horticultural land and make crop management easier. A typical example, using heavy earthmoving machinery, is illustrated in Plate 14.5. Recontouring has sometimes had the opposite effect to that desired. The hydrology of small catchments has been disrupted, soil has been eroded from the bare surfaces and crops have often failed to flourish in the reconstituted soils. Guidelines have now been developed to help ensure that soil quality is not diminished through recontouring; topsoils should be removed carefully and then replaced on the new surface, layers of very different textures avoided, and soil compaction from earthmoving machinery minimised.

Soil rehabilitation after mining is now a major soil-research activity; the mining proposals range through open-cast goldmining at Waihi, coal mining in the lower Waikato (Plate 3.2), wax-resin extraction at Kaimaumau in Northland, peat mining on the Chatham Islands, and lignite mining in Southland (Plate 14.6). Research indicates the importance of topsoil-storage techniques to minimise deterioration of structure and biological populations, as well as the need to avoid compaction during replacement, ascertain fertiliser requirements and assess the possibility of plant toxicities. Soil rehabilitation also offers the exciting opportunity to use other organic-rich industrial wastes, by composting them and incorporating them into the organic cycle of a new synthetic soil (Plate 14.6).
This is the third attempt to farm the steep hill country of the remote Aotuhia locality in eastern Taranaki. Whereas the earlier attempts can be excused their lack of scientific analysis of the problems involved, this most recent attempt was carried out by the state (through the former Department of Lands and Survey) in the mid-1980s, using funds from the taxpayer and with the supposed benefit of a comprehensive land-use study and the approval of the catchment authorities. Aotuhia and other controversial hill country development schemes have highlighted the environmental shortcomings and economic folly of some state-subsidised clearance of marginal land.
Hill Country - Soil Landscapes in Transition

The 1970s was a decade of intense interest in the productive potential of New Zealand's hill country. Pastoral agriculture had reached a production plateau and an expanding exotic forestry industry was hungry for land for new plantations. The conflict over whether land should be used for pasture or forestry was most acute in the hill country but, unfortunately, the welter of reports urging more intensive use of this land showed little awareness of the soil limitations which would dictate the long-term economics of any intensified development. Too often land-development subsidies or settlement schemes made the development of marginal land seem more attractive than it really was; sometimes the same piece of land was cleared of forest for the third time this century (Plate 14.7).

The soils of the hill country are extremely variable and very difficult and costly to map in detail (see Chapter 4). Their traditional use for pastoral agriculture has often not been soundly based. The clearance of forest and shrublands on hilly landscapes of the volcanic plateau of the central North Island (Chapter 2) or the Tertiary mudstones of the East Cape and Wairarapa (Chapter 7) exposed the underlying unconsolidated material to accelerated erosion on such a massive scale that many waterways turned into rivers of mud. Likewise, in the South Island high country the elimination of tussock vegetation by indiscriminate burning and overgrazing (by both rabbits and domestic stock) led to calls for land-use controls and the establishment of an influential soil conservation movement.

Yet even now, with the benefit of scientific knowledge on land potentials, it is still difficult to encourage sound conservation principles in the use of the hill country. Hill country does have some natural advantages over lowlands – rainfalls are generally higher, some aspects are sheltered from winds, and a degree of soil creep downslope can rejuvenate the fertility of the soil. But these advantages are often outweighed by disadvantages: difficult access, impossibility of cultivation, shallow soils of low fertility, moisture stress and wind on exposed slopes, and a tendency to erosion.

All too often hill-country land titles do not coincide with natural landscape boundaries, making it difficult for the landowner to achieve a mixture of land uses that are economic. If the farming unit does not have the proper balance of high/low altitude pasture for summer/winter grazing, or if the topography is too rough for adequate paddock fencing, then optimum use of the land is not possible. Nowhere is this more apparent than in the basin and range country of the South Island (Chapter 10), and the broken hill country of the North Island (Chapters 4, 6 and 7).

Most of the hill country of the North Island was covered in indigenous forest before European settlement and there is probably a sound soil-conservation case for establishing much of it in exotic forest plantations and allowing the slopes susceptible to severe erosion to revert to indigenous shrubland. Detailed soil surveys of complex hilly topography are likely to be too expensive, but the thoughtful application of land-capability mapping by soil conservators in Catchment Authorities can lead to a successful blend of ecological wisdom and common sense in hill-country use. In future we are much more likely to see mixed landscapes similar to that of Plate 14.8, a harmonious blend of production and conservation.

Plate 14.8

By acknowledging the limitations imposed by topography and soil, land users can produce patterns of productive and protective landscape which are economically viable, environmentally sensible, and pleasing to the eye. In this view looking westwards across the upper catchment of the Raparapahoe Stream south-west of Te Puke, indigenous forest has been retained on the steeper gully and hill slopes; pastures have been developed on the easier hill slopes and a small plantation of exotic trees in the gully head in the foreground. Kiwifruit orchards and other horticulture have been established on the better soils on the gently rolling tephra-covered surfaces between the gullies.
Natural Landscapes and Soil Reserves

Until recently there has been little scientific interest in the reservation of soils as parts of natural ecosystems. It is not correct to talk of 'preserving' soils, since an entity as dynamic as soil is continually changing in response to its environment (Plate 14.9), developing through the influence of time and the soil-forming factors discussed in Chapter 1. But such gradual change can be grossly disturbed if the natural vegetation is cleared away. This is particularly true for topsoils which are strongly influenced by vegetation. There is practical value in having a benchmark soil in a reserved natural landscape, as the effect of management practices on similar soils outside the reserve can then be measured. But the fundamental reason for protecting unmodified soils is so that future generations of New Zealanders will be able to look back with pride and interest at representative remnants of the old landscape of Aotearoa.

It is a matter of deep regret and national loss that so many of the soil profiles illustrated throughout the regional chapters of this book can no longer be found in their original natural setting. For instance, there are hardly any areas of pumice soils left under the indigenous shrubland which colonised the vast areas of fresh rhyolitic tephra from the Taupo eruption – the major landscape-forming event of historical times in the North Island (Plate 14.10). There is no contiguous reserve in the Manawatu sand country linking the best examples we have of a chronosequence of coastal sand soils (Chapter 6). Regrettably it is now too late to reserve a section since the original vegetation has been largely eliminated. Where such post-glacial dune systems still occur under indigenous forest and swamp vegetation, as in the Haast locality of South Westland (Plate 11.16), it is still very difficult to convince the production-oriented planning authorities that they should be reserved. Even the important Franz Josef chronosequence (Fig. 1.2) is not completely protected, for part of it lies outside Westland National Park.

The soils and landscapes represented in New Zealand's system of protected natural areas are biased towards mountainous, non-productive land; only 5 percent of our protected natural areas (that is, only 0.5 percent of New Zealand's land area) has been reserved at some economic sacrifice. The remaining 95 percent could never be used for agriculture or forestry anyway. As a consequence, most of the soils of the lowlands are not represented in reserves; very little indigenous vegetation can be seen in the photographs of lowland arable soil landscapes in the preceding chapters. Similarly, the wholesale drainage of wetlands for agricultural use (Plate 14.11), or their flooding for electricity generation (Plate 10.19), has resulted in the loss of many potential reserves of gley and organic soils under their natural vegetation.

Plate 14.9

Soils and vegetation are dynamic parts of our natural environment; each can change in response to gradual changes in the other over time (see Chapter 1). Disruption of the natural ecosystem can tend to obscure some of the soil/vegetation patterns that have evolved in harmony over a long period of time – such as the dramatic changes in tree size and composition across this natural pahki on the West Coast of the South Island. For this reason, some of these landscapes must be reserved in their natural state as benchmarks illustrating natural processes which scientific investigation may eventually unravel.
Efforts must be made to reserve important soil landscapes before they are irreparably changed. This photograph shows the depleted vegetation of Ouaha Ridge, the remnant of post-eruption vegetation on thick pumice closest to the Taupo eruption vent in the north-east corner of Lake Taupo. The shrubland has been burnt many times and is completely encircled to landward by pumice lands which have been stripped of their vegetation in preparation for the planting of exotic forests.

The course of the upper Taieri River in the Styx basin of Central Otago (see also Plate 10.9) has produced some superb examples of mature river morphology, such as floodplain scrolls, cut-off meanders (ox-bow lakes), and former channels which have become infilled with sediment and vegetation to form swamps. Despite their high wildlife-habitat value and scientific interest, attempts to reserve these wetlands (and their associated gley and organic soils under natural vegetation) have been resisted by the agricultural community and local authority. In fact, much of this remarkable soil landscape has been drained with canals — despite the soils’ value as upland sponges which help to hold back floodwaters which occasionally threaten the Taieri lowlands (Plate 13.5).
Plate 14.12

View south-west across the lower Hutt Valley to Wellington and the Kaikoura Ranges beyond Cook Strait. In the 1930s, large areas of the recent alluvial and organic soils of the Hutt Valley were still devoted to market gardens. The escarpment along the western side of the valley and harbour marks the Wellington Fault. The retention of recreational open space on the floodplain and lower terraces of the Hutt River is a wise form of land use in a heavily populated area. The benefits are several: homes are less likely to be flooded, travellers on the arterial roads along the river have an uninterrupted view of a more pleasing landscape, and the playing fields are of better quality because they have been sited on well-drained coarse-textured soils (contrast with Plate 14.16).

Urban Expansion on to High-Value Soils

With the exception of the port cities of Auckland, Wellington and Dunedin, most provincial towns and cities in New Zealand were established on recent alluvial soils where the settlers found easy access to flat, well-drained sites. The siting of Palmerston North on the Manawatu Plains (Plate 6.5), and Hastings on the Heretaunga Plains (Plate 7.7), are typical examples. As the urban population grew, these settlements generally expanded on to similar fertile soils; Lower Hutt is a classic example, for residential, industrial and commercial buildings now cover all the land formerly used for market gardens (Plate 14.12).

How significant is this permanent loss of productive soils to urbanisation? A 1974 study estimated that 111 000 ha (or 37 percent of the urban area at that time) involved soils of high value for food production. Other investigations have shown that only 5 percent of this urban land will remain in production by being used for home vegetable gardens. Although only about 4 percent of the total area of potentially arable soils of high value for food production, these urbanised soils may be significant because they are generally strategically located close to export ports and airports.
In an attempt to protect the national interest in retaining as much as possible of the limited resource of high-value soils, government has attempted to minimise the loss through town-planning regulations. The results have been mixed (Plate 14.13). Cities and towns such as Palmerston North, Hamilton, Auckland, New Plymouth, Tauranga and Levin continue to expand onto such soils. Even the efforts to plan the ideal satellite city at Rolleston to accommodate the growth of Christchurch were flawed; after the boundaries had been set it was pointed out to the planners that a quarter of the area consisted of soils of high value for food production.

For a time, planning authorities tried to restrict subdivision of productive farmland to lots no smaller than 4 ha, often forcing small rural lot owners to take on more land than they wanted; in many cases half a hectare would have satisfied them. If hobby farmers and those simply desiring a rural home are to be catered for in our landscape, then it is wasteful to saddle them with larger areas of land, most of which is then underused. In fact, some intensively farmed small rural lots can be highly productive. The challenge is to develop ways of accommodating people who want to make a livelihood out of the intensive use of small parcels of rural land — while at the same time limiting urban sprawl onto such productive land.

Plate 14.13
The urban fringe on the western side of Waitara, northern Taranaki. These New Plymouth soils (Plate 4.10) are highly versatile and of high value for food production; they lie just within the thermic soil-temperature zone (Fig. 14.3). At least five different land uses are illustrated: horticulture (nursery), cropping (maize), industrial, residential, and recreational (sports field). Ideally, residential and industrial areas should be established on alternative soils of lower value for crop production.
Soils for Urban Development

New Zealand cities and towns are situated where they are for historic reasons, and rarely because their soils were ideal for building on. Within any municipality, however, there is usually a wide range of building sites to choose from and a prospective buyer is wise to check on any likely geological, climatic or soil-failure risks. Active fault lines should be avoided and the floodplains and lowest terraces of rivers and streams can carry the risk of flooding.

Some local authorities have zoned hilly land for residential development but then, in deciding where and what sort of structure to build, a different set of potential soil problems associated with slope stability have to be faced. The engineering properties of two contrasting soils in the Wellington urban area illustrate how soils can have different suitability for residential use: the Heretaunga soils of the high terrace remnants (Plate 6.10) and the Korokoro and Makara hill soils (Plate 8.5) are both suitable for road foundations and proper cut-and-fill reshaping of the landscape; both are capable of supporting building foundations and have a low tendency for shrinking and swelling. The Heretaunga soils, however, have a higher tendency to corrode concrete and untreated steel and the Korokoro and Makara soils have severe limitations for septic tank effluent disposal.

Some hill soils in urban areas are potentially very unstable, such as those formed in weakly consolidated tephras and loess. These can become very fluid if they are reworked through cut-and-fill excavations and then become saturated with water. Classic examples have occurred in poorly designed subdivisions on the dense grey soils of the Port Hills of Sumner near Christchurch. Removal of vegetation and landscape recontouring exposes the highly erodible loessial subsoils which are susceptible to sheet, rill and gully erosion (Plate 14.14). Some slope failures are even more dramatic, such as the devastating Abbotsford slide in the Dunedin suburbs in 1979 (Plate 14.15).
The Abbotsford 'block glide' of August 1979 was one of the most spectacular examples in New Zealand of geological hazard disrupting an urban community. The residential development was situated on a thick layer of gently dipping Tertiary sediments capped by the Abbotsford mudstone. Through a combination of excavations at the toe of the slope, and water percolation probably leading to saturation of the sediments at the base of the mudstone layer, the whole slope became mobile and glided downhill as a more or less cohesive block.

With hindsight, the area should not have been built on because of the potential instability.
Urban Amenity Areas and Domestic Gardens

The properties of soils and their management is of critical importance in maintaining parks, playgrounds, sports fields and racetracks. Considering the high proportion of the New Zealand population which uses such recreation areas, it is surprising how long it has taken for the soil factor to be taken seriously. Unfortunately, not many local authorities or schools have been able to establish their sports fields on well-drained, coarse-textured recent alluvial soils such as those illustrated in Plate 14.12. Too often the parent material is cut-and-fill which is bulldozed into a gully, levelled and quickly sown with ryegrass. Too often schoolchildren are disappointed by the cancellation of their games because of the inability of such playing fields to absorb winter rains (Plate 14.16).

The main reason for poor sports fields is soil compaction (Plate 14.17). Compaction can be caused by heavy machinery at the stage of field construction or by players congregating in certain parts of the field (e.g. goal mouths). Prevention of compaction is much more satisfactory than any cure. Heavy-tracked vehicles can cause enormous damage to soil structure (Plate 14.17) and wide, rubber-wheeled soil-spreading machines should be used instead.

Usually, soil compaction can be overcome only by the installation of a comprehensive drainage system. The design of such drainage schemes will depend upon how much money park managers are prepared to spend on rectifying the problem. Obviously the drainage system at Athletic Park is much more sophisticated than that at Tawa College (Plate 14.16). Regular topdressing with sand can improve soil drainage and turf cover, but this expensive technique is only justified for bowling greens and golf courses. Other playing surfaces may require special soil management to achieve a desired durability or resilience. Examples are the use of clayey soils for cricket pitches which become suitably hard when dry, or crushed limestone in the bases of major softball pitches or on BMX tracks. Once drainage is satisfactory, a fertiliser programme is important to maintain a healthy grass sward and, in some areas with a dry summer climate, irrigation is also highly desirable.
In home gardens almost anything is possible if the gardener is prepared to make the effort. Soils can be almost entirely reconstructed, and environmental limitations, such as moisture stress, low temperatures and wind and nutrient deficiencies can be removed by watering, glasshouses, shelterbelts and fertilisers. As with arable soils, the deeper the soil the better; it should be well drained and can be made more friable by soil amendments, particularly organic matter in the form of compost. Soil structure can be maintained by avoiding compaction, adding organic matter, and rotating annual crops with perennial crops. Pests can be minimised by the rotation of crops, the use of companion plants, and/or the judicious use of pesticides.

Knowledge of the physical and biological character of the soil is a prerequisite to sustaining the productivity of the land, whether it be in relation to the agribusiness of large-scale plantation forestry, the family farm or simply the home garden. But such knowledge alone rarely determines land use; in addition, a range of cultural and economic factors exert a powerful influence, so it is fitting that the final chapter acknowledges this dimension.

Plate 14.17

One of the main problems in the formation of suitable playing fields is the poor understanding that many engineers have of soil properties. This photograph is a typical example of a severely compacted subsoil for playing fields being prepared for an Auckland college. The volcanic parent material is clay-rich and the impact of the earthmoving machinery has rendered it virtually impermeable. Even if high-quality topsoil is spread on top, the damage has been done.