Use of Climate, Soil, and Crop Information for Identifying Potential Land-Use Change in the Hokianga and Western Kaipara Region

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Climate data derived from National Climate Database

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Executive Summary

This document contains information collected as part of a project to broadly map the climate and interpret the soils in the western Kaipara and Hokianga regions of Northland, in order to identify potential cropping areas. It is a companion document to several maps of the climate, soil, and suitability of selected crops, which can be accessed by hyperlinks contained within the text.

The crops examined in this study are peanut, Māori potato, manuka (for oil), banana, mate tea, avocado, cherimoya, fig, blueberry, and hydrangea. It is shown that there is potential for growing all of these crops in at least some part of the study region. Information provided for each of these crops includes a summary of market potential and other reasons for interest, experience to date with growing them in New Zealand, infrastructure requirements, and basic growing requirements.

It is emphasized that successful commercial production of a new crop depends on these market, infrastructure and management factors as well as on suitable climate and soil conditions.

1. Introduction

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This document contains information collected as part of a project to broadly map the climate and interpret the soils in the western Kaipara and Hokianga regions of Northland (Map 1 – click on this hypertext link to view the Location Map), in order to identify potential cropping areas. This document is a companion document to the climate, soil, and crop suitability maps. It describes the general climate and soil properties of the study area as well as the influence of phenomena such as El Niño and La Niña and climate change on the climate of the Kaipara and Far North districts. Detailed information about the crops selected for study has been included. The document also outlines the methods used in the climate, soil, and crop suitability map production and details the main patterns shown in the maps. Hypertext links (shown in blue text with an underline) to printable PDF versions of the maps are included in the text.

The project was funded by a grant from the Ministry of Economic Development in August 2001, to develop under-utilised rural land in the Western Kaipara and Hokianga, and to promote alternative land use. It was hoped that an inventory of climate and soil information would lead to economic development initiatives in the horticultural, pastoral farming and forestry sectors of the region.

Two councils, the Kaipara and Far North District Councils, were involved in the project, acting as links to the local communities. Both councils undertook the role of project liaison with interested community groups – including community consultation, and management of project meetings. The responsibility of dissemination of project results also fell to the Councils.

A number of research organisations were involved in this project. NIWA (The National Institute of Water and Atmospheric Research Ltd.) led a team of scientists from Landcare Research, HortResearch, and Crop & Food Research. The study brought together scientific expertise from many different fields (climate, soil, and horticulture), in order to produce knowledge that would be relevant, and of use, to land owners in the district now, and into the future.

1.1 Project Aims

The project had three main goals:

- To provide an inventory of climatic and soil information, based on existing data.
- To identify areas that show significant potential for the development of 10 selected crops, chosen as sustainable for the soils and climate of the study area.
- To ensure the information above is accessible and understandable to the broad community.

It is important to elaborate further about certain goals, with key points underlined:
The primary project goal was to produce an inventory of climate and soil information in the western Kaipara and Hokianga region, with the aim that once this 'knowledge base' was created, it would be an important resource for future analyses or applications, whatever they may be.

The inventory actually consists of 35 maps. The 28 climate maps contain estimates of climate data, at the scale of 1:250,000, based on existing data. The 7 soil maps also contain estimated soil data, at the scale of 1:50,000, based on existing data.

Firstly, because climate is not measured directly at every point in the study area, climate data needs to be estimated in-between the sites at which climate data is actually measured. Estimation makes use of known relationships between topography (hills, valleys, etc) and climatic variables such as rainfall, temperature, etc. Estimates, of course, have uncertainty associated with them. Also, in areas where there are large distances to the nearest climate stations, e.g. in high elevation areas, the uncertainty is likely to be higher.

Secondly, the scale of each climate map is 1:250,000, which means that for a particular climatic variable, for example mean December temperature, the map contains one estimate of mean December temperature for every 500 metres by 500 metres (25 hectares).

And thirdly, the use of existing data has ensured that this project was relatively 'cost-effective'. Because it was thought that certain soils in the region were poor, and that steeply sloping land in some areas would limit crop activities anyway, the expensive option of installing new climate stations across the study region to collect new data was not undertaken. Instead, this project aimed to identify areas that show good *potential* for cropping using available data. In future projects, in the regions that show promise, it may be beneficial to install climate stations and to sample soils, to achieve crop mapping at a higher resolution, if this is required by the community.

Finally, a lot of effort was put into making the project information understandable to the broader community, with three public meetings, which also proved an invaluable opportunity to gain information about what the community wanted to see from this project.

The results from this project have been made easily accessible from two public libraries in the study region, and are also available from both the Kaipara and Far North District Councils (or their representatives). It is hoped that eventually the results may be posted on the Internet.

Within this document itself, there has been a strong emphasis on keeping the information understandable to the general public, by use of colourful maps (a picture is worth a thousand words), a glossary at the back to explain key technical words, and by ensuring the introduction section explains the main findings as clearly as possible. However, this document does contain science – climate and soil science both use technical words with very specific meanings, and technical information about the horticultural crops is quite detailed. In the interests of those readers who need a more detailed background, important technical or scientific information is therefore included.

1.2 How The Crops Were Selected

Community groups identified ten crops of interest over the first two public meetings, following consultation and guidance from the horticultural scientists.

The public were encouraged to think about the reasons why they wished to use idle land or to alter land use – was it to grow food for whanau (family), or to sell for profit? What was the size of land available for use, and the money available for investment? What scale operation did they wish to have (from a small scale designed to develop horticultural expertise, through to a larger commercial level)?

Overall, there was a clear response from the community for information about crops suitable to be grown on smaller blocks of land, with lower capital investment and lower labour skill requirement.

The horticultural scientists then described some 'positives' about the study region –

- The closeness to the local Auckland market
- The earliness of crop development due to Northland's relatively warm climate/ earliness into the market place at a time when prices would be high
- Organics might be the way to go to get into a 'niche' market

A large number of crops were then discussed, with feedback from the horticultural team. For example, olives were suggested as a possible crop, but it was advised that mean temperatures were probably too cold in the region for good crop growth. Another suggestion was saffron, but discussion about the highly skilled labour force required (crop extraction is manual and quite difficult), and about the global competition to be faced (employing very cheap labour elsewhere), meant that it was probable that a New Zealand venture might be very risky in a business sense. Several other crops were advised against because of climatic requirements not being realistic.

The Far North and Kaipara District Councils wanted to diversify land use away from the typical kumara agriculture, forestry, and dairy industry, to create different economic opportunities – to prevent having 'all the eggs in one basket'. The feedback from the Councils was therefore to veto crops that were related to industries the region was already dependent on (for example, maize as a dairy feed). The ten crops finally selected (described in Chapters 7 through 16) were:

- peanut
- Māori potato
- manuka (for oil)
- banana
- mate tea
- avocado
- cherimoya
- fig
- blueberry
- hydrangea

1.3 General Climate and Soil Information

In general, the study area receives around 1400 mm of rainfall per year, with a maximum in winter (around 450 mm) and a minimum in summer (around 250 mm). Most of the area experiences a deficit of soil moisture for at least half of the summer season, with the largest deficits in coastal lowland areas. Average temperatures in summer are around 18 °C and in winter are around 10 °C. This leads to typical growing degree days (base 10 °C) in excess of 1700 °C, which is ample for many crops including sub-tropical species. Frosts are not very common in the study area, even in the winter months, with frost-free periods often greater than two years in many areas. Sunshine hours are typically around 600 hours in summer, which is the seasonal maximum, and around 350 hours in winter, which is the seasonal minimum. Total sunshine hours for the year are around 1800 hours and the district receives most of its wind from the southwest to the northwest.

The general climate information described above paints a useful, but very broad picture of the climate of the study area. One of the goals of this mapping project is to fill in the details of the climate at a scale (1:250,000) that can be used to identify areas where possible changes of land use are viable. Descriptions of the 1:250,000 climate maps are presented in Chapter 4. Additional climate information in the form of tables and a detailed discussion of past climate fluctuations and scenarios for future climate change is also presented in Chapters 5 and 2, respectively.

As far as the soils of the area are concerned, much of the area is described as sand country, hill country from strongly weathered sedimentary or volcanic rocks, and occasional steepland. Slopes are generally subdued (70% of the study area has slopes less than 20°), with quite high representations of flood plains and terraces. A significant limiting factor of the soils of the area is drainage, with nearly half the project area having imperfectly drained soils – a problem not uncommon in Northland. Most soil water volumes in the area, on the other hand, would be non-limiting for crops. Detailed descriptions of the soils of the area are presented in Chapter 6.

1.4 Summary of the Main Findings from the Crop Potential Maps

Detailed descriptions of the crop potential maps (with hyperlinks to the associated maps) are presented in Chapter 18.

Peanut

There is potential for growing Peanuts over much of the low elevation parts of the study region. Areas with the best potential are near Taheke and Otaua, the area from Rangiahua to Okaihau, along the Kaihu River north of Dargaville, on the Wairoa River plains, on the west coast between around Baylys Beach and Glinkes Gully, and the area around Lake Humuhumu (see Map 1 for location of place names). The four main physical factors that are likely to limit the success of peanut crops are a high risk of heavy rainfall close to harvest, low pH values (high acidity) in the subsoil, insufficient water in the soil profile, poor soil drainage, and slopes that are too steep.

Māori Potato

There are several areas that stand out as having potential for growing Māori potatoes. These areas are the Wairoa River plains, the western side of the Pouto Peninsula, the area near Taheke and Otaua, and the area from Rangiahua to Okaihau (see Map 1 for location of place names). Within the study area the main physical factors that can limit the success of Māori potato crops are slopes that are too steep and poor soil drainage.

Manuka (For Oil)

Several areas around the region show potential for growing Manuka. The area east of Tokatoka shows good potential, as do the Awakino river valley (north of Dargaville) and the area near Taheke and Otaua. The area around Lake Omapere and the area on the northern side of the Hokianga Harbour around Panguru also show good potential (see Map 1 for location of place names). The main physical limiting factors for growing Manuka are too high maximum temperatures, too low minimum temperatures, and slopes that are too steep.

Banana

There is potential for growing bananas for most of the study region. The areas that show greatest potential for growing bananas are around Waihue (north of Dargaville), Aranga (5km east of Maunganui Bluff), Otaua, Umawera, Waipoua, Waimamaku, and the area from Rangiahua to Okaihau (see Map 1 for location of place names). The main physical limiting factors are soil-related and are shallow potential rooting depth, imperfect to poor soil drainage, and moderate to low profile available water.

Mate Tea

The highest potential for growing Mate Tea within the study region is the area north of around Dargaville as well as along the western side of the Pouto Peninsula. The main physical limiting factors are soil related and are caused by shallow potential rooting depth, low profile available water, and poor drainage. In addition, spring, summer, and winter rainfall totals are generally too low in the Dargaville area. Areas of particularly high potential include the area near and to the east of Panguru, the area from Rangiahua to Okaihau, and the area around Umawera (see Map 1 for location of place names).

Avocado

There are some small areas within the study region that show potential for growing Avocado. These are near Taheke and Otaua, the area from Rangiahua to Okaihau, along the western side of the Pouto Peninsula, and the area around Lake Humuhumu near the town of Pouto (see Map 1 for location of place names). The main limiting climate and soil factors are too cold spring maximum and minimum temperatures, insufficient soil drainage, slopes that are too steep, too shallow potential rooting depth.

Cherimoya

There are several small areas within the study region where there is potential for growing Cherimoya. These are near Taheke and Otaua, the area from Rangiahua to Okaihau, near Waimamaku, near Aranga (5km east of Maunganui Bluff), along the western side of the Pouto Peninsula, and in particular around Pouto where nearly all the climate and soil factors are optimal (see Map 1 for location of place names). Other areas are limited physically because the extreme minimum temperature tends to be too cool, the slopes are too steep, and the soil drainage is insufficient.

Fig

There is potential for growing Figs near Waimamaku, in the area along the western side of the Pouto Peninsula and around Pouto itself, as well as in the area along the Punakitere River near Taheke and Otaua (see Map 1 for location of place names). The main physical limiting factors are too cold minimum temperatures during the growing season, slopes that are too steep, insufficient soil drainage, and shallow potential rooting depths.

Blueberry

There is highest potential for growing Blueberry around Lake Omapere, near Kaikohe, and along the Punakitere River near Taheke and Otaua, on many of the lower slopes of the Parataiko and Tutamoe Ranges, near Aranga (5km east of Maunganui Bluff), and along the western side of the Pouto Peninsula (see Map 1 for location of place names). The principal physical limiting factors are the slope, insufficient winter chilling in lower elevation areas, and insufficient soil drainage. Relatively low maximum temperatures in summer in the Ranges may limit the early ripening potential of Blueberry.

Hydrangea

Areas that show potential for growing Hydrangea are on the slopes of the Maungataniwha Range and to a lesser extent the Parataiko and Tutamoe Ranges, around Umawera, the area from Rangiahua to Okaihau, around Kaikohe, near Taheke and Otaua, near Donnellys Crossing, in the hills around Aranga (5km east of Maunganui Bluff), near Kairara (10km east of Lake Taharoa), along the west coast from Omamari to north of Lake Mokeno, and around Pouto (see Map 1 for location of place names). The main limiting climate and soil factors are slopes that are too steep and poor soil drainage.

2. Climate fluctuations and changes affecting the Kaipara and Far North Districts

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In this section we describe climate fluctuations and trends in the western Kaipara and Hokianga study area including an analysis of climate extremes. We examine the regional effects of El Niño and La Niña conditions, consider whether longer-term climate trends or shifts are present, and outline future climate changes likely to be caused by continuing global greenhouse gas emissions. This information complements the accompanying climate maps, which are based on data from 1970 – 2001.

2.1 Year-to-Year Climate Fluctuations in the Western Kaipara and Hokianga Area

Figure 2.1 shows a temperature time series for Dargaville from 1943 to 2001. The highest annual average temperature during this period was 16.6°C in 1998, and the lowest was 13.9°C in 1945. 1998 was the warmest year in the instrumental record (since about 1860) for both the globe as a whole (IPCC, 2001) and for New Zealand. The relatively cool temperatures in 1992 and 1993 were probably influenced by the spread through the upper atmosphere of small particles (aerosols) from the eruption of Mt Pinatubo in the Phillipines (Parker *et al.*, 1996). The standard deviation in annual average temperatures at Dargaville through the 1943 – 2001 period was 0.5°C.

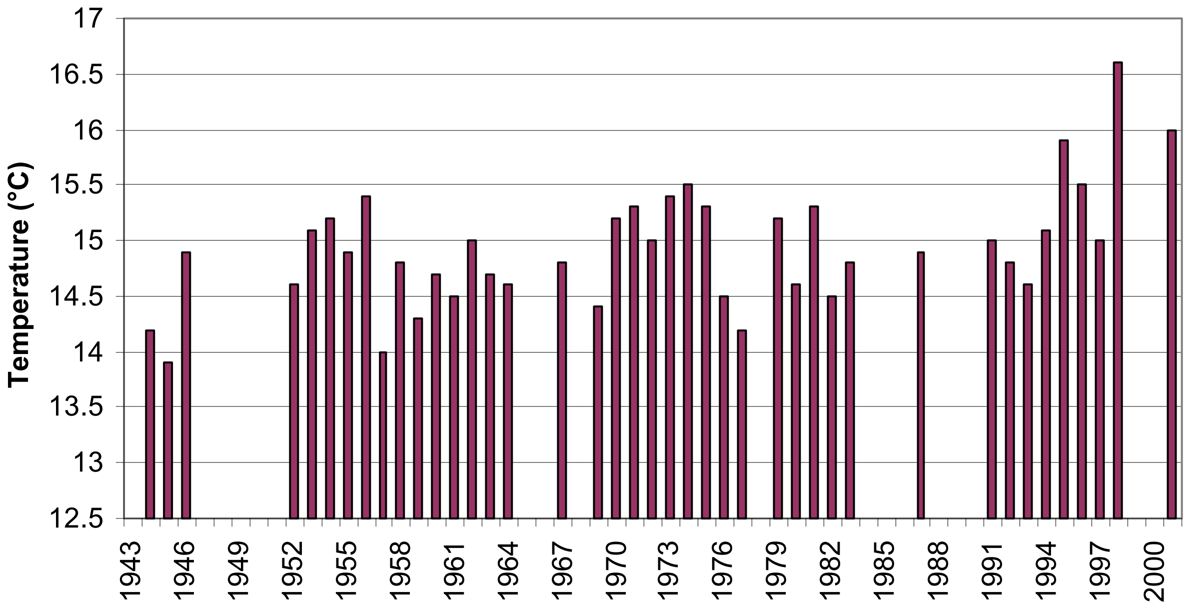


Figure 2.1: Mean annual temperatures measured at Dargaville from 1943 to 2001.

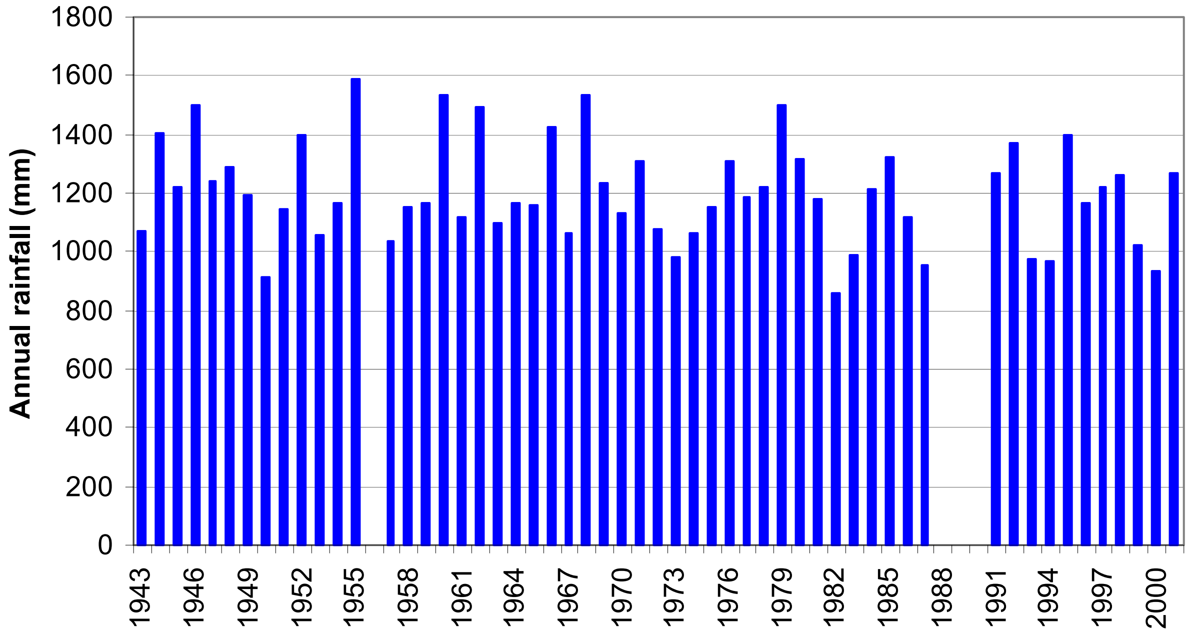


Figure 2.2: Mean annual rainfall measured at Dargaville from 1943 to 2001.

Figure 2.2 is a similar figure, showing the year-to-year variation in rainfall at Dargaville over the same period. The minimum annual rainfall was 859 mm in 1982 and the maximum was 1591 mm in 1955, and the standard deviation was 173 mm.

Further information about climate variability for the Kaipara and Far North districts is provided in the next section and in the accompanying climate maps, which show the upper and lower quintiles as well as the mean values of various climate elements.

2.2 Climate Extremes

A question that is often asked is 'are extreme climate events changing?' That is, are heavy rainfalls becoming heavier, or more frequent? Are dry periods or droughts becoming more common? Have frosts in Northland really almost disappeared?

By looking at historical rainfall and temperature records, and using annual *indices* of extreme climate, it is possible to assess the variability and trends seen in extreme events in the past.

Eight indices of extreme climate were calculated for each year where sufficient data existed. If, in any year, the probability that the particular extreme event of interest might be missing exceeded 0.5, then the index for that year was set to missing.

The annual rainfall indices are:

- The greatest five day rainfall total (mm)
- Maximum number of consecutive days with rainfall less than 1mm (days)

- The number of rain days, where a rain day is defined to have rainfall greater than or equal to 2mm (days)
- The average size of the wettest four daily rainfall events (mm)
- The frequency of exceeding a long-term ‘heavy rainfall’ threshold (the 1961-1990 average 99th percentile)

The annual temperature indices are:

- The number of days where minimum air temperatures are less than or equal to 0 °C
- The percentage of days when the daily minimum temperature is lower than a long-term ‘cold’ threshold (the 1961-1990 average 10th percentile of minimum temperatures)
- The percentage of days when the daily maximum temperature is higher than a long-term ‘hot’ threshold (the 1961-1990 average 90th percentile of maximum temperatures)

The rainfall indices will identify whether extremely high daily rainfall has changed in frequency or intensity at a location, whether there are more or less days with rainfall (of any type), and whether dry spell lengths are changing. Changes in extreme extended-duration rainfalls are also examined. The temperature indices will analyze the changes in the frequency of air frosts, cool nights and warm days.

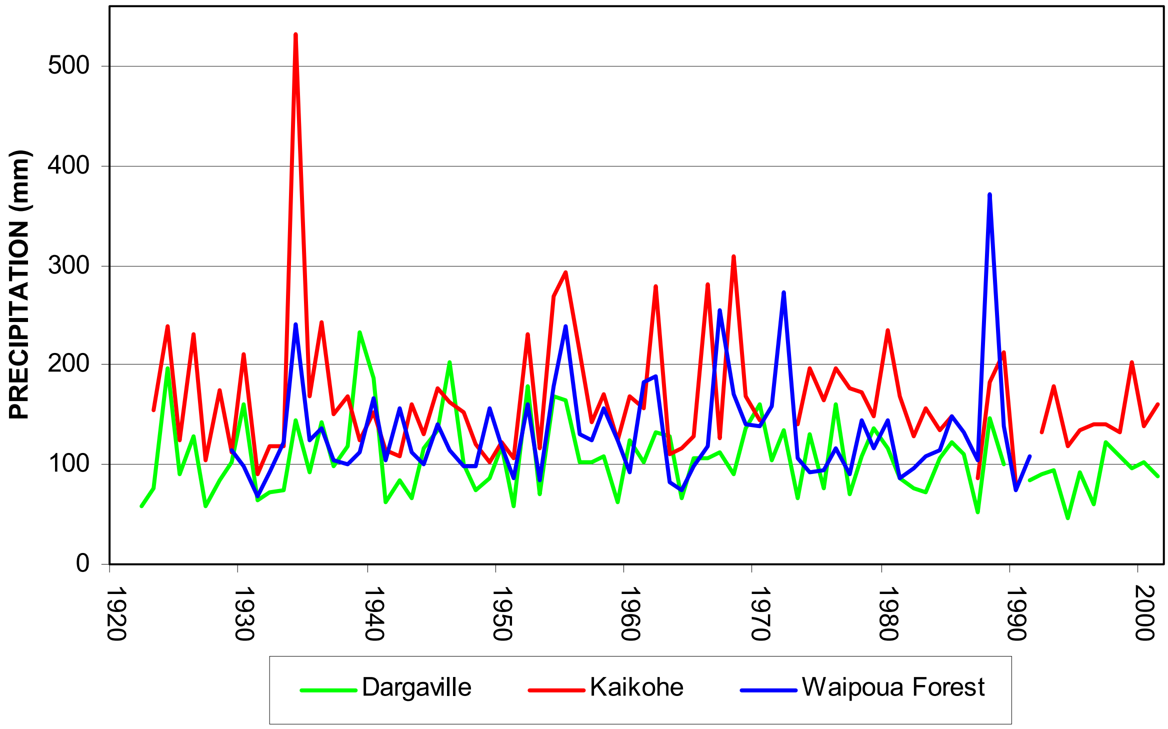


Figure 2.3: Annual greatest 5-day rainfall total at Dargaville, Kaikohe, and Waipoua Forest.

The greatest 5-day rainfall total each year is important to farmers and landowners, because it measures extended-duration, heavy rainfall events. Extreme rainfalls over a 5-day period typically result in widespread flooding, with river levels rising and continuing to rise, and soil moisture levels become saturated over an extended duration, increasing rainfall runoff into the river systems.

Extremely large 5-day rainfall totals at Dargaville (Figure 2.3) show large variability in the historical record, with an average of around 107mm, but with peaks up to 234mm, as recorded in 1939. A small, non-significant decreasing linear trend is observed in the size of 5-day rainfall totals at Dargaville across the length of the record. It can also be seen that extreme 5-day rainfall totals at the station show a lot of variability prior to about 1950.

The greatest 5-day rainfall totals at Kaikohe have varied enormously in the historical record, from a peak of 533mm in 5 days in 1934, to an average of 165mm. No significant long-term trend is evident, although the size of extended-duration rainfall has remained muted (less variable) in the 1980s and 1990s.

The 'extreme 5-day' index at Waipoua Forest shows large variability, with an average of around 130mm, but with possible peaks up to around 370mm, as recorded in 1988. There is no significant linear trend observed at Waipoua Forest. It is important to note that the huge total recorded in 1988 is an outlier, and is very 'influential' – it draws the eye, and is located at the end of the data series. It leads us to suspect that 5-day rainfall totals are increasing at Waipoua Forest - but this is not necessarily the case, as there is large variation from year to year, and no following data.

The 'dry spell duration' index is indicative of drought – but because drought is a complex mix of low rainfall, and high evapotranspiration of moisture from the soil (caused by wind, high temperatures), the 'dry spell duration' index may only capture part of the drought 'equation'. The index displays information about extended periods of no rainfall (defined to be less than 1 mm per day) – the duration of so-called 'dry spells'.

A lot of variability is seen in the dry spell duration at Dargaville (Figure 2.4), from the enormous peak of 55 days seen in 1928, to another peak of 39 days seen in 1976. The average dry spell length is about 20 days. A significant decrease can be seen in the dry spell length at Dargaville over the entire record, at the rate of 0.4 days per decade. This decrease remains when the large outlier in 1928 is removed, but becomes not statistically significant.

The extreme dry spell duration also shows huge variability at Kaikohe, with an average dry spell length of 18 days, and a large maximum (outlier) recorded in 1988 of 58 days. This extended period of drought-like conditions started in March 1988, and finished on June 6th. No significant long term trend is observed.

A lot of variability is seen in the dry spell duration at Waipoua Forest. The average dry spell length is about 16 days at Waipoua Forest, but in some years the longest dry spell has only been 7 days long, and other years up to 39 days in duration (1976). No clear trend can be seen in the dry spell length.

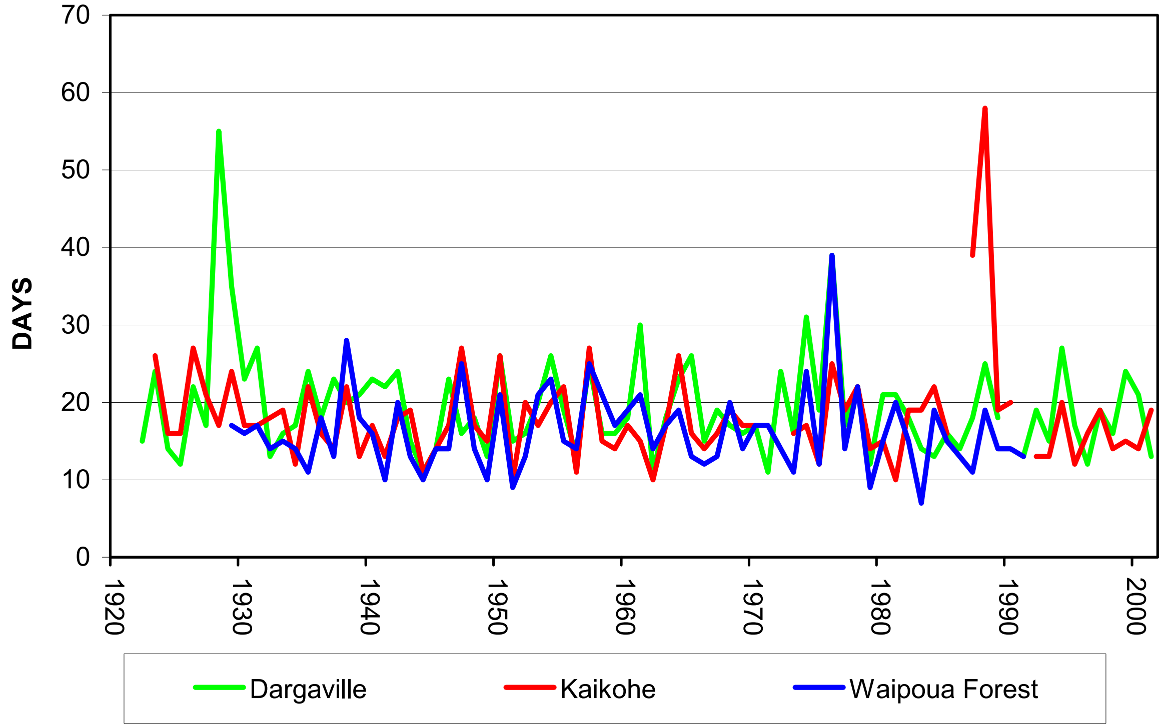


Figure 2.4: Annual dry spell duration at Dargaville, Kaikohe, and Waipoua Forest.

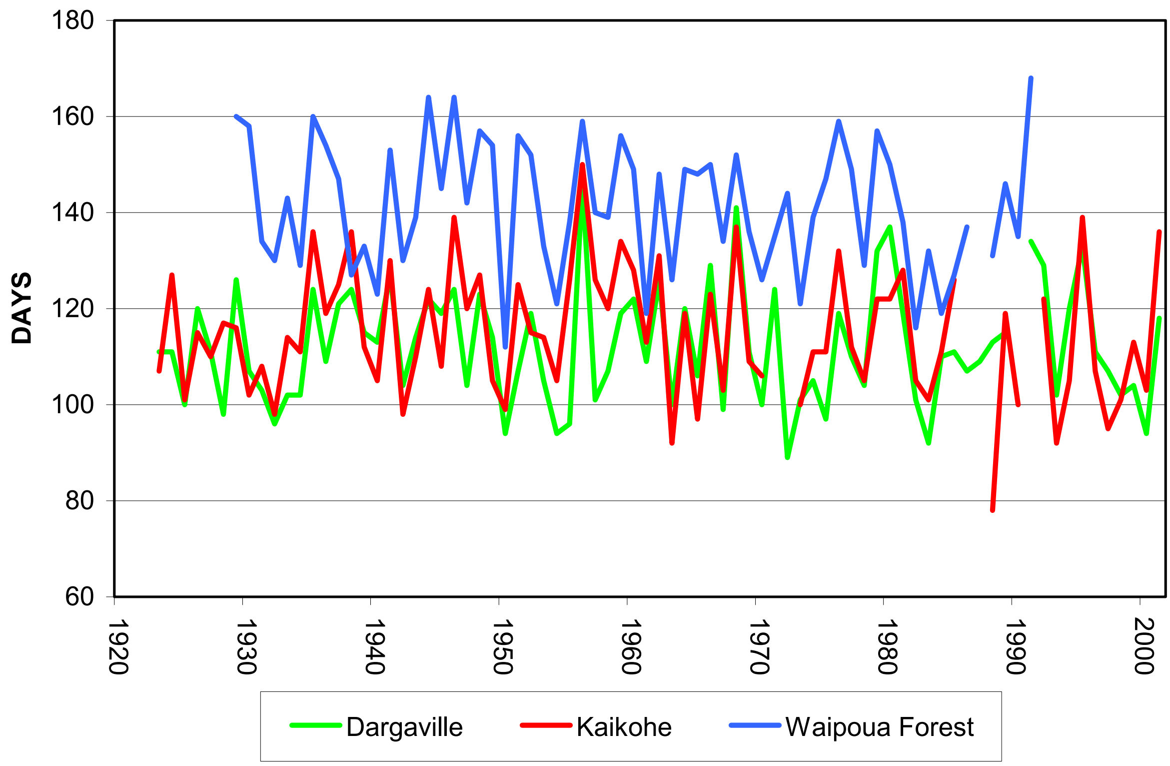


Figure 2.5: Annual number of raindays at Dargaville, Kaikohe, and Waipoua Forest.

The number of 'rain days' at Dargaville is shown in Figure 2.5. There is an average of around 110 rain days per year – about 30% of the time there will be some type of precipitation (either light, moderate or heavy) here. This has varied over the observational record between a minimum of 89 days in 1972, to a maximum of 146 days in 1956. There is no clear trend in rain days at Dargaville.

The average number of rain days per year at Kaikohe is around 115. Since the peak of 150 rain days in 1956, there has been a slow, (non significant) decline in the number of rain days recorded.

The number of 'rain days' at Waipoua Forest is also shown in Figure 2.5. There is an average of around 140 rain days per year – about 38% of the time there will be some type of precipitation (either light, moderate or heavy) at this site. This has varied over the observational record between a minimum of 112 days in 1950, to a maximum of 168 days in 1991. No statistically significant trend in rain days is seen over the entire record at Waipoua, although a small decrease is observed between 1950 and 1990. Again, there is a large value (outlier) at the end of the data series.

The 'extreme rainfall intensity' at Dargaville averages at about 45mm – that is, the average size of the largest four daily rainfalls per year is typically around 45mm per day (Figure 2.6). This has varied in the past between 24mm and 80mm. Although no clear trend in the average intensity is evident, it appears that the variability of the extreme rainfall intensity has decreased over time.

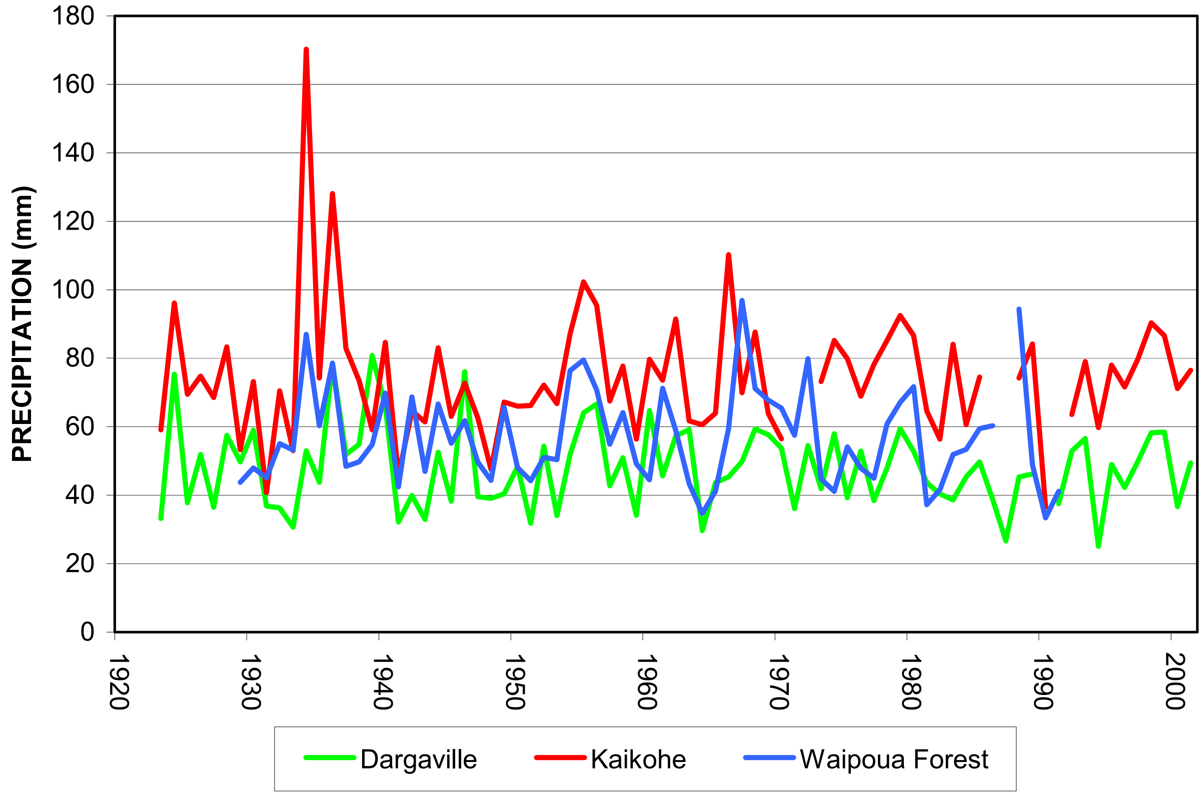


Figure 2.6: Extreme annual rainfall intensity at Dargaville, Kaikohe, and Waipoua Forest.

The extreme intensity index (the size of the wettest four rainfall events per year) has varied in the past between 170mm in 1934, to 36mm in 1990 at Kaikohe. No significant long-term trend is observed in extreme daily intensity at Kaikohe, with an average value of around 75mm. However, the latter decades show less variability than the 1930s and 1960s, for example.

The 'extreme rainfall intensity' at Waipoua Forest averages at about 60mm – that is, the average size of the largest four daily rainfalls per year is typically around 60mm per day (Figure 2.6). This has varied in the past between 33mm and 97mm (occurring in 1967, 1988 respectively). Although no clear trend in the average intensity is evident at Waipoua Forest, it may be that the variability of the extreme rainfall intensity has increased since about the 1960s.

The frequency of extreme daily rainfalls at Dargaville (Figure 2.7) shows a large variation in the historical record, with an average of around 3 'heavy rainfall' days per year. Between 0 days and 8 days per year have exceeded the 'heavy rain' threshold in the past. No obvious linear trend is evident in the frequency of extreme daily rainfall at Dargaville. However, the 1950s, 1960s and 1970s, all in the negative phase of the Interdecadal Pacific Oscillation (IPO) and influenced by enhanced northeasterly winds, showed more extreme daily rainfall events than the period after 1977 (positive phase of the IPO, with enhanced southwesterly winds – see later in this chapter for information on the IPO).

The frequency of extreme daily rainfalls has not changed significantly at Kaikohe over the period of record. There is an average of 4 days of 'heavy rainfall' per year at Kaikohe, but this has ranged in the past between 9 days and 0 days (1962 and 1990, respectively).

The frequency of extreme daily rainfalls at Waipoua Forest shows large variation in the historical record, with an average of around 4 'heavy rainfall' days per year. In the past, between 0 days and 9 days per year have exceeded the 'heavy rain' threshold defined earlier. No clear trend in heavy rain frequency is evident at Waipoua Forest from the available data.

The number of days with an air frost has steadily decreased over the instrumental record at Dargaville (Figure 2.8), from a peak of 17 days per year in 1957. The average number of air frosts in the past has been around 5 per year, but this average has dropped to 3 days in the 1990s. This decrease is statistically significant, at a rate of 0.7 days per decade.

Due to a fairly short temperature record, with a significant amount of missing data, it is difficult to draw any conclusions regarding the number of air frosts recorded at Waipoua Forest. In the available record, the number of air frosts per year at this site has varied between 0 and 11.

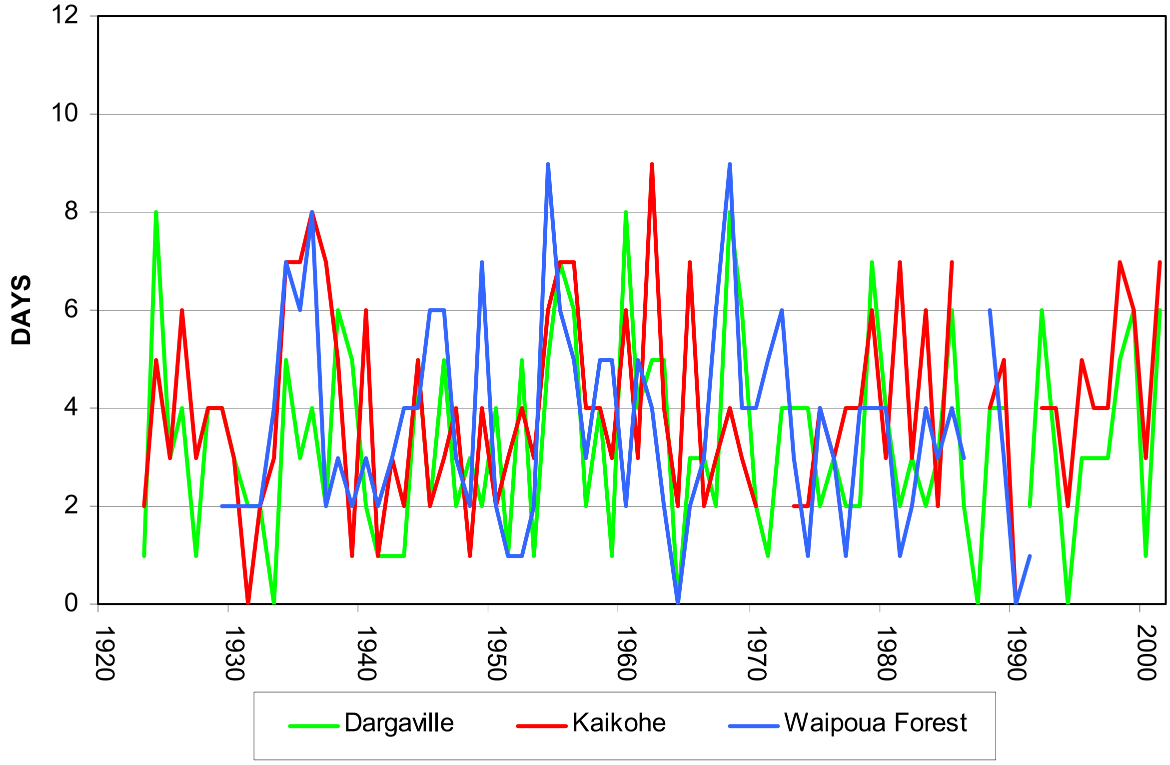


Figure 2.7: Extreme annual rainfall frequency at Dargaville, Kaikohe, and Waipoua Forest.

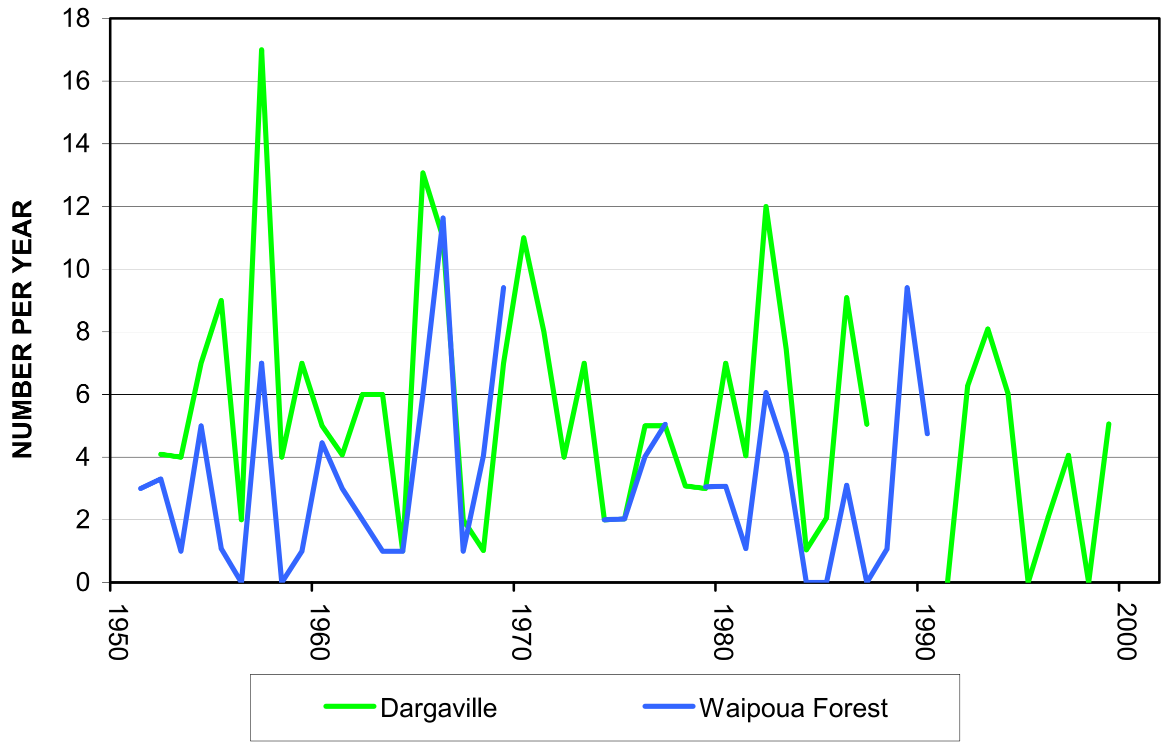


Figure 2.8: Annual number of air frosts at Dargaville and Waipoua Forest.

A plot of the percentage of 'cool nights' is shown in Figure 2.9 (this is the percentage of days when the daily minimum temperature is lower than a long-term 'cold' threshold). A decrease is observed since about 1960, with the lowest value of 2% shown in 1998. This decrease is weakly significant, and in the order of a reduction of 0.3% per decade.

For Waipoua Forest, the percentage of 'cool nights' index should average at 10%, but we see that in the observational record, this has varied between 19% in 1970, to 4% in 1986.

Of note is the recent sharp increase in the percentage of 'warm days' seen at Dargaville (Figure 2.10). The maximum value of 37 % was recorded in 1998, which is known to be the warmest year in a very warm decade across New Zealand, including the Northland region. A linear increase in this index is statistically significant, at a rate of 2% per decade. When removing the two large (outlier) values in the 1990s, there is still a significant increase in the number of warm days in Dargaville.

At Waipoua, it is clear that the late 1960s and early 1970s were characterised by warm daytime maximum temperatures. In the 1980s, 'warm days' were much less common. The changeover point of the late 1970s may be significant – as about that time, the climate of New Zealand shifted from a more northeasterly climate pattern, to a more southwesterly regime. This is consistent with this observed reduction in the number of extreme maximum temperatures (warm days) at Waipoua Forest, because enhanced southwesterly winds typically bring cooler, cloudier conditions to western areas, such as the coastal Kaipara and coastal Hokianga.

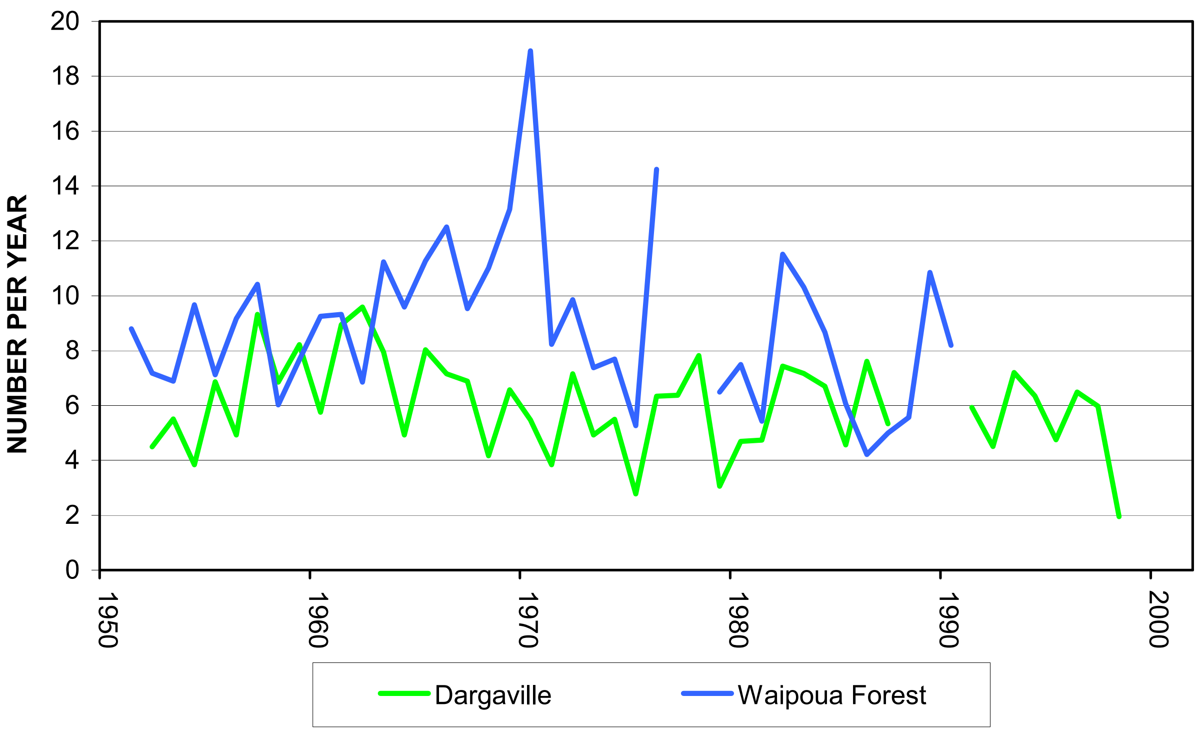


Figure 2.9: Annual number of cool nights at Dargaville and Waipoua Forest.

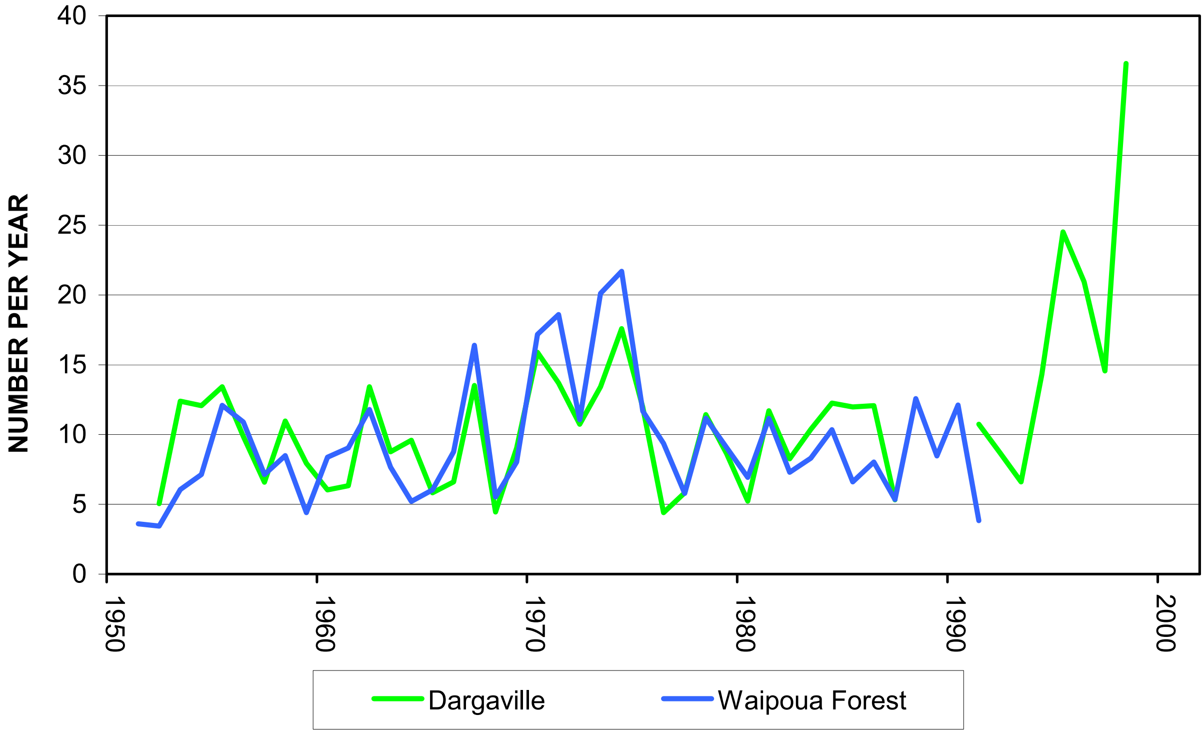


Figure 2.10: Annual number of warm days at Dargaville and Waipoua Forest.

In summary, based on all available data, and acknowledging that there were some missing data, mean rainfall and the number of rain days have not significantly changed at Dargaville. However, mean annual temperatures have clearly increased over the record period, with a corresponding significant decrease in air frosts and cool nights, and a significant increase in warm days.

Extreme events (both very wet or very dry) appear less common in recent decades, with a non-significant decrease in the extreme 5-day amount and a significant decrease in dry spell duration. Although there are no clear, significant trends in extreme daily rainfall frequency or intensity, both indices are more muted (less variable) in the 1980s and 1990s than in previous eras. This is an important point – since 1977, with an enhanced southwesterly climate regime, and higher pressures affecting northern New Zealand, extreme rainfalls have been less common than in other times in the past. However, in 1998, a switch to the northeasterly phase of the Interdecadal Pacific Oscillation (or IPO, see section 2.4) occurred, and it is possible that Northland rainfall may again become more 'volatile', as seen in the earlier part of the rainfall record. The community must be aware of the extremes seen in the past, in order to plan for a range of possible extreme climate events in the present.

Mean annual rainfall at Kaikohe shows no significant change over the period of record. Also, the frequency of extreme daily rainfall, and the extreme dry spell duration, have not changed significantly. No significant long term trend is observed in extreme daily intensity at

Kaikohe. However, the latter decades show less variability than the 1930s and 1960s, for example.

The number of rain days at Kaikohe exhibits a slow, (non significant) decline from a peak in the 1950s. Extreme 5 day rainfall totals have varied enormously in the past, but have remained muted (less variable) in the 1980s and 1990s. Similarly to Dargaville, the extreme rainfall climate at Kaikohe appears to have been more 'muted' (benign) in the 1980s and 1990s, when an enhanced southwesterly climate pattern was dominant. In the decades to come, since a switch to the northeasterly phase of the IPO in 1998, it may well be that Kaikohe rainfall may again become more 'volatile', as seen in the earlier part of the rainfall record.

Mean rainfall and the number of rain days at Waipoua Forest have probably decreased slightly in the period 1950 to 1990. Mean annual temperatures have generally increased. There are no clear trends in 5-day extreme rainfall, dry spell duration, extreme frequency or extreme intensity, at Waipoua, although large outliers of extreme rainfall have occurred recently in some of the indices. The late 1960s and early 1970s was a period of extreme temperature, with large numbers of both cool nights and warm days. Extreme temperatures have been less common from the late 1970s, which may be related to the phase change of the IPO to a more southwesterly climate pattern.

2.3 The Influence of El Niño and La Niña on the Climate of the Kaipara and Far North Districts

Seasonal rainfall and temperature in many parts of New Zealand are influenced by El Niño and La Niña events which occur every few years (Gordon 1986, Mullan 1995, Mullan 1996). During an El Niño event, pressures tend to be higher than average over Australia and lower than average to the east of New Zealand. Consequently the winds on to New Zealand tend to be more from the south and west than normal. In broad terms this tends to bring more rain than normal in the west of New Zealand and less in the east, and temperatures tend to be lower than average. During La Niña conditions, the pressure and wind anomalies tend to be opposite to El Niño, giving an enhanced flow of relatively warm air onto the country from the northeast. Thus during a La Niña event, temperatures over much of the country tend to be warmer than normal, and it tends to be wetter than average in the north and east of the North Island.

Rainfall

Figure 2.11 shows that during El Niño there tends to be less rain than normal in all seasons throughout the Kaipara/Hokianga region. There is also a strong gradient, particularly in spring and summer, from wetter in the west to drier in the east. During La Niña (Figure 2.12), most of the region tends to be about normal in the west to above normal inland, with the exception of spring where rainfall is wetter than normal everywhere within the study area.

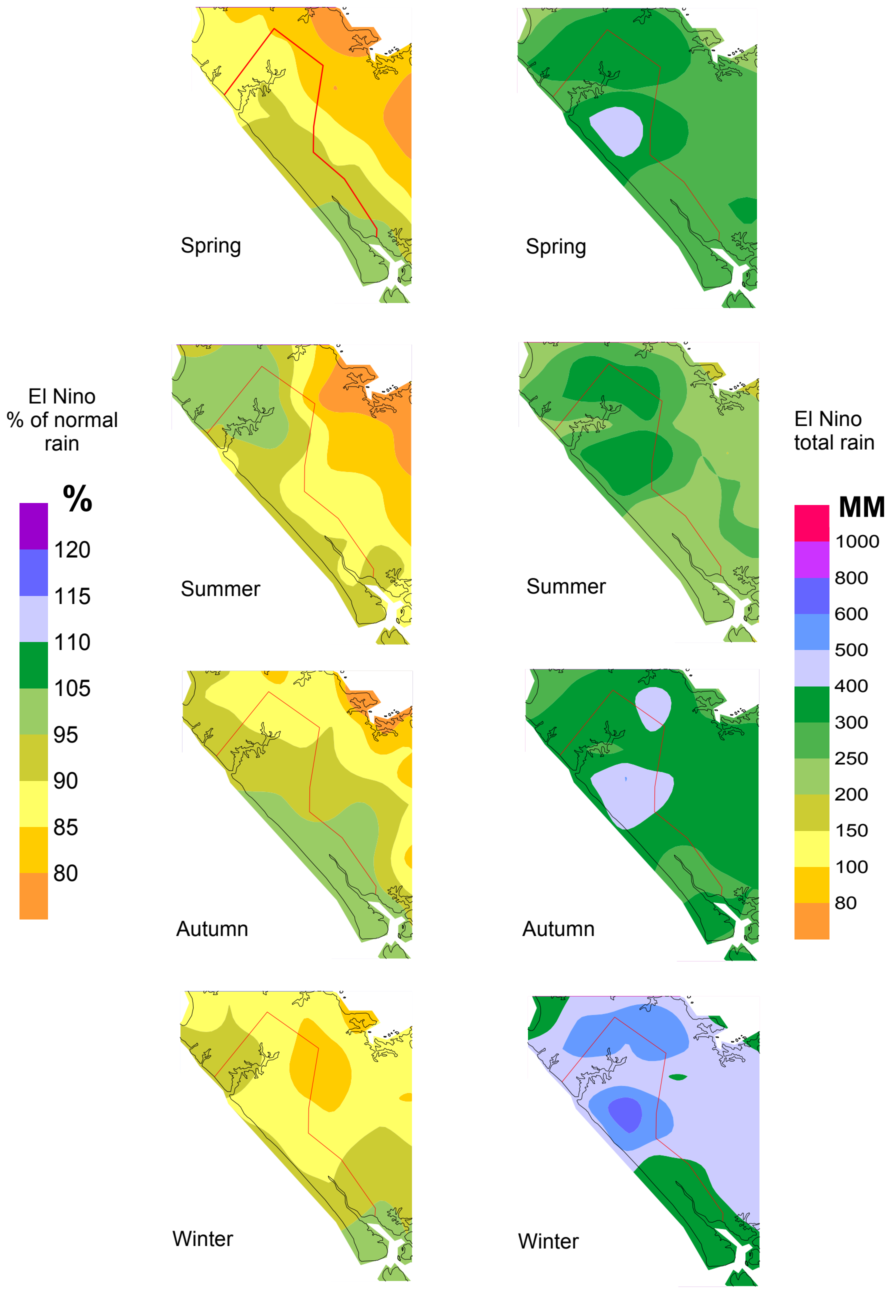


Figure 2.11: The average rainfall over the Kaipara/Hokianga study area expressed as a percentage difference from normal (left) and as actual rainfall values (right) for "strong" El Niño seasons from 1949/50 to 2000/01. (The study area is enclosed by the continuous red line in this diagram).

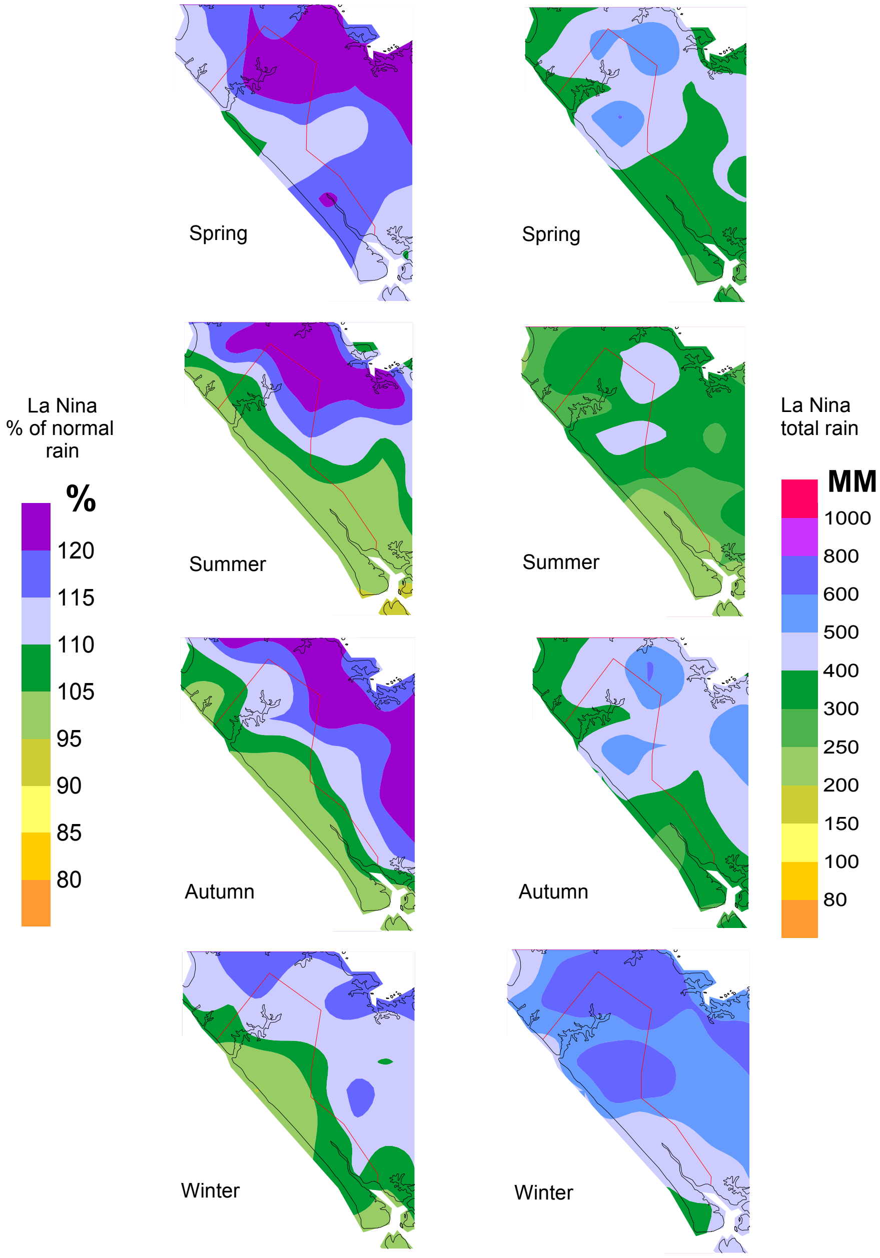


Figure 2.12: The average rainfall over the Kaipara/Hokianga study area expressed as a percentage difference from normal (left) and as actual rainfall values (right) for "strong" La Niña seasons from 1949/50 to 2000/01. (The study area is enclosed by the continuous red line in this diagram).

However, there is considerable variation in rainfall between individual El Niño (or La Niña) events. Figure 2.13 shows the Dargaville winter rainfall for each winter since 1943, separated into El Niño, "normal", and La Niña situations. Although most El Niño winters are drier than average at Dargaville, this figure shows some El Niño winters are close to the average.

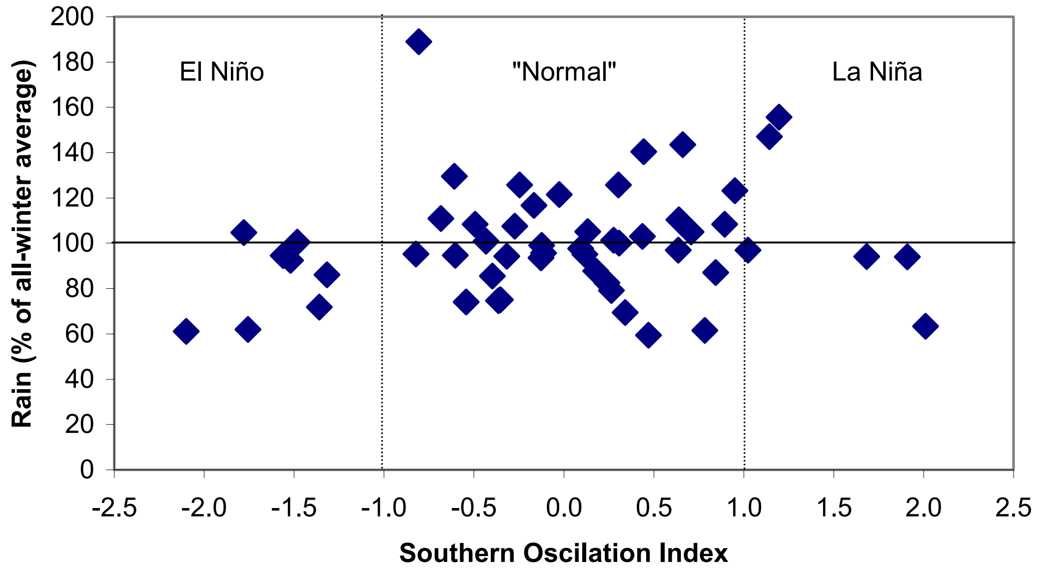


Figure 2.13: Dargaville winter rainfall versus Southern Oscillation Index, for individual winters between 1943 and 1999. The Southern Oscillation Index identifies El Niño (SOI less than -1) and La Niña (SOI greater than 1) conditions.

Likewise, La Niña winters can be relatively wet but they can also be drier than average. Thus the occurrence of an El Niño or a La Niña changes the "odds" of getting a dry winter, but does not provide absolute certainty for predicting winter rainfall. The situation is similar for other seasons.

Temperature

Table 2.1 shows that, on average, all seasons are warmer than normal at Dargaville when a La Niña is present. However, there are mixed results normal during an El Niño with warmer summers and cooler winters. There are insufficient temperature monitoring stations with records of 50 years or more in the Kaipara and Far North districts to enable us to produce average temperature maps for El Niño and La Niña years analogous to the rainfall maps in Figures 2.11 and 2.12. However, New Zealand temperature analyses undertaken by Mullan (1995) indicate this pattern of relatively warm La Niñas and El Niño summers and relatively cool El Niño winters is likely to occur across most of the Kaipara and Far North districts.

As already discussed for rainfall, there is considerable variation in temperature between individual El Niño or La Niña events. Figure 2.14 illustrates this for Dargaville winter temperatures for individual years since 1943, separated into El Niño, "normal", and La Niña situations.

Table 2.1: Average temperature differences (°C) from normal (1961-1990) for La Niña, "normal", and El Niño seasons, at Dargaville. The table is based on data from 1943 to 1999.

	Summer	Autumn	Winter	Spring
La Niña	+0.3	+0.4	+0.4	+0.5
Normal	0.0	0.0	0.0	0.0
El Niño	+0.3	0.0	-0.3	0.0

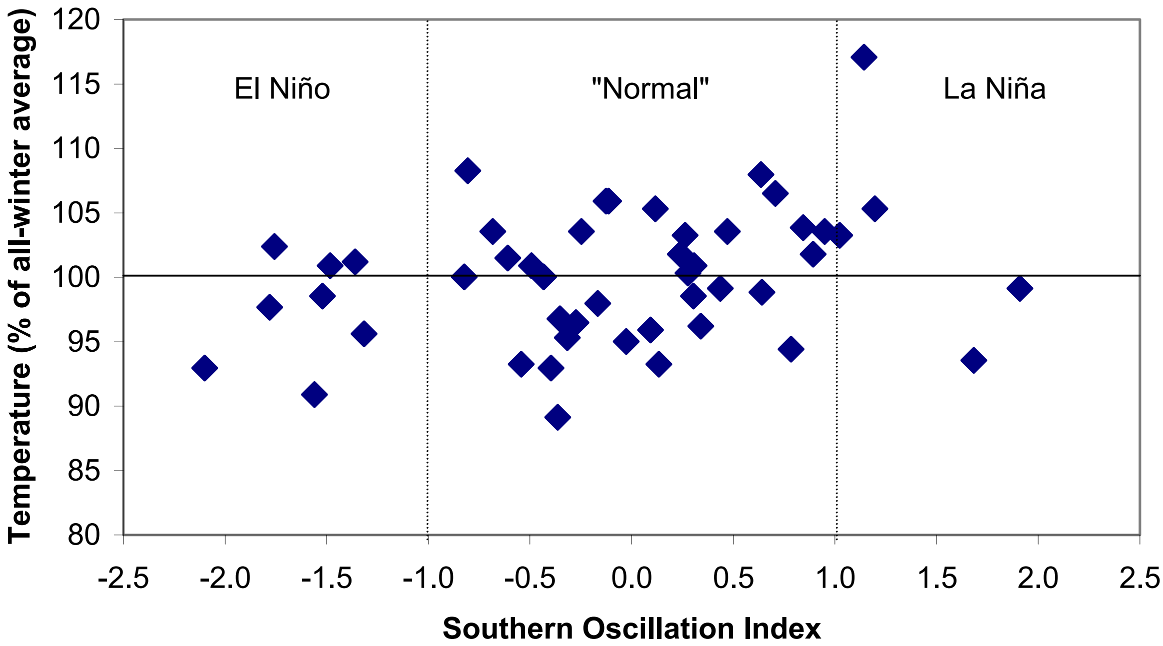


Figure 2.14: Dargaville winter temperature versus Southern Oscillation Index, for individual winters between 1951 and 2000.

2.4 Climate Shifts - The Interdecadal Pacific Oscillation

Recent research (Salinger and Mullan 1998, 1999) shows that long-term shifts occur in New Zealand's climate once every 20-30 years, caused by large-scale changes across the whole Pacific region (the Interdecadal Pacific Oscillation or IPO). Around 1977 there was a shift to more prevalent west to southwest flows over New Zealand, with increased rainfalls in the south and west of the South Island and reduced rainfall in the north of the North Island. This shift persisted through to about 1998.

The New Zealand-wide analysis undertaken by Salinger and Mullan (1999) suggests that the Kaipara and Far North district rainfalls were lower for the period 1979 - 98 compared to the period 1951 – 77. The average temperatures across New Zealand were higher in the 1979 – 98 period, in line with the long-period trend discussed in the next section.

Table 2.2: Percentage difference in average rainfall between the period 1951-77 and the period 1979 – 98, for two recording sites in or near the Kaipara and Far North districts.

Location	**Rain: (1979-98) - (1951-77)**
Dargaville	-3%
Kaitaia	-6%

Table 2.2 shows changes in the average rainfall measured at two sites in or near the Kaipara and Far North districts between these two periods. The region does indeed appear to have been somewhat drier during the 1979 - 98 period, but the rainfall difference was not large. This reflects the fact that the change in average rainfall between the two periods is small compared to the normal year-to-year variability. This is obvious from an inspection of Figure 2.2.

With respect to temperature, the latter period (1979 – 98) was on average about 0.3°C warmer than the earlier (1951 – 77) period at Dargaville, the only station in the districts with a continuous temperature record back to 1951.

2.5 Anthropogenic climate change

Global average surface temperature increased by about 0.6°C during the twentieth century. Most of the observed warming since 1950 is likely to have been due to the increase in greenhouse gas concentrations caused by fossil fuel use and other human activities (IPCC, 2001). Larger global climate changes are likely during the coming century (IPCC, 2001). This section provides some guidance on the expected effect of these global changes on the climate of the Kaipara and Far North districts.

Changes in the Kaipara and Far North districts through the 20th Century

Temperatures averaged across the whole of New Zealand increased by about 1.1°C over the 120 years between 1861-70 and 1981-90 (Salinger *et al.*, 1996). In line with the global findings discussed above, at least part of this change is probably due to increasing greenhouse gas concentrations in the atmosphere. The year 1998 was the warmest in New Zealand since climate observations began in the 1860s. While rainfall patterns and amounts across New Zealand have varied from decade to decade due to the "climate shifts' discussed in the previous section, no clear long-term trends have yet been identified in New Zealand rainfall which can be unambiguously attributed to global greenhouse gas increases.

The longest continuous temperature record archived from the Kaipara and Far North districts is from Dargaville and extends back only to 1943. This is shown in Figure 2.1. The best-fit linear trend to this data is a warming of 0.15°C per decade, which is consistent with the general warming trend across New Zealand as a whole. However, there are quite large statistical uncertainties in calculating long-term trends from individual stations such as Dargaville, because of the significant natural year-to-year variability in temperature. Long-term trends can generally only be unambiguously identified by averaging together records from many temperature measuring stations.

Continuous rainfall records from Dargaville extend back to 1943 also. The Dargaville observations show significant year-to-year and decade-to-decade rainfall changes, but no clear century-scale trends. This is consistent with the discussion above for New Zealand as a whole.

Expected Climate Changes in the 21st Century

NIWA scientists have recently published updated scenarios on how New Zealand's climate is likely to change through the coming century due to continuing global emissions of greenhouse gases (Mullan et al., 2001). Predictions of future greenhouse gas concentrations contain significant uncertainties, since emissions will be influenced by political, social and economic changes. The models used to predict climate changes due to specified emission scenarios also contain uncertainties, especially when they are scaled down to make regional or local predictions[1].

The NIWA climate scenarios assume a 1% per annum increase in equivalent carbon dioxide concentrations[2], and specified emissions of aerosols (small particles which offset some of the warming effect of greenhouse gases). These greenhouse gas increases lie near the centre of the range of plausible emission scenarios developed by the Intergovernmental Panel on Climate Change. NIWA developed a range of predictions for 2030 to take account of climate model uncertainties, by considering the second highest and second lowest predictions from 6 different global climate models. These are shown in Figure 2.15.

The expectation from these models is a warming of between about 0.7°C and 0.9°C in the Kaipara and Far North districts between the 1980s and 2030s. Another general expectation from the models is that rainfall will increase in the west of New Zealand and decrease in the east, due to enhanced westerly air flows. The expected rainfall change in the Kaipara and Far North districts is a reduction of between 0-5% in annual rainfall.

Figure 2.16 shows predictions for climate changes through to the period 2070-2099, obtained by averaging predictions from four different climate models. Taking into account the differences between the different climate models, NIWA's predicted changes between the 1980s and 2080s in the Kaipara and Far North districts are:

- Annual mean temperature: An increase of 1.8°C to 2.2°C.
- Annual mean rainfall: A decrease of 1.6 to 9.0%.

Another important change is that as the climate warms, there is a potential for periods of heavy rainfall to become even more intense. More research is required on this, but predictions for Australia and New Zealand from one paper (Whetton *et al*., 1996) range from no change to a fourfold increase in the frequency of heavy rainfall events by 2070.

Other climate changes expected in the Kaipara and Far North districts through the coming century include a decrease in the number of frosts, an increase in the number of very hot days, and (possibly) an increase in the frequency or intensity of drought conditions. Research

[1] The methods used to develop New Zealand regional climate change predictions from large-scale global climate modelling results are explained in the paper by Mullan *et al*. (2001).
[2] "Equivalent" carbon dioxide emissions take account of other greenhouse gases as well, such as methane and nitrous oxide

on the likely local impacts of global climate changes is continuing, and should provide more quantified information on the likely changes in heavy rainfalls and other climate extremes.

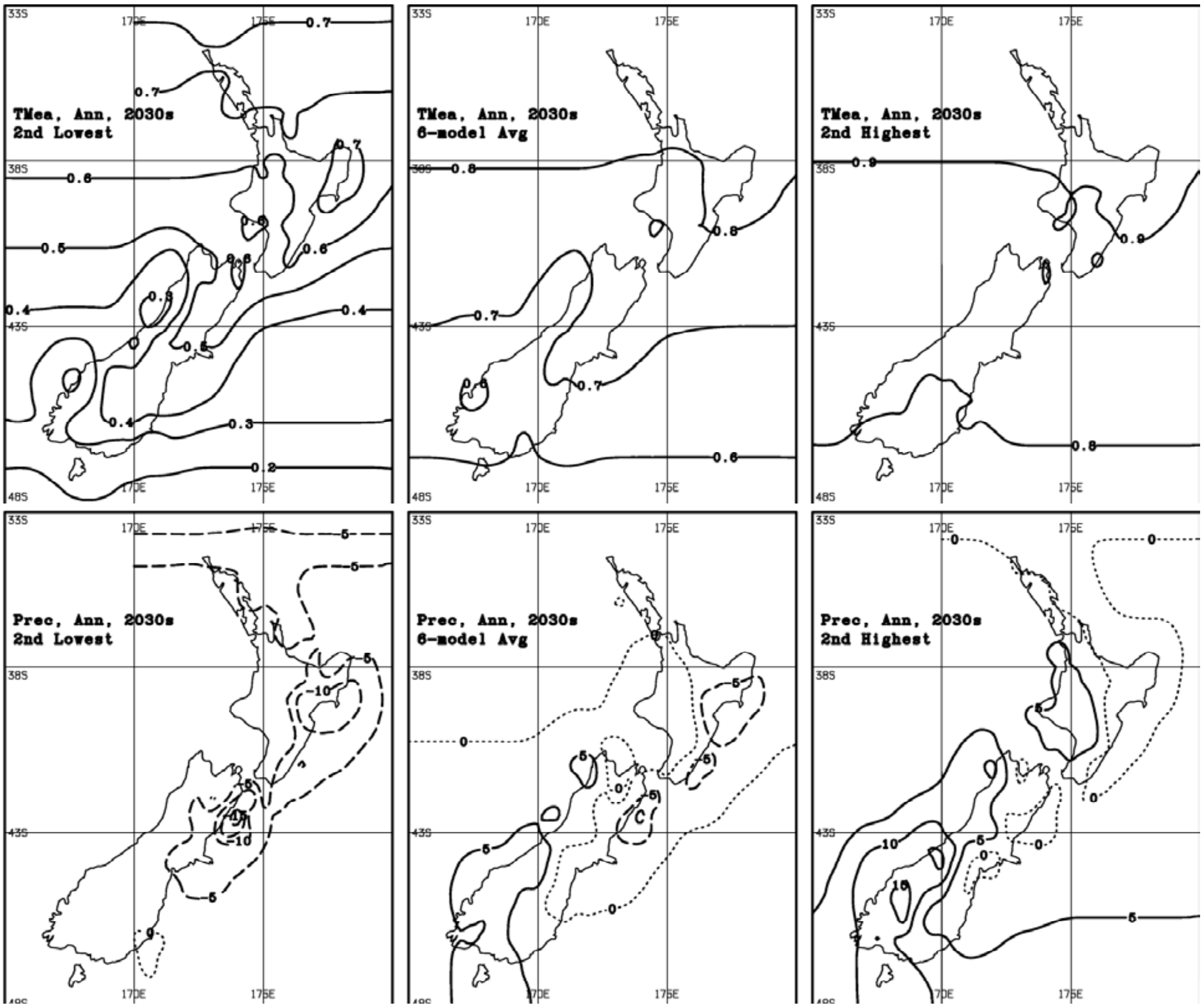
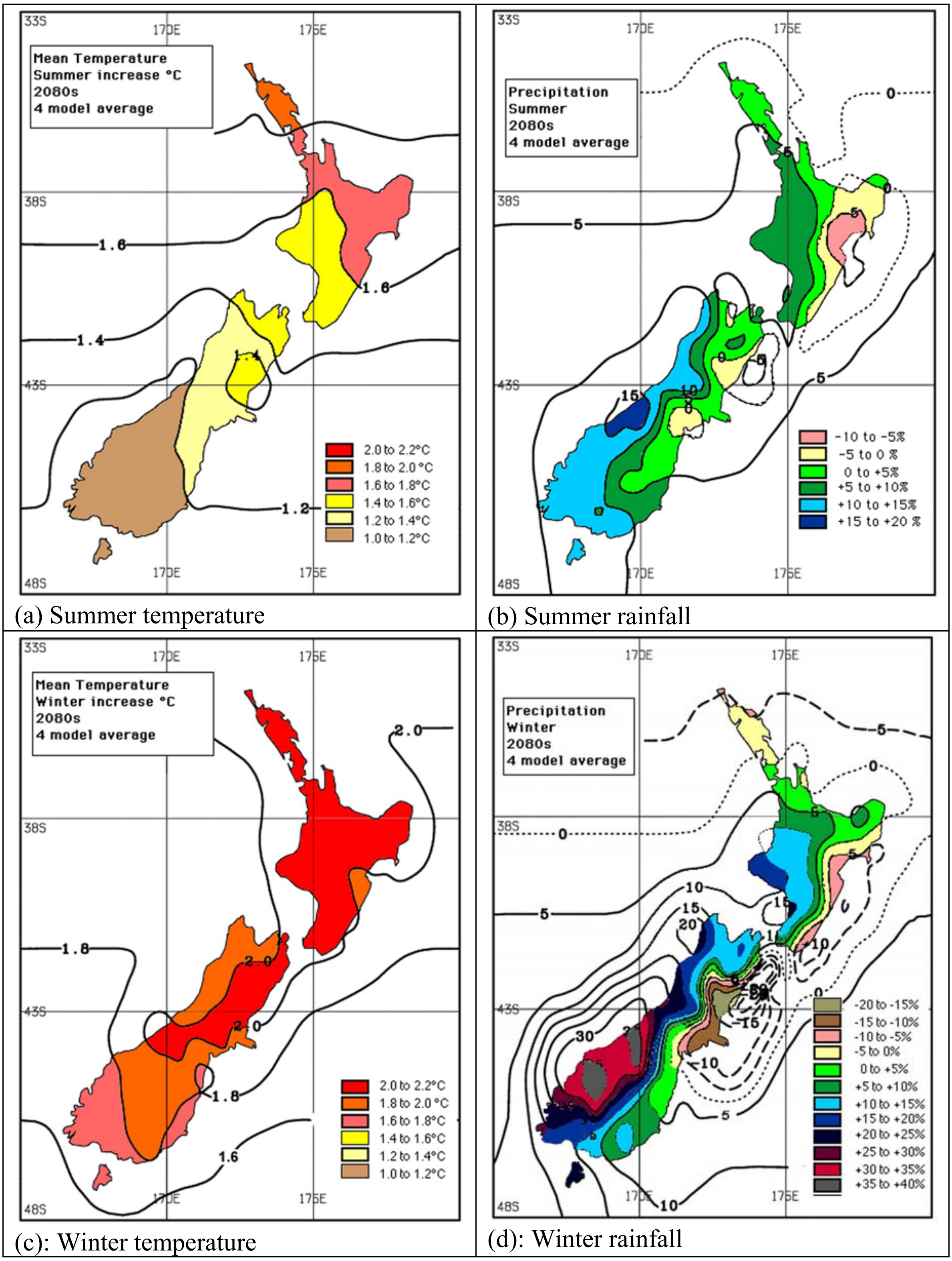


Figure 2.15: Scenarios for change in annual mean temperature (top) and annual mean precipitation (bottom) between the 1980s and the 2030s. The maps in the left, middle and right columns are the second lowest, average and second highest predictions, respectively. These maps result from running several global climate models under the assumption that global carbon dioxide concentrations will increase at a rate of 1% per year.



(a) Summer temperature

(b) Summer rainfall

(c): Winter temperature

(d): Winter rainfall

Figure 2.16: "Central" scenario for changes in New Zealand climate between now and the 2080s.

3. Derivation of the climate maps

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Craig Thompson, *NIWA, Private Bag 14-901, Kilbirnie, Wellington*

The spatial variation of the rainfall, growing degree days, soil moisture deficit and air temperature maps was determined using a thin-plate smoothing spline interpolation (Hutchinson, 1995). In general terms, this is a technique for filling in the gaps between locations where data are available, using geographic variables such as location (latitude and longitude) and elevation above sea level to aid the interpolation. Specifically, a thin-plate smoothing spline is a surface that is fitted to the data with some error allowed at each data point, so the surface can be smoother than if the data were fitted exactly. A single parameter controls the smoothing and is normally chosen to minimise the mean square error between the actual values at the stations and their values predicted by all the other stations. That is, each station is omitted in turn from the estimation of the fitted surface and the mean error is found. This is repeated for a range of values of the smoothing parameter and its value, which minimises the mean error. The smoothing parameter value associated with the minimum mean error is taken to give the optimum smoothing. In fitting the rainfall, growing degree days, soil moisture deficit and air temperature data, each climate station was weighted according to its record length during the period 1970-2001 (stations with long record lengths were weighted more heavily than stations with short record lengths) and the model was optimised so that the predictive error was relatively small. In the alpine regions, where there are fewer stations, there will be a higher degree of uncertainty in the estimates, despite spline dependence with topography, than in low-land regions where more data are available.

The frost maps were derived using a combination of climate station minimum air temperature data and infrared radiance data from National Oceanic and Atmospheric Administration (NOAA) weather satellites. Infrared data at 1 km grid resolution were obtained for several cold cloud-free winter nights for the Kaipara, Far North, and neighbouring districts. The average winter radiances at the climate station locations were statistically related to the average date of the first and last air frosts at the stations. These dates are the dates when the minimum air temperature first measures less than 0 °C (first frost) and when the minimum air temperature last measures less than 0 °C (last frost). The regression relationship developed at the station locations is used to estimate first and last frost dates over the whole district, at the grid resolution of the satellite data. Lastly, the maps are linearly interpolated to the 1:250,000 grid scale.

In order to assess the viability of certain crops, information is required on the frequency of extreme climate events such as droughts, out of season frosts or unusually low growing degree days totals, as well as information on average conditions. For this reason, information about the natural variability of the present climate of the Kaipara and Far North districts has been included in the form of mapping upper or lower quintiles of selected climate features. The upper quintile is the value which is on average equaled or exceeded once in every five years. The lower quintile is the value which is on average equaled or exceeded four in every five years. Using spring rainfall as an example, the upper quintile represents the high rainfall total exceeded in one fifth of the years from which the climate information used in the mapping was collected. Likewise, the lower quintile is the value below which the spring rainfall totals have fallen for one fifth of the observation years.

4. Description of the climate variables and their main patterns

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This section describes the main patterns of the climate maps produced for the Kaipara/Hokianga area. Table 4.1 lists all the climate maps and gives them identifier numbers, which will be referred to in this section. The maps can be viewed by clicking on the associated hyperlink.

Table 4.1: List of climate maps produced for the Kaipara/Hokianga region.

Map identifier	Map description
1	Location map
2	Lower quintile summer rainfall total
3	Mean summer rainfall total
4	Upper quintile summer rainfall total
5	Lower quintile autumn rainfall total
6	Mean autumn rainfall total
7	Upper quintile autumn rainfall total
8	Lower quintile spring rainfall total
9	Mean spring rainfall total
10	Upper quintile spring rainfall total
11	Lower quintile frost-free period
12	Mean frost-free period
13	Upper quintile frost-free period
14	Lower quintile annual growing degree days base 10°C
15	Mean annual growing degree days base 10°C
16	Mean number of days of soil moisture deficit in summer
17	Upper quintile number of days of soil moisture deficit in summer
18	Mean number of days of soil moisture deficit in autumn
19	Upper quintile number of days of soil moisture deficit in autumn
20	Mean temperature in September
21	Mean temperature in October
22	Mean temperature in November
23	Mean temperature in December
24	Mean temperature in January
25	Mean temperature in February
26	Mean temperature in March
27	Mean temperature in April
28	Mean temperature in May
29	Wind speed, frequency, and direction

4.1 Rainfall

Lower quintile, mean, and upper quintile seasonal rainfall has been mapped for the Kaipara and Hokianga area (Maps 2 through 10). In summer, rainfall is on average around 400 to 500 mm in the Parataiko and Tutamoe Ranges, decreasing to around 300 mm in the foothills of these and the Maungataniwha Ranges (Map 3). Summer rainfall around the Hokianga Harbour is typically around 250 to 300 mm (Map 3). There is a low rainfall area around Dargaville and south to the Kaipara Harbour. In this area, the average summer rainfall is around 200 to 250 mm (Map 3), but once in every five years, on average, it may be in excess of 350 mm (Map 4) or as low or lower than 100 mm (Map 2).

Rainfall in autumn is higher than in summer, on average, as is shown in the comparison of Map 3 and Map 6. The area from Dargaville south is still relatively dry, with an average rainfall of between 250 and 350 mm (Map 6). Once in every five years, on average, the autumn rainfall will exceed around 400 mm in this area, however (Map 7). The mountains can receive in excess of 850 mm in autumn (Map 7), although the average totals are typically around 600 mm (Map 6). On average, once in every five years the autumn rainfall in the mountains can be as low or lower than around 450 mm (Map 5).

Spring rainfall totals around the Hokianga Harbour average around 300 to 350 mm increasing to between 350 and 400 mm towards Kaikohe and at Umawera (Map 9). Once in every five years, on average, spring rainfall around the Hokianga Harbour can be less than 250 mm (Map 8) or more than 400 mm (Map 10), though. Spring rainfall near Dargaville is normally in the 250 to 300 mm range (Map 9), which is similar to the rainfall in autumn. Around Lake Mokeno on the Pouto Peninsula spring rainfall is typically lower than at Dargaville, at around 200 to 250 mm (Map 9) and it is as low or lower than 150 mm once in every five years, on average (Map 8).

4.2 Frost-Free Period

The length of the frost-free period is defined as the number of consecutive days with minimum air temperatures above 0 °C starting from the last frost of the year. Frosts in the Hokianga/Kaipara region are quite rare but do occur on occasion and tend to be more prevalent at high elevations where the air temperature is cooler, in shaded forested areas, and in confined valleys where sinking cold air can pool and stagnate. The inland valley between Taheke and Kaikohe, through which the Punakitere River flows, is an example of this. Map 12 shows that the frost-free period for this broad valley is typically around 350 to 400 days, while the surrounding hills typically have around 600 consecutive days without frosts. Once in every five years, on average, the length of the frost-free period does not exceed 300 to 350 consecutive days in this valley (Map 11), although it can also exceed 450 days on occasion (Map 13). The mouth of the Hokianga Harbour very rarely gets a frost, with an average frost-free period in excess of 1000 days (Map 12). In contrast, the frost-free period for the area east of the Wairoa River is typically around 300 days (Map 12) and is on average less than 250 days once in every five years (Map 11).

4.3 Growing Degree Days

The amount of heat above a base temperature (in this case 10 °C) accumulated during a day is termed the degree day accumulation (Edey, 1977). Growing degree days are the accumulated degree days for a specified period, for example over a 12 month growing season (September – August). Map 14 shows the growing degree days total which is on average equaled or exceeded four in every five years. In other words, once in every five years, on average, the growing degree days total is this low or lower. Map 14 shows that the lower quintile annual degree days are still quite high all over the Hokianga/Kaipara region. For example, the Parataiko and Tutamoe Ranges receive at least 1100 growing degree days four in every five years, while the Hokianga Harbour gets at least 1700 (Map 14). The average annual growing degree days for the area as a whole is around 1700 (Map 15), with the Umawera area typically receiving 1900 to 2000 annual growing degree days (base 10) and the Dargaville area receiving around 1800 units (Map 15).

4.4 Soil Moisture Deficit

Soil moisture is calculated from the daily water balance of rainfall, evapotranspiration and runoff (Porteous *et al*., 1994). The daily water balance keeps track of water (rainfall) entering the pasture root zone in the soil, and being lost from this zone by evapotranspiration or use of water by the plants. The balance is done for an average soil type where the available water capacity (the amount of water in the soil 'reservoir' that plants can use) is taken to be 150 mm. When there is a surplus of rain and this reservoir of water overflows, the excess water is assumed to be lost from the reservoir, and is therefore deleted from the water balance. After the overflow, the reservoir is assumed to return to field capacity in a day or two, depending on how large the surplus was. Evapotranspiration is assumed to continue at its potential rate until about half of the water available to plants is used up, whereupon it decreases, in the absence of rain, as further water extraction takes place. A day of soil moisture deficit occurs when the actual rate of evapotranspiration is less than potential. In the water balance, this is taken to be when half the available water has been used up, at which point initial or insipient wilting is likely to occur. Evapotranspiration is assumed to cease if all the available water is used up.

Map 16 shows the mean summer soil moisture deficit, represented as the mean number of days of deficit for the season. There is a general trend of lower soil moisture deficit in the mountains and higher deficit in the low elevation areas. Soils south of Dargaville are typically in deficit for 40 – 45 days during the summer. Once in every five years, on average, this area can have more than 65 days of soil moisture deficit in summer (Map 17), however. Around the Hokianga Harbour there are typically around 35 days of soil moisture deficit in summer (Map 16), while in autumn there are usually around 10 to 15 days (Map 18). The Dargaville area and Pouto Peninsula can receive in excess of 25 days of soil moisture deficit in autumn on average once in every five years (Map 19), though the normal number of days of deficit for autumn for this area is around 10 to 15 days (Map 18).

4.5 Air Temperature

The mean air temperature around the Kaipara/Hokianga region in September is 12 to 13 degrees for low elevation areas and around 10 degrees in the mountains (Map 20). By

October, the mean temperature in the low areas is now around 14 to 15 degrees (Map 21) and by November it has warmed further to between 15 and 17 degrees in many of the lowland places (Map 22). Meanwhile the higher elevation areas have warmed to an average temperature of around 13 °C. In summer (December – February) mean temperatures for the region as a whole are about 18 °C. The warmest summer temperatures are in February near Taheke where the mean daily air temperature is 20 to 21 °C (Map 25), while the coolest summer temperatures are in December on top of the mountain ranges where the mean daily temperature is still around 14 degrees (Map 23). Mean March air temperatures are slightly cooler than those in February with temperatures of between 18 and 19 degrees in and around the Hokianga Harbour and Dargaville (Map 26). By April, these areas have mean air temperatures of around 16 to 17 degrees (Map 27) and by May the mean temperatures are between 13 and 15 °C in the lowland areas (Map 28).

4.6 Wind Speed and Direction

Mean wind speed and direction has been represented by a number of wind roses on Map 29. Larger versions of the wind roses are also shown in the Appendix. A wind rose has the following features: the scale on each of the axes represents the percentage frequency of winds from the respective direction (north, south, east, west etc.) and the colours of the rose represent the mean speed of wind from the respective direction. The wind rose at Dargaville shows that the wind is from the west 27 % of the time, from the southwest 14 % of the time and from the east 14 % of the time. The mean wind speed from the east is almost always light (between 1 and 19 km/hr), while winds from the west can sometimes (about 1 % of the time) reach speeds of more than 39 km/hr. The wind rose for Kaitaia has a similar shape to that at Dargaville, with westerlies, southwesterlies and easterlies dominating, but the mean speeds are much more frequently greater than 20 km/hr. In stark contrast to these locations Waitemarama receives frequent strong winds from the northeast all the way around to the west and to the south.

5. Additional climate information

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In addition to the climate maps, five tables of additional climate information have been prepared. These tables show information on sunshine hours, probability of frost, first and last frost dates, soil temperatures, and cool season chill units for locations within or near the Kaipara and Far North districts.

5.1 Sunshine Hours

Long records of sunshine data are quite rare in New Zealand, compared with other climate data. Table 5.1 shows the sunshine hours for five locations within or near the Kaipara and Far North districts. The data are broken down by season and show the mean, lower and upper quintile values. The summer season typically has the highest sunshine hours, with Dargaville averaging 610 hours (around 6.8 hours of bright sunshine per day). Once in every five years, on average, the number of summer sunshine hours exceeds 697 hours (approximately 7.7 hours per day) or is less than 544 hours (approximately 6.0 hours per day). In winter, the mean, upper and lower quintile values for Dargaville are 346, 382 and 299 hours, or around 3.8, 4.2 and 3.3 hours of bright sunshine per day.

Table 5.1: Mean, 20 percentile, and 80 percentile seasonal sunshine hours for locations within or near the Kaipara and Far North districts.

Station name	Period of Record	Statistic	Spring	Summer	Autumn	Winter
Kaikohe DSIR	01/1973-02/1986	20%ile Mean 80%ile	424.5 480.7 530.5	516.9 590.1 670.7	369.7 424.6 459.8	328.6 365.5 398.8
Waipoua Forest	01/1930-02/1964	20%ile Mean 80%ile	418.6 449.5 490.1	469.9 530.4 611.1	358.5 388.3 434.5	277.8 309.9 347.3
Dargaville	02/1943-12/1998	20%ile Mean 80%ile	462.1 501.0 536.7	543.7 609.7 697.0	397.1 439.7 486.2	299.2 346.3 382.8
Kaitaia Observatory	05/1985-02/2002	20%ile Mean 80%ile	487.1 532.4 569.7	592.1 630.3 693.9	442.0 492.5 548.9	392.7 422.5 460.1
Kerikeri	09/1938-12/1973	20%ile Mean 80%ile	505.6 538.7 571.4	528.1 601.5 685.9	376.6 436.7 497.7	377.2 402.9 430.6

5.2 Probability of Frost

Table 5.2 shows the probability of receiving a frost in any month for a selection of locations throughout the northern North Island. The probabilities are obviously higher in winter, but are still relatively low even then, with the maximum probability of frost only 13.6% in Riverhead Forest in July. The probability of frosts from November through to April at all locations is less than 1%. Kerikeri only has a little over 1% chance of getting a frost in June, and this is the highest probability month.

Table 5.2: Probability of frost for every month at several locations in the north of the North Island. The numbers multiplied by 100 give probabilities as a percentage (for example, the probability of getting a frost in Kerikeri in June is 1.2%).

Station name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kerikeri	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.003	0.000	0.000	0.000	0.000
Umawera	0.000	0.000	0.000	0.000	0.011	0.061	0.061	0.022	0.007	0.000	0.000	0.000
Waipoua Forest	0.000	0.000	0.000	0.000	0.004	0.014	0.046	0.020	0.007	0.001	0.000	0.000
Dargaville	0.000	0.000	0.000	0.001	0.009	0.035	0.066	0.026	0.005	0.000	0.000	0.000
Waitangi Forest	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Glenbervie Forest	0.000	0.000	0.000	0.003	0.041	0.116	0.166	0.129	0.058	0.015	0.001	0.000
Whangarei AP	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Whangarei	0.000	0.000	0.000	0.000	0.000	0.003	0.023	0.002	0.000	0.000	0.000	0.000
Warkworth	0.000	0.000	0.000	0.001	0.001	0.020	0.040	0.011	0.001	0.000	0.000	0.000
Oyster Point	0.000	0.000	0.000	0.000	0.011	0.027	0.079	0.010	0.007	0.000	0.000	0.000
Woodhill Forest	0.000	0.000	0.000	0.002	0.005	0.040	0.074	0.031	0.003	0.001	0.000	0.000
Riverhead Forest	0.000	0.000	0.000	0.000	0.017	0.098	0.136	0.063	0.016	0.000	0.000	0.000
Whenuapai AP	0.000	0.000	0.000	0.001	0.009	0.057	0.104	0.036	0.009	0.000	0.000	0.000
Henderson	0.000	0.000	0.000	0.002	0.006	0.094	0.123	0.052	0.029	0.000	0.000	0.000
Auckland, Owairaka	0.000	0.000	0.000	0.000	0.000	0.011	0.018	0.005	0.000	0.000	0.000	0.000

5.3 First and Last Frost Dates

The mean, lower and upper quintile dates of the first and last air frosts are shown in Table 5.3, for locations within or near the Kaipara and Far North districts. Several locations have never recorded a frost and many other locations have several frost-free years. First frosts typically occur around the 19th of June for Dargaville, but can come as early as the 28th of May. Last frosts are typically around the end of July for Dargaville, but once every five years on average there can be a frost as late or later than August 22nd. Frosts are more common in forested locations like Waipoua Forest, Glenbervie Forest, Woodhill Forest, and Riverhead Forest. In Glenbervie Forest, for example, first frosts are usually around the end of May and last frosts are usually around the 19th of September.

Table 5.3: First and last frost dates at several locations in the north of the North Island. Most of these stations have several years when no frosts were recorded. Thus, both the total number of years of record and the number of years with a frost are listed. The 20th percentile, mean, and 80th percentile first frost date (FFD) and last frost date (LFD) are calculated using data from the frost years only and are only calculated at locations where the number of years with a frost is greater than one.

Station name	Lat (°S)	Lon (°E)	Length of record (years)	Number of years with a frost	20% FFD LFD	Mean FFD LFD	80% FFD LFD
Purerua	35.12	174.02	18	0	-	-	-
Kaitaia Observatory	35.14	173.26	16	0	-	-	-
Kerikeri	35.17	173.92	20	4	Jun 7 Jun 24	Jun 23 Jul 20	Jul 5 Aug 14
Waitangi Forest	35.25	174.07	52	1	-	-	-
Umawera	35.32	173.55	9	9	May 24 Jul 16	Jun 9 Jul 29	Jun 29 Aug 13
Kaikohe	35.42	173.82	28	0	-	-	-
Waiotemarama	35.52	173.42	16	0	-	-	-
Waipoua Forest	35.65	173.55	42	33	Jun 8 Jul 6	Jul 3 Jul 28	Jul 20 Aug 22
Glenbervie Forest	35.65	174.35	40	40	May 11 Aug 30	May 27 Sep 19	Jun 10 Oct 10
Whangarei	35.73	174.30	22	7	Jun 22 Jun 23	Jul 6 Jul 15	Jul 9 Jul 26
Whangarei Airport	35.77	174.37	36	1	-	-	-
Dargaville	35.95	173.83	50	42	May 28 Jul 7	Jun 19 Jul 29	Jul 10 Aug 22
Port Fitzroy	36.18	175.35	42	0	-	-	-
Leigh	36.27	174.80	35	0	-	-	-
Warkworth	36.43	174.67	31	24	Jun 14 Jul 12	Jul 3 Jul 29	Jul 20 Aug 18
Oyster Point	36.57	174.43	10	10	May 29 Jul 12	Jun 16 Jul 21	Jul 8 Aug 1
Tiri Tiri Lighthouse	36.60	174.90	21	0	-	-	-
Woodhill Forest	36.75	174.43	43	40	Jun 1 Jul 14	Jun 18 Aug 3	Jul 8 Aug 21
Riverhead Forest	36.77	174.58	15	15	May 21 Aug 7	Jun 3 Aug 18	Jun 12 Aug 31
Whenuapai Airport	36.78	174.63	43	43	May 29 Jul 11	Jun 15 Jul 30	Jul 5 Aug 21
Waiheke Island	36.80	175.10	18	0	-	-	-
Henderson, River Park	36.85	174.62	16	16	Jun 2 Jul 16	Jun 10 Aug 20	Jun 23 Sep 10
Auckland, Owairaka	36.90	174.73	51	26	Jun 13 Jul 6	Jul 1 Jul 18	Jul 16 Aug 6

5.4 Soil Temperature

The date at which the 10cm soil temperature first reaches 12ºC for three consecutive days can be used as the first sowing date for capsicum, eggplants and sweetcorn (Kerr *et al.,* 1981). Table 5.4 shows the mean, lower and upper quintile dates for locations within or near the Kaipara district. The mean sowing dates occur earlier in coastal areas than inland locations. They tend to be between late-August and early-September, but can be in early-August or in early-October once in every five years. Kaikohe has the latest mean first sowing date of the 4th of September, while at Dargaville (near the coast) the mean first sowing date for the above crops is the 25th of August.

Table 5.4: Mean, 20 percentile, and 80 percentile date at which the 10cm soil temperature first reaches 12ºC for three consecutive days for locations within or near the Kaipara and Far North districts.

Station name	Period of Record	20%ile	Mean	80%ile
Kaikohe	07/1973-12/2001	1st Aug	4th Sep	9th Oct
Dargaville	07/1972-12/1987	14th Aug	25th Aug	9th Sep
Kaitaia Observatory	07/1985-12/2001	10th Jul	4th Aug	20th Sep

5.5 Cool Season Chill Units

Exposure to cool temperatures is necessary to induce flowering in a plant (Kerr *et al*.;1981). After buds have been exposed to cool temperatures to complete the rest period, exposure to warmer temperatures stimulates growth. Mean, lower and upper quintile cool season chill units are shown in Table 5.5, for locations within the Kaipara and Hokianga study area. Accumulation of chill units is lower in coastal areas, such as Dargaville, than in inland regions. For example, by the end of September, there are on only on average 1090 accumulated chill units in this location, which is less than the mean accumulated chill units in Kaikohe by the end of August.

Based on these estimates, there are usually insufficient chill units accumulated over the May through September cool season for many pipfruit, berry and kiwifruit crop species, most of which require at least 1,500 units. Golden Queen peaches may be an exception requiring only 1,250 accumulated units.

Table 5.5: Mean, 20 percentile, and 80 percentile accumulated chill units for locations within the Kaipara/Hokianga district.

Station name	Period of Record	Statistic	May	May-Jun	May-Jul	May-Aug	May-Sep
Umawera	05/1972-09/1977	20%ile	<0	288	536	880	970
		Mean	125	436	794	1102	1312
		80%ile	248	592	988	1332	1678
Waitemarama	05/1977-09/1989	20%ile	96	310	754	1168	-
		Mean	136	415	823	1215	1554
		80%ile	200	538	913	1298	-
Kaikohe	05/1973-09/2001	20%ile	38	322	752	1134	1322
		Mean	126	454	866	1298	1582
		80%ile	243	603	1135	1526	1886
Waipoua Forest	05/1951-09/1990	20%ile	78	352	734	1048	1236
		Mean	145	472	870	1241	1478
		80%ile	228	589	1008	1394	1699
Dargaville	05/1952-09/2001	20%ile	<0	135	464	660	782
		Mean	53	284	612	922	1090
		80%ile	141	460	855	1204	1444

5.6 Climate References and Further Reading

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6. Description of the soil maps

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This section describes the soil maps produced for the Kaipara/Hokianga area. Table 6.1 lists all the soil maps and gives them identifier numbers, which will be referred to in this section. The maps can be viewed by clicking on the associated hyperlink.

Table 6.1: List of soil maps produced for the Kaipara/Hokianga region.

Map identifier	Map description
30	Soil terrains
31	Soil series, types and phases (the soil name)
32	Slope class
33	Subsoil acidity
34	Potential rooting depth
35	Soil drainage classes
36	Profile total available water

6.1 Soil Terrains

Nine soil terrains are depicted in the Atlas of Soil Information, and each terrain represents a broad division of the landscape according to the general type of soil parent material and slope. Sloping land is divided into land with slopes less than 16° (flat to rolling) and land with slopes greater than 15° (hill country and steepland). Soil terrains give a spatial framework to the soil and climate-related themes. There are over 115 soil types in the project area, but most are distributed within a single soil terrain (Map 30).

The following soil terrains are recorded:

1. Sand country (723 km^2, 21%)
2. Flood plains (372 km^2, 11%)
3. Peatland (53 km^2, 2%)
4. Downland from sedimentary rocks—most slopes <16° (31 km^2, 9%)
5. Downland from volcanic rocks—most slopes <16° (226 km^2, 7%)
6. Hill country from weathered sedimentary rocks (180 km^2, 5%)
7. Hill country from mixed crushed & sheared rocks (703 km^2, 21%)
8. Hill country and occasional steepland from volcanic rocks (660 km^2, 19%)
9. Hill country and steepland from greywacke and argillite (102 km^2, 3%).

6.2 Soil Series, Types and Phases (the Soil Name)

The soil series, type and phase provide a link to soil attributes that require consideration when investigating land-use opportunities and management requirements. The attributes (such as potential plant rooting depth) can be represented spatially because their values have been attached to soil map units. The mapped soils and names are listed in Table 6.2. For improved understanding of these soils, it is essential to refer to the published legend of soils (Cox *et al*. 1983), where soil series, type and phase are set out in suites according to parent material, and further arranged into leaching regimes.

Soils are grouped into *series* of similar soil profiles, similar temperature, moisture regime and parent material. The series is frequently given the name of a locality where it is well developed. *Soil types* within a series are defined by topsoil texture, and so textural terms are placed after the series name. *Soil phases* are an informal subdivision of soil types to reflect a soil property of potential importance to land use and management.

Soils according to soil terrains

Sand country: Sand country soils occur all the way up the coast (Map 30), and for a significant distance inland, and become older and more weathered away from the coast (Map 31). The sequence begins seaward with the very weakly developed and recent Pinaki series (86 km^2, 3%). Red Hill series occur inland from these (90 km^2, 3%) and these have just enough development to provide one of the better opportunities for land-use intensification (especially in some protected interdune basins), although subsoil acidity would need checking that it is not too low (Map 33). Tangitiki soils (256 km^2, 8%) are slightly older and show high variability over short distances, with some sites strongly podzolised ('egg cup podzols' where large kauri trees once grew). This variability would make general crop predictions unreliable. Podzols named Te Kopuru (131 km^2, 4%) occur furthest inland on the oldest dunes. These are uniformly poor in many attributes affecting the growth of deeper rooting and moisture-sensitive crops.

Flood plains: About 11% (rather high for New Zealand districts) of the project land area comprises flood plains (Map 30) and these may be well suited to some high value land uses. The poorly drained clays and peaty clays of the Kaipara soil suite are already well understood and widely used for kumara growing—with highly specialised management. The narrower flood plains of the hill country are less well understood and are generally not used for cropping. Whakapara soils from alluvium derived from sedimentary rocks dominate in the south (43 km^2, 1%), whereas Mangakahia soils from alluvium derived from volcanic terrains are mapped in the Far North (88 km^2, 3%). Although both series are well supplied with plant nutrients, they are imperfectly drained (Map 35) and may also be subject to flooding. Careful site assessments are required when considering moisture-sensitive crops.

Peatland: About 51 km^2 of Parore peaty sandy loam occurs in small valleys in the sand country (Map 31). While these soils are generally very poorly drained (Map 35) with shallow rooting depth (Map 34), they may provide growing environments for a limited range of crops.

Downland from sedimentary rocks (most slopes $<16^o$): The easy slopes in this soil terrain make it a potential area for land-use intensification or diversification. The largest contiguous area of this land is northeast of a line from Dargaville to Ruawai, and east of the Kaihu River in the Waihue Road area (Map 30). Potential plant rooting depth (Map 34) is generally about 45–60 cm in the latter area (Omu, Aponga and Mata series). The former area is dominated by Arapohue and Rockvale series from argillaceous limestone, and while both have heavy clayey subsoils, potential plant rooting (Map 34) is about 60–90 cm in Rockvale soils (34 km^2, 1%), but is shallow (25–45 cm) in Arapohue soils (36 km^2, 1%). All soils in this terrain are imperfectly drained.

Downland from volcanic rocks (most slopes <16°): Rolling slopes on basalt volcanics, together with terraces from redeposited volcanic material, offer good opportunities for crop production. Soils are naturally well supplied with plant nutrients and have good structure. While upper subsoils can be firm and plant rooting slightly restricted (Map 34), the soils do not become firmer with increasing depth (unlike soils of the sedimentary downlands). Kohumaru clay appears to provide an opportunity for land-use intensification, as does Waimatenui clay, Waiotu friable clay, and Pakotai clay (together, covering 239 km^2, 7%, Map 31). Most of this downland has imperfectly drained soils (Map 35).

Hill country from weathered sedimentary rocks: This soil terrain is underlain by stable rocks (not crushed or sheared), and they are mostly sandstones. The main soil series is Waiotira and these are moderately well drained (Map 35) and have few root restrictions above about 60 cm depth (Map 34), but may need checking for subsoil pH (Map 33). Slope generally precludes arable land uses (Map 32).

Hill country from mixed crushed and sheared rocks: This soil terrain is underlain by tectonically disturbed and finer grained sedimentary rocks (Map 30). The rock masses are mixed and unpredictable, and often subject to earthflow and gully erosion. Soils likewise form complex patterns. The Far North part of the study area has most of this terrain, and while this land has limited cropping potential (too hilly, erodible, infertile, etc.) areas of Waiotira soils are the most versatile (Map 31).

Hill country and steepland from volcanic rocks: Very large contiguous areas of Tangihua Volcanics and Waipoua Basalts exist in the middle of the project area (Map 30), and much of it is under indigenous forest. Where steep and rocky it is often scrub-covered, with limited productive potential beyond environmental protection and biodiversity preservation.

Hill country and steepland from greywacke/argillite: Greywacke covers just 102 km^2 (3%), and lies northeast of Rangiahua (Map 30). Soils are evenly divided between the Te Ranga steepland soils (39 km^2) where slope steepness (Map 32) constrains land-use options, and the hilly Marua series (45 km^2, Map 31). Marua clay loams are versatile, being moderately well drained (Map 35) and plant rooting (Map 34) is very deep (to about 90–120 cm). Rangiora clay and clay loams (20 km^2) are less versatile, being more strongly weathered on the easier greywacke slopes, imperfectly drained (Map 35), and have more restricted plant rooting (although still moderately deep at 60–89 cm, Map 34).

Table 6.2: List of soil names found in the Kaipara/Hokianga region.

Soil code	Soil series	Soil type	Soil phase	Area (km^2) of series
Water bodies				54
Town				4
BRock (sand dune)				151
AE	Autea	clay loam		231
AEH	Autea	clay loam	hill	
AEe	Autea	clay		
AEeH	Autea	clay	hill	
AK	Awapuku	clay loam		42
AKH	Awapuku	clay loam	hill	
AP	Aponga	clay		76
APH	Aponga	clay	hill	
AR	Aranga	clay		23
AU	Arapohue	clay		36
AUH	Arapohue	clay	hill	
AUd	Arapohue	clay	deep	
AW	Awarua	clay		2
AY	Awanui	clay		9
AYH	Awanui	clay	hill	
C1	C1 complex			1
C8	Onetai			26
C9	Waimamaku	bouldery complex		78
C9H	Waimamaku	bouldery complex	hill	
HI	Hihi	clay		15
HK	Hukerenui	silt loam		25
HKH	Hukerenui	silt loam	hill	
HKa	Hukerenui	sandy loam		
HKgH	Hukerenui	gravelly silt loam	hill	
HKr	Hukerenui	silt loam		
HU	Hunoke	clay		1
HUH	Hunoke	stony clay loam	hill	
KB	Kiripaka	silt loam	bouldery	9
KBe	Kiripaka	bouldery silt loam	bouldery	
KM	Kohumaru	clay		13
KN	Konoti	clay		7
KNH	Konoti	clay loam	hill	
KNr	Konoti	clay		
KO	Kamo	clay loam		3
KP	Kaipara	clay loam		194

Soil code	Soil series	Soil type	Soil phase	Area (km^2) of series
KPy	Kaipara	peaty clay loam		
KR	Kara	silt loam		18
KRa	Kara	sandy loam		
KRe	Kara	clay		
KRp	Kara	silt loam	pan	
KT	Katui	clay loam		47
KTH	Katui	clay loam	hill	
MA	Mata	clay loam		5
MF	Mangakahia	clay		88
MFm	Mangakahia	clay loam	mottled	
MN	Mangonui	clay		4
MRH	Marua	clay loam	hill	45
MRuH	Marua	clay loam	hill	
MTH	Motatau	clay	hill	16
OA	Okaka	clay		57
OAH	Okaka		hill	
OC	Otangaroa	clay		<1
OD	Otaha	clay		<1
OG	Otonga	peaty clay loam		2
OK	Okaihau	clay		11
OM	Omu	clay loam		26
OMH	Omu	clay loam	hill	
ON	Omanaia	clay loam		47
ONH	Omanaia	clay loam	hill	
ONe	Omanaia	clay loam		
OW	Ohaeawai	silt loam		14
OWb	Ohaeawai	silt loam	shallow, bouldery	
PC	Pakotai	clay		8
PD	Puketitoi	sandy loam		30
PDH	Puketitoi	sandy loam	hill	
PG	Pungaere	clay	gravelly	<1
PK	Papakauri	silt loam		<1
PM	Pukenamu	silt loam		<1
PMH	Pukenamu	silt loam	hill	
PN	Pinaki	sand		86
PNH	Pinaki	sand	hill	
PPH	Pokapu	silt loam	gravelly	3
PR	Parahaki	fine sandy loam		<1
PTH	Paretaiko	silt loam	hill	13
PZ	Parore	peaty sandy loam		51
RA	Rangiora	clay		20

Soil code	Soil series	Soil type	Soil phase	Area (km^2) of series
RAH	Rangiora		hill	
RL	Red Hill	sandy loam		90
RLH	Red Hill	sandy loam	hill	
RLa	Red Hill	sandy clay loam		
RLaH	Red Hill	sand	hill	
RP	Riponui	clay		16
RPa	Riponui			
RT	Ruatangata	clay		5
RV	Rockvale	clay		34
RVe	Rockvale	clay	coarse subsoil	
TC	Takahiwai	clay		27
TEK	Te Kopuru	sand		131
TES	Te Kie	clay loam	steep	247
TErS	Te Kie	reddish clay loam	steep	
TF	Te Tio	clay loam		41
TFH	Te Tio	clay loam	hill	
TMH	Taumata	clay loam	hill	29
TO	Tutamoe	clay		111
TRS	Te Ranga	clay loam	steep, stony	39
TRuS	Te Ranga			
TT	Tangitiki	sandy loam	sand	256
TTH	Tangitiki		hill	
TU	Takitu	clay loam	gravelly	10
TUH	Takitu	gravelly clay loam	hill	
WBH	Whaka	clay loam	hill	<1
WCS	White cone	sandy clay loam	steep	7
WE	Waitemata	silt loam		2
WF	Whakapara	sand		43
WFm	Whakapara	clay	mottled	
WK	Wharekohe	silt loam		54
WKa	Wharekohe	sandy loam		
WKap	Wharekohe	sandy loam	pan	
WKfp	Wharekohe	fine sandy loam	with pan	
WN	Whirinaki	clay loam		74
WNH	Whirinaki	clay loam	hill	
WO	Whareora	clay loam		1
WT	Whatoro	clay		45
WTH	Whatoro	clay	hill	
WU	Waipuna	clay		13
YC	Waiotira	clay loam		201
YCH	Waiotira	clay loam	hill	

Soil code	Soil series	Soil type	Soil phase	Area (km^2) of series
YCe	Waiotira	clay		
YCeH	Waiotira	clay	hill	
YF	Waipapa	clay		<1
YK	Waikare	silt loam		23
YKH	Waikare	silt loam	hill	
YN	Waimatenui	clay		186
YNH	Waimatenui	clay	hill	
YO	Waiotu	clay		33
YOH	Waiotu	friable clay	hill	
YP	Waipoua	clay		59
YPH	Waipoua	clay	hill	
YR	Wairiki	clay loam		9
YU	Waipu	clay		10
YUy	Waipu	peaty silt and clay		

6.3 Slope Class

Slopes of New Zealand Land Resource Inventory (NZLRI) polygons are recorded as one or a complex of two slope classes defined by an upper and lower slope angle and expressed in degrees of slope: A (0–3°), B (4–7°), C (8–15°), D (16–20°), E (21–25°), F (26–35°), G (>35°). Each class is important for particular aspects of land management, for example, the use of wheeled vehicles is appropriate up to and including slope C; discable hill country using tracked vehicles lies in class D; non-discable hill country is in class E. Cultivation for cropping is not feasible for E slopes and steeper. Consideration of slope underpins almost every land-use and management decision.

Slopes are generally subdued, especially in the Kaipara area (Map 32). The only significantly steep country is where Tangihua Volcanics form craggy mountain slopes between Waimamaku and Omanaia, and in the greywacke hills northeast of Mangamuka. Seventy percent of the area has slopes less than 20°, and these can be cultivated (although with a significant risk of erosion and soil loss on slopes greater than about 12°).

6.4 Subsoil Acidity (minimum pH over the depth range 0.2-0.6 m)

Soil acidity is a measure of whether the soil solution is acid, neutral or alkaline, and is expressed in pH units. Where solutions contain equal concentrations of H^+ and OH^- ions, pH 7 is neutral; pH values <7 indicate acidity, and pH >7 indicate alkaline conditions. Because the pH scale is logarithmic, pH 6 is 10 times more acid than pH 7, and so on. Classes are given for the 20–60 cm soil depth range, because adverse pH can have a significant effect on root growth at these depths and pH is very difficult to alter below the topsoil. The pH affects plant growth largely through its influence on nutrient availability, the presence of toxic ions, and soil biological composition including the amount and type of bacteria present. For example, several essential elements such as iron, manganese and zinc tend to become less available as the pH is raised to >7.5. Molybdenum availability, on the other hand, is higher at the higher pH levels. At pH values below 5.0 to 5.5, aluminium, iron and manganese may be soluble in sufficient quantities to be toxic to the growth of some plants. Although most plants tolerate a fairly wide range of pH, each has a narrower range for optimum growth, and this is not the same for all soils.

Subsoil pH over much of the project area is moderately low to very low (over nearly 70% of the land area, Map 33). Amelioration of low subsoil pH is usually impractical, so taking account of existing subsoil pH becomes important when crop/soil matching. Soils with a high cation exchange capacity, such as those rich in clay (as are many soils in Northland) or organic matter, have greater reserves of acidity or alkalinity than do soils with lower cation exchange capacity such as sandy soils. Consequently, their pH values are less easily changed and are said to be 'well buffered'. Such soils would therefore require significant additions of lime to raise pH levels.

A review of soils of the project area according to the New Zealand soil Classification (Hewitt 1998) reveals a 'pH alert' list (Table 6.4) of soils with likely low or very low pH in some part of their subsoils. The list is comprehensive, but not necessarily exhaustive.

Table 6.3: pH classes for soils in Kaipara/Hokianga region.

pH class	**Range of min pH**	**Description**	**Notes on plant growth relationships**	**Project area (km^2,%)**
1	7.6–8.3	High	May seriously interfere with plant growth	0, 0
2	6.5–7.5	Moderately high	May depress growth, possible deficiencies of some nutrients may be induced	0, 0
3	5.8–6.4	Near neutral	Satisfactory pH for many plants.	640, 19
4	5.5–5.7	Moderately low	Earthworm numbers, microbial activity, and nutrient cycling may be restricted	1177, 35
5	4.9–5.4	Low	Al often toxic and probably limits growth	922, 28
6	4.5–4.8	Very low	Both Al and Mn are likely to be toxic	441, 13
7	2.5–4.4	Extremely low	Both Al and Mn are probably toxic	0, 0
B	Not rated (bare sand)			151, 5

Table 6.4: Subsoil pH 'alert' list.

Soil names and symbols	Subsoil pH observations
Otonga peaty clay loam (OG)	The organic material to a depth of 60 cm from the soil surface, or to its base if shallower, has pH of 4.5 or less throughout the major part
Waiotira series (YC, YCe, YCeH, YCH) Waipu peaty silt loam and peaty clay (YUy) Takahiwai clay (TC)	pH of 4.8 or less in some part between 20 and 60 cm from the mineral soil surface, or, a horizon within 60 cm of the mineral soil surface with pH less than 4.8
Mangonui clay (MN) Parataiko silt loam, hill soils (PTH) Waipoua clay (YP) & Waipoua clay, hill soils (WPH)	pH of less than 5.1 in the major part of the B horizon to 60 cm from the mineral soil surface
Tutamoe friable clay (TO) Aranga clay (AR)	pH of less than 5.1 in some part of the B horizon to 60 cm from the mineral soil surface
Waipu clay (YU) Kara series (KR, KRa, KRe, KRp)	pH of less than 5.5 in some part from the base of the A horizon to 60 cm from the mineral soil surface
Hukerenui series (HK, HKa, HKgH, HKH, HKr) Wharekoe series (WK, WKa, WKap, WKfp) Aponga series (AP, APH) Rangiora series (RA, RAH) Okaka series (OA, OAH) Waikare series (YK, YKH) Puketitoi series (PD, PDH) Riponui series (RP, RPa) Tangitiki series (TT, TTH) Omu series (PM, OMH) Pukemanu series (PM, PMH) Red Hill series (RLa, RLaH) Autea series (AE, AEe, AEeH, AEH) Awanui series (AY, AYH) Mata clay (MA) Rockvale series (RV, RVe) Te Tio clay loam (TFH) Taumata clay loam (TMH) Wairiki clay loam & silt loam (YR)	All soils belonging to the Ultic Soil Order are on 'pH alert', because an accessory property of the Order is that KCl-extractable aluminium levels in B horizons are usually more than 1 cmol (+)/kg and Al-toxicity is possible. Podzols likewise are 'acid soils' and a single representative occurs in the project area (Te Kopuru sand – TEK)

6.5 Potential Rooting Depth

Potential rooting depth (PRD) is the depth to a layer that may physically or chemically impede root extension. It is the depth of soil that can be potentially exploited by the rooting systems of most common crops, providing a medium for root development, water and nutrient uptake. The presence of toxic chemicals, such as high levels of aluminium, may also limit root depth, and chemical criteria can be used to determine PRD when critical limits of the chemical species are known (such as using pH values below 5.5). Soil physical characteristics known to influence root development are penetration resistance, aeration, water retention, sharp contrasts in soil properties including pans, waterlogged horizons, stiff and slowly permeable clays, and stony horizons with few or no fines <2 mm. PRD can be assessed by measurements of penetration resistance or by packing density estimates. A penetration resistance of >3000 kPa (Taylor *et al*., 1966) and a packing density critical limit of 1.85 Mg m^{-3} define the potential rooting depth (Jones, 1983).

Plant root penetration is seriously restricted in Kaipara soils (because of poor drainage) and Te Kopuru soils (because of subsoil pans and poor drainage), with root extension being limited to the soil volume above 45 cm (Map 34). These soils account for most of the shallow to very shallow rooting soils. Soils in class 4 (20% of the land area) may restrict root extension in some tree crops, and a large area (classes 1, 2, and 3—62%) is not limited by this soil attribute.

Table 6.5: Potential rooting depth of soils in Kaipara/Hokianga region.

PRD Class	PRD Class range (m)	Description	Project area (km^2,%)
1	1.20–1.50	Very deep	176, 5
2	0.90–0.19	Deep	511, 15
3	0.60–0.89	Moderately deep	1407, 42
4	0.45–0.59	Slightly deep	656, 20
5	0.25–0.44	Shallow	297, 9
6	0.15–0.24	Very shallow	132, 4
B	Bare sand—not rated		151, 5

6.6 Soil Drainage Classes

Soil drainage classes provide a qualitative indication of the likely wetness status of the soil and its seasonal aeration constraints. Drainage classes are visually assessed from the presence or absence of grey soil matrix colours, the colour, size and percentage of mottles (blotches of greyish or reddish colour), and the position of the water table. Grey colours are generally reliable indicators of oxygen-deficient conditions. Waterlogging of pores markedly reduces gas exchange rates and induces seasonal anaerobic or partially anaerobic conditions. The classes may also be used to understand water availability, drainage requirements and trafficability/workability constraints.

Well and moderately well-drained soils provide favourable environments for plant roots. Imperfectly drained soils present some problems for drainage-sensitive crops. Poorly drained and very poorly drained soils present serious problems to most crop plants.

Table 6.6: Drainage classes for soils in the Kaipara/Hokianga region.

Drainage class	Description	Project area (km^2,%)
1	Very poor	184, 6
2	Poor	511, 15
3	Imperfect	1434, 43
4	Moderately well	312, 9
5	Well	739, 22
B	Bare sand—not rated	151, 5

Nearly half the project area has imperfectly drained soils (Map 35), and this is not unusual for Northland soil environments. A further fifth of the area is more poorly drained. Imperfect to poor drainage of soils is a normal condition for almost all flood plains. Poorly drained Kaipara soils occur on the wide Wairoa River flood plain, Mangahakia mottled clay loams occur in narrow river valleys in the Far North, and Whakapara mottled clay loams occur in narrow rivers valleys draining the non-volcanic hill country of Kaipara. Imperfect to poorly drained soils also occur on strongly weathered sedimentary rock terrains, and in the older inland dunelands where Tangitiki and Te Kopuru soils are recorded. Better drainage status occurs with Pinaki and Red Hill soils in the younger coastal dunelands, in hill country underlain by Tangihua Volcanics, on steeper parts of the older Waipoua Basalts, and on the young basaltic terraces and undulating lands of Kaikohe.

6.7 Profile Total Available Water

Profile total available water (PAW) is the total amount of water available to plant roots within the potential rooting depth, or to a depth of 0.9 m, whichever is shallower, expressed as mm of water. It is water that occurs between the field capacity and wilting point and, as such, is estimated as the difference in volumetric water content between −10 kPa (the pressure level at field capacity) and −1500 kPa (the pressure level at wilting point). Only a portion of the PAW is considered to be readily available. Readily available water is the difference in volumetric water content between −10 kPa and −100 kPa. Much of the PAW is held more tightly in the soil micropores at suctions greater than −100 kPa, and becomes more difficult for plants to absorb the closer the soil water potential moves towards wilting point. As a result, while plants do not wilt, plant growth becomes increasingly restricted because the soil water held at lower potentials is not readily available for plant use. For most clayey soils of the project area, readily available water would be about one quarter of the PAW.

Eighty-five percent of the project area has soils with moderate to high levels of PAW, and most soil water volumes would be non-limiting for most crops (Map 36).

Table 6.7: Profile Available Water (PAW) classes for soils in the Kaipara/Hokianga region.

PAW class	PAW class range (mm)	Description	Project area (km^2, %)
1	250–350	Very high	0, 0
2	150–249	High	154, 5
3	90–149	Moderately high	1440, 43
4	60–89	Moderate	1387, 42
5	30–59	Low	172, 5
6	0–29	Very low	27, 1
B	Bare sand—not rated		151, 5

6.8 Soil References and Further Reading

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7. Growing peanut

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Peanuts are an unusual plant. They are a legume, related to peas and beans, but the harvested peanut itself is a seed in a pod that grows in the ground. Basically the plant flowers above ground in the normal way. Once the flowers are pollinated a special stem called a peg grows down to the ground surface and penetrates it. The peg has the fertilized embryo in its tip. Once underground a pod forms around the embryo and the seed matures into the kernel (what we usually wrongly call the "nut"). Overseas, peanuts are often called groundnuts.

Figure 7.1: A peanut plant. The soil has been gently pulled away to reveal the pegs and the pods growing within the soil. Even though there are some well-developed pods you can also see some recent flowers on the plant. So by harvest time there can be a wide range of nut age and maturity (see text).

7.1 Why Grow Peanuts?

Peanuts are a basic food consumed around the world both as raw or roasted nuts and in various processed forms such as spreads, snack foods and cooking oil. Major areas of world production are throughout the African continent, India, China, USA, Argentina, and on a smaller scale Australia.

Peanuts were chosen for this project because:

- They are a crop with a relatively ready market within New Zealand. Each year New Zealand imports a lot of peanuts (Table 7.1).

- They do not require a particularly great financial investment to get started on a small scale – although some investment is needed to grow the crop on any commercial scale.
- Initially at least, they do not require highly-skilled labour for their production – but ongoing success will require the people involved to develop skills in choosing the best ways to grow, harvest and process the peanuts.

Through most of the 1980s and 1990s, the "landed" price of imported peanuts in New Zealand was consistently over US$1,000 per tonne. In the last three years the landed price has dropped to US$850-900 per tonne. However, if we assume that the current low prices are not permanent and that we can produce a high quality product then growers should be able to attain returns of NZ$1,200 per tonne or more. The returns could be considerably more for the supply of niche markets.

Previous growers in New Zealand often sold peanuts in the shell through health shops and found a very ready market. This marketing technique is a realistic proposition in the first stages of any new commercial development. As production increased, peanuts could be shelled and sold both as raw nuts and for processing into peanut butter and snacks. The production of peanut oil would be much further down the track, and it may never be profitable given the cheapness of imported oil.

Table 7.1: New Zealand imports of peanuts (in shell and shelled). The information is from the UN Food and Agriculture Organization (**http://apps.fao.org/page/collections?subset=agriculture**)

Year	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Metric tonnes	6,186	6,926	6,817	7,484	5,875	5,794	7,480	5,099	5,178	4,490	4,111
Value in millions of US$	6.9	6.9	6.3	7.5	6.0	5.9	7.8	5.2	4.6	3.8	3.7

7.2 New Zealand Experience Producing Peanuts

Previous research (Anderson & Piggot, 1981: van Tilburg, 1988) has shown that the crop can be grown successfully in New Zealand. Yields and quality can be good when crops are grown with good management in the right climate and soil types. In Northland, a number of successful crops were grown on a small scale in the 1980s. Currently we know of no commercial peanut crops being produced in New Zealand.

In the past, growers who produced peanuts were often very successful on a small scale. However, they tended to hit problems and lose their enthusiasm for growing the crop once areas reached about one hectare. The major problems that limited further commercial development of the crop were weed control and the absence of the infrastructure needed to produce and handle any substantial amount of crop. Let's look at those historic problems and consider how significant they are today.

Figure 7.2: A peanut crop growing in Northland in the 1980s.

Weed control

Peanut yields are very sensitive to competition from weeds. Initially, organic production may require a lot of hand-weeding - and you must take care to avoid damage to the pegs. The early peanut crops in New Zealand were grown conventionally, using herbicides. Even so, there were problems.

There were two main herbicides available to control weeds that emerged before the crop, Alachlor and Linuron. Unfortunately, at the application rates needed for effective weed control those herbicides could damage the crop as well. To add to the problem, there was little in the way of effective herbicide options once the crop had emerged.

It's not all doom and gloom! There are now more options. These include a range of herbicides to kill grass weeds (e.g. Centurion, Fusilade and Gallant). Recently the herbicide Spinnaker has become available – and this effectively controls a wide range of non-legume weeds including grasses. Furthermore, it can be used safely both before and after the crop has emerged.

Infrastructure

Growing the crop. There are no problems with sowing the crop as some seeders used for maize or squash can be used safely. Although not completely ideal the crop could also be lifted and placed back on the ground using standard potato or kumara lifters. Harvesting the crop can be more of a problem, as at the moment there is little specialist machinery available for stripping the pods from the plants. One option considered by a grower some years ago was to import a second-hand tractor-operated stripper from Queensland, a relatively low cost solution.

Processing the crop. A major problem here was drying the crop. Drying facilities are definitely needed as peanuts must be dried to below 8% moisture for storage. The crop would be harvested from mid to late March when temperatures are reducing - and the likelihood of rain is increasing - so drying in the field will be unreliable. Commercial maize driers would need extensive adaptation particularly because these use augers. Peanuts should not be augured. Furthermore, drying must not occur too rapidly or at too high a heat. The best situation is when drying is carried out at temperatures no more than 12^{o}C above the outside air temperature.

Crop processing often requires the peanut to be shelled. Usually this is done after drying. A shelling machine would then be required. However, this need not be purchased in the first commercial year. Crop & Food Research has an experimental-scale sheller. This could be used to shell seed for the early smaller scale commercial crops. There would be no need to purchase a larger sheller until a decision was made to grow the crop on a larger scale and invest in it further.

After shelling, further processing may require you to "blanch" the kernels – remove their reddish skin. There are various ways of doing this, but often it is not a good idea to wet the kernels during the blanching – because you may have to dry and then store them before the next stage of processing. In the USA, warm air is blown over the skins to loosen them and then rollers rub the skins off. There is an opportunity here for someone to design and build a simple reliable machine for use in Northland! However again investment in blanching facilities can be made later in the commercial development process as many peanuts are sold or processed unblanched.

Peanuts are best stored in their shells, so shelling and blanching should be done close to the time when the peanuts are going to be used.

7.3 Aflatoxin, A World Wide Issue

A major and increasing international concern with peanuts is the risk of aflatoxin contamination. Aflatoxin is a poison that can cause cancer in humans. It is produced by some fungi that can colonise peanuts under some conditions. In 2002 an enquiry was made as to the availability of New Zealand grown peanuts to market in Europe - as the buyer was unhappy with current aflatoxin levels in peanuts sourced from China.

Penalty payments are incurred by Australian growers if aflatoxin levels exceed 15 ppb (parts per billion). That means there is a *very* small tolerance for aflatoxin – 15 ppb is equivalent to about three teaspoons of the poison in a thousand tonnes of peanuts.

Aflatoxin production is favoured by water stress and by temperatures between 25 and 32°C (Rachaputi et al., 2001). In Northland, periods of optimum temperature for aflatoxin are relatively short and the risks of infection are far lower than for Australia and most of the other peanut production areas of the world. If we handle the peanuts correctly after harvest, the lower risk of aflatoxin contamination would give New Zealand peanuts a potential marketing advantage. Part of that correct handling is to make sure that the peanuts are not stored at water contents greater than 12% in mature kernels and about 18% in immature kernels.

7.4 Basic Growing Requirements

Ideally, peanuts should be grown in a sandy loam to silt loam soil with moderately flat topography, and a topsoil pH of over 6.0. Medium levels of soil fertility are required. Peanuts have a deep taproot (see *Glossary*) so are moderately drought resistant but yields will suffer if there is an extended dry period. Very acid subsoils will restrict taproot growth, and we do not suggest that you try growing peanuts in areas where the subsoil has a pH less than 5.5.

Planting should be by early November, preferably after soil temperatures reach 15^{o}C. In order for the crop to develop to harvestable maturity, there should be a minimum of 500 degree days from 1 November to 31 March. That degree day figure is calculated using a 14^{o}C base temperature.

Under New Zealand conditions only the shorter season Spanish/Valencia type peanuts perform well and from trials 20 years ago the cultivar (see *Glossary*) New Mexico was recommended as a consistent performer in New Zealand. Many crops (such as maize) are what we call *determinate.* This means that once flowering starts the crop ceases to produce new leaves and flowering is usually over in a short time. Peanuts though are *indeterminate*. This means that under good conditions new leaves, flowers and pods will continue to be produced even if the crop already has some mature seeds. At harvest most crops will contain kernels or nuts with a quite wide range of ages or maturities.

Your choice of when to harvest must be a compromise – choose a date when you have a lot of mature pods, but when there is little risk of rainfall causing problems with the harvest and drying of the pods. Inevitably if you harvest very early to avoid rain you will lose yield from the later produced pods, which might not be mature in time. If you leave it too late then the early pods may be lost in the stripping operation, and rainfall might spoil the drying process.

Sowing rate should be between 200,000 and 250,000 seeds per hectare (that's 20 to 25 seeds per square metre). Pre-emergence weed control options include Glyphosate, Alachlor at up to six litres per hectare product and Linuron at one kilogram per hectare. Spinnaker can be used to control a wide range of weeds at 400 millilitres per hectare either pre or post emergence while grass herbicides can also be used. If wide rows are used then you can control weeds using machinery or by hand - but care must be taken not to damage the developing pegs. Diseases are best controlled by fungicide seed treatment, maintaining a weed free crop and long peanut rotations.

At harvest, peanuts should be lifted from the soil, left to field dry for a few days and then stripped from the "vine" and finished off by drying in the shell in a suitable drier. Alternatively they can be stripped and artificially dried immediately after lifting.

In good growing conditions shelled yields of over 4 tonnes per hectare have been recorded in Kaipara and 2.5 tonnes per hectare should be a realistic aim.

7.5 Conclusions

- Peanuts can definitely be grown successfully in Northland (see Chapter 18).
- A good return can be obtained from the crop, particularly in the supply of niche markets.
- The major constraints in the past have been problems with weed control and the lack of an industry infrastructure. Weed control is now likely to be less of a problem, but a suitable infrastructure must be developed before peanut crop can be developed for commercial production.

7.6 Information Sources

People

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8. Growing Māori potato

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Māori potatoes are a collection of varieties of ordinary potato (*Solanum tuberosum* L.). So they are brothers and sisters to the same spuds that are used to make regular potato chips and mash!

It is sometimes claimed that Māoris grew potatoes in pre-European times (Roskruge, 1999). However, it is generally accepted that Māori potatoes originate from introductions made in the early years following the arrival of Europeans in New Zealand. The French explorer de Surville planted potatoes in New Zealand in 1769. Cook planted potatoes here on his second voyage in 1773. The Māori were quick to recognize the advantages of potatoes. Those advantages include higher yield than kumara and greater reliability, particularly in the cooler more Southern areas of New Zealand.

It is likely that most types of Māori potatoes came from introductions made before 1840. Varieties differ in colours, shapes and cooking characteristics. Sometimes the same type of Māori potato is grown under a different name in different areas.

Some varieties of Māori potatoes have red or blue skins and in some the colour goes through the flesh. The natural chemicals responsible for these colours are called anthocyanins (see the *Glossary*). Internationally there has been a recent emphasis on the health benefits of anthocyanins, so there is potential to promote the coloured flesh varieties as a health food.

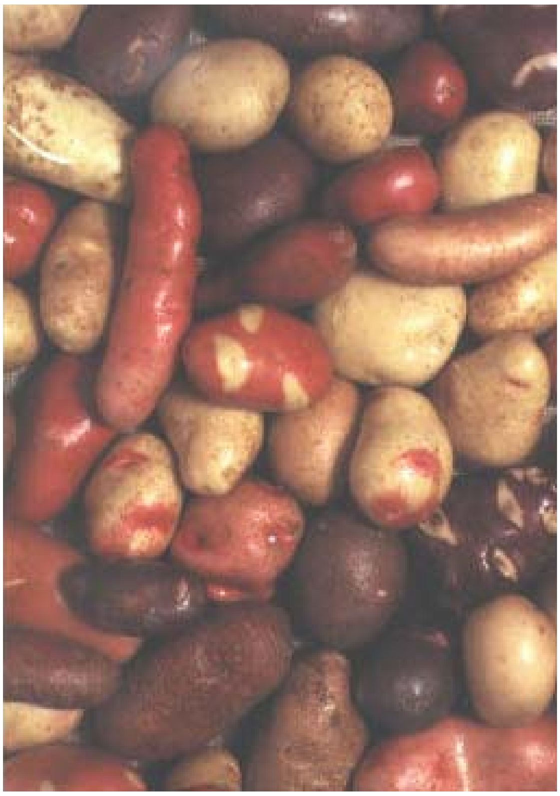

Figure 8.1: An assortment of Māori potato varieties.

8.1 Why Grow Māori Potatoes?

When selecting crops for this project, the community group was enthusiastic to include Māori potatoes. Most experience with Māori potatoes to date has been through efforts to produce them on a small scale, often to feed whanau. The feeling was that the community would be comfortable with building on this existing expertise. It was also suggested that commercialising Māori potatoes on a larger scale presents an opportunity for a product that the market place could associate with the district. These are all worthy reasons for pushing ahead with Māori potatoes as an economic development opportunity for the district. However, there are some drawbacks that need to be kept in mind. We will discuss in detail these below, but the key point is that there are some risks and costs associated with the need to scale up production so that marketing can get underway.

8.2 Experience Producing Māori Potatoes

Potatoes in general are a significant crop in New Zealand, grown on approximately 10,000 ha. They have a total "farm gate value" of about $100million per year. That makes them the most valuable arable or vegetable crop in New Zealand. Currently there are about 300 commercial growers, but this number is decreasing. Over half New Zealand's potato crop is produced by the 30 largest growers. The area north of Auckland is a very minor production area. There appears to be only four commercial growers in the region, two in the Kumeu area and one each near Whangarei and Kaitaia. All of these are comparatively small-scale producers.

We can find no reliable figures for New Zealand's total production of Māori potatoes. Māori potatoes are grown mostly in home gardens or community gardens. A few varieties (such as Urineka) are sometimes grown on a small commercial scale and marketed irregularly in a few retail outlets. They are recognized as a unique product.

8.3 Infrastructure for Māori Potatoes

The on-farm infrastructure requirements for growing Māori potatoes as a commercial crop are very similar to those for standard commercial production. They are outlined below in "Basic Growing Requirements".

Initially at least, the infrastructure for marketing will not be too difficult to build up. Marketing could be carried out by growers directly supplying retail outlets such as health food shops, green grocers or even individual supermarkets. Alternatively, marketing could be carried out in association with an established wholesaler who already supplies larger markets such as supermarket chains. For both approaches, the infrastructure requirements are mainly facilities to sort and bag the potatoes, and transport.

More important than buildings and machines…

People and attitudes will be crucial. If you want to grow and sell the potatoes to shops, supermarket chains or wholesalers then you *must* be prepared to keep up a significant effort to maintain the market linkages. This means a significant commitment to ensure that a succession of crops are grown and harvested so that the market is continually supplied for most of the year. Retailers and wholesalers want reliable good quality *and* a steady supply. They have to be confident that you will deliver the potatoes when they want them. This is especially important because you will want the retailers and wholesalers to help build the market for a relatively novel product. Concentrate on building good working relationships with these people.

8.4 Things to Watch Out For

There are some pitfalls to the concept of Māori potatoes as a commercial crop in the North. Let's get them out in the open.

- The Māori potatoes available appear to be badly infected with viruses that make them yield much more poorly than they could. The main viruses that affect potatoes in New Zealand are potato leaf-roller virus, and two others with the surprising names of potato virus X and potato virus Y. The infections are passed from one plant to another by aphids. "Clean" potatoes planted out soon become reinfected if you repeatedly reuse potatoes from this year's crop as seed potatoes for next year's crop.
- New Zealand has a potato seed certification scheme that prepares high quality, virus-free seed potatoes for growers to plant. (See the *Glossary* for a definition of "seed potato".) At present, no Māori varieties are in the scheme. To clean up the varieties that look promising for Northland will cost around $3,000 per variety. The first seed potato lines would come available a minimum of three years from their entry into the scheme.
- Ideally, a potato seed merchant would make a commitment to maintain the seed potato supply and ensure that virus-free seed potatoes are regularly available. That company will in turn need some confidence that there will remain a market for their certified seed potatoes. So the trick here is to build a relationship with a suitable company. Bear in mind that you may not want people from outside your area to have access to the variety that you have jointly put through the certification scheme. Perhaps a simple legal agreement will be a good idea.
- Nationally, the potato industry has a well-developed infrastructure- but it is very weak north of Auckland. You will have more difficulty getting supplies and advice than mainstream potato growers elsewhere in the country.
- You might put a lot of effort into developing the crop and the market and then others might try to take over the market. Right now, the market for Māori potatoes is small but if it grows it could be invaded by larger commercial growers outside Northland. They may have advantages of well developed infrastructure and lower costs per tonne of potatoes produced. Māori potatoes cannot be protected by Plant Variety Rights as they have been grown for so long. (Rights can only be granted within the first twelve months of commercial production of a new variety.) It will be very difficult to develop Māori potatoes from the Hokianga and Western Kaipara as a bulk commercial crop like ordinary potatoes.

8.5 Basic Growing Requirements

Māori potatoes should ideally be grown in an easily worked silt loam to clay loam soil. The soil should be well drained (this means that you should not be able to see water lying on the soil surface for more than a day after heavy rain). Potato yield and quality can be badly affected by water logging of the soil. You can add to this the obvious problems that you will have getting clean potatoes if there has been much recent rain and the soil is poorly drained.

It is best if the growing area is flat or moderately flat. This makes things much easier and safer for machinery, but it also reduces the risk of soil erosion. Land prepared for potatoes is vulnerable to erosion under heavy rain, especially on hillsides.

There are few temperature requirements, apart from the avoidance of frost prone areas for winter planted early crops.

Irrigation is unlikely to be needed for early crops. However, irrigation is highly desirable for main crop potatoes in many of the soil and climate combinations of Northland. If you can irrigate the potatoes in dry weather then you will have a much better chance of getting good yields and potato quality.

Planting should be from early May for early crops through to mid November for late harvest main crops. If you are growing on a commercial scale then a potato planter, harvester and a reasonable spray rig will be necessary. Basic growing practices would follow the standard techniques currently used by the potato industry.

8.6 Conclusions

- Māori potatoes could definitely be grown over a wide area of Northland (see Chapter 18).
- There are serious questions about whether this area is the best place to attempt to establish Māori potatoes as a bulk commercial product.
- There is already a very small established niche market.
- There is good potential to grow and market Northland Māori potatoes as a specialist niche crop. This will require careful business planning, especially in terms of getting reliable yields and effective marketing in a way that emphasizes special regional aspects of the product. Currently, Māori are not well represented amongst commercial potato growers, and an emphasis on Māori supplying Māori potatoes may well help as a marketing approach.
- Finally, success here will depend a lot on building relationships at both ends of the business. Get a good working relationship with a potato seed merchant so you get the competitive advantages of virus-free potatoes to plant. Build a good working relationship with the people you grow the potatoes for – remember that retailers and wholesalers want good quality and reliable steady supply.

Putting all of these things together, we suggest that you:

1. Aim for Māori potatoes as a high-value specialist niche product (so you'll need to pay good attention to quality);
2. Concentrate on one or two distinctive varieties;
3. Make sure there is a prominent regional emphasis in marketing material; and

4. Get the advantages of your own virus-free supplies. If you can keep a tight rein on the supply of clean seed potatoes you will get a big advantage over any rivals. So again, we return to the importance of building a relationship with a potato seed merchant.

8.7 Information sources

People

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General information on potatoes and the vegetable industry

www.vegfed.co.nz

9. Growing manuka for oil

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There is a worldwide industry in "essential oils". These are high-grade oils extracted from plants, to be used in perfumes, flavourings, medicines, aromatherapy, etc. The properties, preparation and handling of these essential oils are quite different from the bulk plant oils that are extracted as basic food stuffs or industrial products (like canola, soybean, peanut or sunflower oils).

You can obtain essential oil from the leaves and seed capsules of the manuka bush by steam distillation. Young foliage is cut from bushes in wild populations, bagged and carried to the distillation equipment. There it is compressed into cartridges that are loaded into the still pot. Then the oil is extracted by passing steam through the plant material. The oil evaporates, it is separated from the rest of the plant material, and then it is cooled so that it forms a liquid. The distillation equipment must be carefully adjusted to get the best compromise between good oil yields and extraction costs.

The oil is the active component in important traditional uses of manuka in Māori medicine. With the worldwide interest in essential oils it is important to ask whether manuka could be grown or harvested from the wild to support a new industry in Northland.

Figure 9.1: Manuka in full flower. (The flower load is heavier than usual, but this season was a really good one for flower production.)

9.1 Why Grow Manuka?

Manuka is suitable as a crop in Northland for several very different reasons. Most importantly, it is an existing native species and a major plant resource that has already adapted to the Northland climate and soils. Previous deforestation and farm development now restrict manuka to land of little use for conventional farming or forestry. Even so, there is plenty of manuka in Northland! Management and manicuring of the native manuka populations could sustain commercial scale oil production. In the long term, more economic production might be achieved by setting up intensive plantings of high quality manuka clones on better ground.

The oil production system – crop production, harvesting, transport, steam distillation and oil handling – is not highly technical or capital-intensive. The existing rural workforce, basic skills and mechanical resources should be adequate for the establishment and operation of the necessary crop production, harvesting and transport activities. Building the extraction plant and maintaining the boiler could be done by the local companies currently servicing the hospitals, dairy, and engineering industries in Northland. Previous commercial production of manuka oils in other areas has provided important information on the distillation process which may require special methods and distillation plant design. Expertise is available to advise on this and to tune the process to specific oil types for optimal quality and cost efficiency.

There was local interest in oil production well before this project began. However, progress was restricted through lack of development funding. Local government support to develop new crops, including manuka, is an important new resource for small and developing business enterprises and should be used as much as possible. Crop & Food Research has some experience producing small samples of oil from Northland, so we have some basic information on oil yield and composition. Discussions with local potential growers and surveys of the plant resource have also provided some preliminary ideas for oil products and production systems suited to the Northland district and society.

Currently, manuka oil products have not been intensively and widely targeted at the tourist markets in New Zealand. The Northland tourist industry is large, mature and experienced. It has a large foot traffic market, an established tourist retail outlet and distribution network, and a tourist-focused commercial and local government infrastructure. All these vital elements lend themselves to a regional approach to marketing manuka oil tourist products as the first phase of establishing an oil production industry, which could then support expansion into other domestic markets or export products.

Manuka oil production will also provide some additional social benefits in Northland, other than directly through employment opportunities. Past traditional use of manuka by Māori would give relevance and credibility to products and promotions with a Māori emphasis. The industry could be structured in such a way that integrates small production units based on family groups or small-holdings. Manuka plantations or existing populations may provide an income on marginal land or small-holdings that are not economic for traditional dairy, pastoral or forestry production. Northland is also an important production area for manuka honey and there is potential to manage wild manuka populations to produce both oil and honey from the same areas. There is also the possibility of incorporating traditional medical materials from manuka in the oil and/or honey production systems as additional products.

9.2 New Zealand Experience Producing Manuka Oil

In 1986, research on manuka oil started in the Applied Biochemistry Division of the old DSIR at Lincoln. Commercial-scale production of manuka oil first began at Te Araroa, East Cape, in 1989 by the founders of Tairawhiti Pharmaceuticals Ltd, with technical support by DSIR[3]. Since then, there has been expanding activity by commercial producers and experimental work in the laboratory and field. This collaborative work between Crop & Food Research and Tairawhiti Pharmaceuticals Ltd and other producers has given New Zealand a lot of technical, business and marketing experience.

Now, manuka oil from New Zealand is traded wholesale on the domestic and international markets. It is also retailed in a variety of formulated toiletry and hygiene products. Most of the market demand is based on the proven antibacterial activity of some lines of oil. The antibacterial activity comes from β-triketones - a select group of chemicals that can be found in the oil. New Zealand manuka oil is also used in aromatherapy.

Three New Zealand companies are currently producing manuka oil on a commercial scale for domestic and export markets. There are several smaller producers producing oil for very limited distribution in different parts of New Zealand.

The Bay of Plenty and East Cape companies produce a manuka oil that has high levels of β-triketones and so is effective at killing bacteria. A Coromandel company produces a mixed manuka/kanuka oil that has few or no β-triketones, but a high content of different chemical compounds called monoterpenes. Monoterpene compounds are less desirable for hygiene or medical products since they have only low antibacterial activity. However, they may be more suitable for toiletry products where aroma is more important, since their aroma is stronger and usually more attractive than the β-triketones.

Laboratory tests have shown that oils from Northland typically have high monoterpene levels and little or no β-triketones. As a result, they are likely to have only low antibacterial activity. On the plus side though, they will probably have a more attractive aroma than oils rich in β-triketones. So, Northland oils may be more suited to aromatherapy, toiletry or tourist products. Careful choices of product formulations, promotion and market areas should avoid full competition with the East Cape manuka oil production, most of which is exported.

9.3 Infrastructure needs

Overview

The infrastructure supporting the planning, marketing and business activities is crucially important. Remember that the production system must be driven by how much and what sort of oil the market wants. Most attempts to set up essential oil production businesses have been restricted by market and business difficulties, not by the technical requirements of oil production. In almost every case, the commitment, importance and costs of the necessary marketing and business activities have been significantly underestimated.

[3] The DSIR staff joined Crop & Food Research when MAF Technology and DSIR were amalgamated in 1982.

The most difficult business aspect for oil producers has been planning their finances. It is important that cashflow does not restrict development of markets and production capacity. So there is a need to commit sufficient financial resources for buying in the necessary technical and business expertise. Unfortunately this critical need is often underestimated. All small or developing businesses should make use of:

- The existing tourist industry infrastructure.
- Free or subsidized assistance available from central Government programmes. These include various schemes run by Technology New Zealand, Industry New Zealand, MAF Sustainable Farming, and AGMARDT.
- Whatever assistance your local Government can provide. In parts of New Zealand, local Government has been unsupportive or even obstructive in areas like resource management and waste disposal. Try to keep a good dialogue with local Government on issues like generation of employment, resource management, waste disposal, land use, regional development funding.

Getting the oil

Good infrastructure and networking or cooperation are important in the crop production, harvesting and oil extraction operations. This is because steam distillation equipment is not cheap, and because harvested plant material must be brought to the distilling equipment.

Manuka grown on small holdings and harvested from wild populations may produce enough plant material for an industry, but it is uneconomic to have a large number of small distillation plants spread through the area. Overall it is cheaper and more convenient to have larger distillation plants (>0.5 tonne foliage batch capacity). Locate these so they serve the maximum number of individual properties no more than about 25 km away. Try to locate the distillation plant so that the areas supplying it can keep it operating over as long a season as possible. The distillation plant will also need to be operated on multiple daily working shifts. Labour, transport and agricultural contracting resources must be available. Compared to other regions, Northland will have a longer growing season, so competition from seasonal demands from other crops should be manageable.

The infrastructure for technical support – agronomic, engineering, distillation, product development and quality assurance – already exists and can be accessed through Crop & Food Research.

So you have the raw oil…

Now let's look at the infrastructure you need to develop, formulate and sell products. The domestic market is envisaged as the first phase of the industry so we'll concentrate on that here. The good news is that much of the infrastructure for the domestic market is well developed in the form of the tourist industry, which already presents a wide range of products to the tourist market.

Producers of Northland manuka products should take advantage of this existing infrastructure as much as possible. If help is needed with this, business expertise and mentoring are available.

Two major elements of successful marketing have become apparent. Oil producers must understand the specific requirements of the consumer/client *and* they must use that understanding to define the choice of plant material, processing methods and product formulation that will satisfy those requirements. Sadly, all too often producers do not adequately understand and service the promotion, distribution and retail presentation requirements and their associated costs in time, effort and money. So read the books and web sites that are available, think about it and then ask straightforward questions to the tourist industry (including shopkeepers), funding agencies and the various technical and business consultants out there.

9.4 Basic growing requirements

Best oil yields come from the foliage of the current growing season. Good foliage production makes the whole process more efficient, but what encourages good foliage production? The keys to success are:

- Select manuka stands where growth is naturally most vigorous and free of plant diseases, especially the black manuka blight. At the same time you should make sure these stands give good oil yields and quality. It can be a very good idea to take cuttings from promising plants and propagate them, so you develop clonal lines that give high quality oil.
- The soil needs to have good water retention. High fertility is not essential though.
- The best sites are sheltered from persistent or salt-laden winds and are accessible to machinery.
- It is best if the site has high rainfall, without significant and regular spring or summer drought periods.

Manuka is tolerant of frost, heavy soils and variable sunshine hours, and should sustain oil production provided the other basic requirements and crop management are adequate.

9.5 Basic processing requirements

On steep slopes you can harvest foliage manually with motorized hedge-trimmers. On flatter sites you can minimize labour costs, so in the long-term look at using hydraulic tractor-mounted mowers that cut directly into towed bins.

After harvest the foliage usually needs to be chopped finer or mulched. Often this is done using a silage chopper. This increases the amount of foliage that you can pack into the cartridges in the still pot. The steam distillation plant consists of 4 basic units:

- A boiler with capacity to produce 500-2000 kg of steam per hour, depending on the scale of operation.
- A steam-jacketed stillpot of 300-1000 kg capacity, with good insulation and drop-in cartridges for rapid un/loading of the plant material.
- A tube-in-shell condenser to match the boiler steam output, with hot exit water recycled to the feed tank of the boiler to save heating costs.
- An oil separator to allow the oil to be separated efficiently from the waste water.

Figure 9.2: Land used for manuka oil production. This is typical flat and hill grazing country west of Hicks Bay. The hill pasture had been cleared and grazed, but it was allowed to revert to manuka when meat and wool became uneconomic because of transport costs in the mid-1980s. The plants in the foreground are 5-10 years old, around 1.5m high and an ideal size for hand harvesting.

Disposal systems will be needed for waste water and plant material, and clean secure facilities are required for drying, filtering, packing and storing the oil.

The details of design and operation of the distillation plant are dictated by the scale of production, characteristics of the foliage, how quickly the oil can be extracted, and cost limits imposed by market and business requirements. Design and operating procedures need to be developed individually for each distillation plant and oil type. There must also be adequate evaluation and optimization of plant design and operation during commissioning to get the best extraction and cost efficiencies.

There are many regulations associated with running distillation plants. There is also quite a lot of what the industry calls “good practice”. You will need to be familiar with the regulations and good practices, especially with regard to:

- Boiler operation, maintenance and steam use;
- Resource management – water use and waste disposal;
- Good production practice for producing and handling the oil, this is required by clients to support their formulated products in their markets (especially overseas);
- Occupational safety and health requirements for businesses operating machinery and handling chemical materials.

9.6 Conclusions

- Manuka for oil has strong potential, provided that the requirements of the target market are clearly identified and built in to your short- and long-term planning for an industry in the district.
- Initially at least the plant material itself can be gathered from the wild. It will pay to keep an eye on where the best quality oil comes from, and eventually plant fresh stands of elite plants propagated from those areas.
- We suggest that initially at least the target market is the tourist industry. Products for the tourist industry will include toiletries and aromatherapy products.
- Northland manuka oil is unlikely to have much antibacterial potency, and targeting the market for such products will probably bring you into direct competition with established players who already have a good product.
- The oil is produced by steam distillation of leaves and twigs harvested either from the wild or from plantations. We recommend a cooperative structure with one or more centralised distillation plants.
- Technical and business advice for industry development is available and should be used. Make use of whatever assistance local and central government agencies can provide.

9.7 Information Sources

Much of the detailed business and marketing experience developed by the current producers will not be available to new producers since it is commercially sensitive and valuable. This may also be true regarding the technical details of individual distillation processes. However, in most cases, the combination of business, marketing and oil production activities and requirements are unique for each producer. New producers should therefore expect to develop their own operation according to the resources, abilities and information they already possess or have access to, and those they will have to obtain. Crop & Food Research can provide information on all aspects of the manuka plant resource, the harvesting and distillation process, and the testing, analysis and evaluation of oils. References to broadsheets, reports and journal papers are given below. Crop & Food Research also has experience as consultants in developing and operating oil production projects, and assisting producers in some aspects of business and marketing activities.

Funding sources

Information on funding sources for assistance for technical aspects of crop production and processing technology can be found on the following websites:
Technology New Zealand – www.technz.co.nz
Industry New Zealand – www.industrynz.co.nz
Agmardt – www.agmardt.org.nz
MAF Sustainable Farming – www.maf.govt.nz

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10. Growing banana

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Botanically, banana is known as *Musa x paradisiacal* L. It is a giant herb with a large underground rhizome (see *Glossary*) and large leaves. Banana originates from tropical South-east Asia. Most people in New Zealand are aware of bananas as a delicious fruit – worldwide they are the second or third most important fruit. Few in New Zealand might realise though that banana and its close relative, the plantain, are actually the fourth most important staple crop in world food production (Kasteele, 1998).

Figure 10.1: Cavendish robusta banana fruiting in a research station in northern Argentina, an area subject to winter frosts.

10.1 Why Grow Bananas?

First the gloom

The majority of the trade in bananas is controlled by multinational companies and based on huge intensively managed plantations in Central and South America. Banana workers in less-developed countries suffer from long hours, low pay, forced overtime, massive exposure to dangerous pesticides, and lack of job security (Richo, 2003). Central American and South American wages of banana workers are often as low as US$2.50-5.00 per day (BBC, 2003), but union action has increased them in some cases to US$11-14 (Kasteele, 1998; AUGURA, 2003).

Despite the importance of bananas worldwide prices are not always favourable. Profit margins for the large scale banana plantations are virtually nil and often negative. The banana multinationals and their growers are in for some further tough times because they have concentrated production on one cultivar (see *Glossary*) of banana. That cultivar is called Cavendish and it is very susceptible to two soil-borne diseases that are now sweeping through the plantations (Pearce, 2003). The global multinational domination of the standard banana market and low profit margins makes it unlikely that New Zealand can compete outright in the large scale multinational export industry based on standard cultivars.

Now the good news

Managed to hold off depression? Good, because here's some positive stuff you need to know.

1. First off, we don't have to compete head on with the multinationals!
2. There are opportunities for New Zealand in several areas. The present large scale production overseas are at risk of major disease outbreaks, which would provide countries growing rarer cultivars an opportunity to step in.
3. The massive use of biocides in the overseas plantations has led to a growing market for organically grown bananas.
4. There are numerous cultivars of bananas that are highly priced in niche markets for specialty fruit.
5. New Zealanders are among the highest per capita consumers of banana in the world. So there could be opportunities for local import substitution.
6. With New Zealands large Pacific-Polynesian population, interest in non-standard cultivars of bananas (including plantains) and alternative products (e.g. leaves) is potentially important, particularly in Northland and Auckland.
7. Banana plantations provide considerable permanent skilled employment as well as a large number of low skilled seasonal jobs during harvesting and packaging. For general comparison, 100 hectares planted in bananas will provide for around 17 full time jobs (Richo, 2003), 50 part time jobs and 167 indirect jobs (AUGURA, 2003). These data are for large scale conventional plantations in Ecuador and Colombia and are indicative only. Mechanization and different work practices will provide different results in New Zealand, but there is a good chance that banana growing could help meet the community's need for new employment opportunities.
8. And *very* importantly – we can grow bananas in Northland.

10.2 Industry and Market

Wholesale prices of standard banana on the world export market vary considerably from country to country and from year to year. From 1997 to 2000 average yearly prices in US$ per tonne varied from 424 to 705 in Japan, the US and France (higher prices still were paid in Germany, up to 1,121 US$/ton in May 1998, (FAO, 2001a)).

Retail prices for fresh fruit also varied. For New Zealand, prices have dropped from 1.33 US$ per kg in 1996 to 0.99 in 2000. For the same years prices in Europe and the US are given in Table 10.1. It is worth noting that monthly values varied up to 2.30 US$ per kg in Japan.

Table 10.1: Retail prices of fresh bananas in Europe and in USA. Values are given in US$ per kg.

Location	1996	2000
France	1.95	1.68
Japan	1.93	2.21
USA	1.08	1.11
UK	1.46	1.49

In 2001, the worldwide export value of bananas was 22.5 billion US$, representing over 12 million tonnes (FAO, 2001b; data for 1999 was 11.7 million tonnes). This is an increase in value of 7.7% from 1997 (Department of Commerce, 2003). There have been claims that there is an oversupply of bananas, but world-wide exports continue to grow at about 3% each year. Overall, only 20% of global production is actually traded (Kasteele, 1998). New Zealand has been importing around 70,000 tonnes of bananas each year, and this amount has remained relatively constant. New Zealand is one of the highest importers of banana per capita in the world (15-21 kg/inhabitant per year).

Faced with this massive commodity trade, Northland is unlikely to make much headway by growing standard cultivars using conventional (chemically intensive) methods. A local banana industry is most likely to succeed supplying niche markets (local and export) for specialty cultivars and, most likely, organically grown fruit.

10.3 Specialty Bananas

There is a particular market niche for specialty bananas, i.e. fruit which stand out because of their colour, flavour (usually sweetness), aroma, or because they are produced organically. Advertising products on the basis that they are both ecologically and socially friendly has also become a particular selling point for specialty products.

Specialty bananas fetch prices several times higher than the standard high volume produce from the tropics. For example, internet marketer Frieda's.com sells Niño Bananas for US$32.80 per 5 pounds bulk, including shipping (equivalent to NZ$29 per kg). Other banana cultivars sell for a range between NZ$28 and 33 per kg in the same conditions. In other words, if they are good quality specialty bananas can retail for around 10 times as much as standard fruit.

10.4 Additional Products

There are several dozen cultivars of bananas and plantains. Although many are sold as fresh fruit, some types need to be cooked and are eaten as starchy vegetables, or fried, or cooked in soups and other preparations. The banana leaf also has a good retail value as it has superior properties (size, toughness, smoothness) for wrapping food in a variety of traditional tropical dishes.

Banana fruit can be processed into a variety of products. These can provide alternative marketing options during price slumps or when quality is not appropriate for fresh fruit. As an example, dried banana can retail in the US at US$33.80 for 4 packages of 8.2 ounces each (Frieda's.com), equivalent to NZ$72.70/kg. Most other banana derivatives are low-price sidelines (starch, pulp, confectionery, leaves and other waste used as animal fodder, and fibres from the leaf sheaths) that nevertheless add to the stability of production.

An additional innovation in organic banana growing is the capacity to develop multiple cropping systems, that can provide more employment, alternative sources of income, and environmental benefits.

10.5 New Zealand Experience Producing Bananas

Bananas have been grown successfully and have fruited at a variety of locations from Northland to Gisborne. The degree of success has depended on cultivars, location (soil, climate), management practices, and marketing efforts. Several cultivars have been imported into the country, and these vary in their environmental tolerance (particularly cold tolerance and disease tolerance, and capability to flower and fruit in New Zealand conditions) as well as their size, growth rates, and fruit size, shape, colour and flavour. A general survey of these cultivars has not been performed but that would be useful to help select the best opportunities.

Some cultivars of interest are South American landraces, imported in the 1990s, which are small and robust (tolerant to wind) and grow in relatively cool conditions. A banana called "Goldfinger" recently released in the US is claimed to be tolerant of low temperatures and resistant to major diseases allowing it to be grown without pesticides (Anonymous, 1993). There are examples of good fruiting in appropriate locations in New Zealand with specialty cultivars such as Misi Luki and Dwarf Pink Banana (more for ornamental purposes) at Landsendt nursery, Auckland (Endt, 2003), as well as several cultivars being grown by Tairawhiti Land Use Research and Development Foundation in Gisborne. Although as yet mostly unproven on a large scale, these and other cultivars like them may be the best base for a Northland industry.

Bananas are highly susceptible to a wide range of pests and diseases. As a result, commercial tropical plantations are often managed through intensive spraying of pesticides and fungicides. Luckily, some of the worse tropical diseases are uncommon or absent in New Zealand, providing a good head-start for organic production. In addition, careful precautionary management in the selection of healthy and/or disinfected planting material, orchard sanitation and destruction of any infected plants are the most important practices toward healthy and productive plantations (Rehm, 1991).

10.6 Infrastructure Needs

Banana cultivation and processing requires a minimum essential infrastructure that can be constructed or adapted from existing structures. For a business to be successful, it is most important to ensure the appropriate lines of market demand, i.e. local buyers and distributors for ripe fruit destined for New Zealand markets; transporters, good roads, storehouses, shipping, ports, exporters or destination country importers for fruit destined for export. The necessary infrastructure must be available at each step.

Figure 10.2: Banana with flower and young fruit in Bay of Islands, New Zealand.

Growing the fruit

The main tasks required in banana cultivation are summarised below. This list is based on information given by Richo (2003).

1. Offspring Stripping – the process in which the offspring are selected from the banana plants. Banana plants are cloned – nothing sinister here, you just need a trained person to select the best shoots that emerge from the underground rhizomes of existing plants. These are then grown on to form the next collection of plants.
2. Fertilisation – banana plants are usually fertilized four times a year with organic or chemical fertilizers. No special equipment is needed on small plantations, but you'll need someone you can trust to work out how much fertiliser to put on and when.
3. Leaf Stripping or Trashing – on larger plantations a worker is dedicated solely to removing old leaves and leaves infected with fungus. No special equipment or advanced training is needed.
4. Chopping and Crowning – clearing away weeds and cleaning a 50-cm. radius from around the banana stalk to keep the area clear and to help avoid disease. Again, no special equipment is needed on small plantations, and staff can be trained readily for this.
5. Bagging – a bag is placed around each bunch of bananas to help it develop more quickly and at the same time keep it safe from insects. Yet again, no special equipment is needed and you can train staff readily to do this task.
6. Fumigation – air fumigation takes place in 15 or 25-day cycles in conventional plantations. This is one of the most expensive steps because of the high chemical and plane rental costs, but is eliminated or reduced in organic plantations.

Figure 10.3: Bagged banana fruit growing in Bay of Islands, New Zealand.

Harvesting and processing

Ripe fruit for local sale are cut off with a machete and carried with minimal bruising to the packing shed. This can be helped by aerial cable systems installed in larger plantations. In the packing shed the fruit is washed and, if needed, treated with disinfectants. The banana hands are detached from the bunch and packed in cartons appropriate to the buyer.

Fruit for export or long-distance transport are usually cut green and packed as for ripe fruit. From this point, they require a low level of refrigeration (14-15°C) until delivery. Once they arrive at their destination, unripe fruit must be ripened. This is usually achieved by storing at slightly warmer temperatures in an atmosphere with 0.1% ethylene until a yellow colour is achieved (Rehm and Espig, 1991).

So what does all this require?

1. Harvest – you'll need experienced workers to collect the bananas (choosing bunches of the right maturity is important).
2. Quality control – On arrival at the packing area, the bunches are inspected and sorted for export, local use, processing, fodder, etc. You'll need eagle-eyed staff who can consistently stick to the standards your customers want.
3. Cleaning – you'll need some simple equipment and careful staff to clean bananas, especially fruit that will be sent long-distance. Bunches are cleaned in tanks of water with preservatives.
4. Packing – after washing, bunches are given their familiar shape by removing excess leaves and giving then a clean, fresh look. They are then packed in boxes in an airtight plastic bag with the help of a rudimentary vacuum. The equipment required for this is not expensive, but remember you'll need a cool storage area and equipment to move the boxes around. Careful staff are essential.

You will also need a way of moving the boxes to your customers.

Marketing

Developing a niche market requires careful nurturing of contacts in the main buying centres. We suggest a good start could be made with supermarkets and other retailers, and the hospitality industry (hotel-motel chains and restaurants). There will be other outlets too. Go especially for those catering for people with previous knowledge/interest in tropical fruit and/or to those interested in trying something new. Try to link up with the tourist industry and use the infrastructure that is already there for that. You'll need someone who is good at finding out what the customer wants and helping you to point your system so it produces that reliably.

Through the whole process remember that you will need much of the usual infrastructure for a business – such as a way of keeping financial records, access to accountants, transport and probably some seasonal finance.

10.7 Basic Growing Requirements

Large banana cultivars such as the Giant Cavendish require the uniformly warm climates and high rainfall of tropical locations. They are also susceptible to wind breakage. Smaller bananas such as the Dwarf Cavendish types are better adapted to subtropical locations and can thrive in Northland. These can tolerate light frosts while dormant in winter. Their smaller stature and closer spacings in a plantation both protect from wind damage and, combined with rapid growth, ensure yields are similar to those of tropical cultivars (30-50 tonnes per hectare per year) (Charpentier, 1976). To achieve all that of course they must receive sufficient water and nutrients.

All bananas prefer warm sunny conditions with a high rainfall (over 1000 mm or less if you can supplement rainfall with irrigation), with nil to minimal frost in winter. Shelter from strong winds is important to reduce toppling and leaf tattering. Frosts are damaging to leaves and will set back plants considerably. Mature plants will survive some frost and continue to fruit.

Bananas are a particularly hungry crop, with a high nutrient uptake. No matter how high the initial fertility of your site, if you want to maintain good yields and quality you will need to replace the nutrients that are removed from the plantation. This need is unavoidable – banana palms are big plants and the fruit themselves have high nutrient concentrations (that is one of the main reasons why bananas are a desirable food). One tonne of bananas contains around 2 kg nitrogen, 0.3 kg phosphorus, 5 kg potassium, 0.4 kg calcium and 0.5 kg magnesium (Jacob and Uexküll, 1963). So a crop that yields 30 tonnes of fruit per hectare will remove 60 kg of nitrogen per hectare and 150 kg of potassium per hectare.

Maintaining a high level of soil fertility (especially soil nitrogen and potassium) will be one of the most challenging aspects of organic banana production in Northland.

Bananas also need ample supplies of water. Irrigation will be highly desirable in dry spells. Bananas need an extensive and deep root system to give them plenty of access to water from the soil (they also need a strong root system close to the surface to give the plant the support it needs). Having said that, be careful not to irrigate *too* much, and don't grow the crop on poorly drained soil. The root system is sensitive to waterlogging, and the diseases that follow it. Furthermore, too much water will also wash away a lot of nutrients and, as you will have gathered above, that's not a welcome prospect. After heavy rain or irrigation the water should be gone from the soil surface within a day.

Loose, well drained, deep and fertile soils are thus important (e.g. rich alluvial or volcanic soils). Improving and maintaining a topsoil rich in organic matter is achieved through heavy mulching, which also reduces weed competition and minimizes labour and working of the soil.

10.8 Conclusions

- There is good potential to establish bananas as a commercial crop in the study area (see Chapter 18).
- Concentrate on bananas as a specialist niche crop, using specialist cultivars.
- Organic production looks to be an approach worth pursuing.
- It is a bad idea to try producing bananas as a bulk commercial crop like those New Zealand imports. We simply cannot compete, and the climate is not suitable for the world's main cultivar of banana.
- Initially at least we suggest the target market should be the local tourist and hospitality industries.
- There are some well-defined areas that look suitable for growing bananas and these should be investigated in more detail.

10.9 Information Sources

People

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11. Growing yerba mate

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Yerba mate is a small evergreen tree with the botanical name *Ilex paraguarensis* St. Hil. It originates from the Chaco region of South America. The leaves are made into a mate tea.

At the start of this project there was much community group interest in developing black tea as a product from Western Kaipara and the Hokianga. However, there is strong world-wide competition in the tea industry, and growing and processing tea profitably can be very demanding. So the scientific advisors suggested yerba mate as an alternative, and this was accepted by the community groups.

Mate fits into a peculiar group of market items that are bought and used because of a powerful image or mystique associated with ancient traditional lore. Mate tea is a drink that has profound cultural significance and is almost venerated in southern Brazil, Paraguay, Uruguay and Argentina. The cultural importance of mate preparation has been compared to the Japanese tea ceremony.

Mate contains mateine (a caffeine derivative), theobromine, theophylline and trigonelline giving tonic and stimulant effects. Mate is claimed to improve digestion, intellectual ability, health and well-being. By reducing appetite, it is proposed as a support for weight loss programmes. It is also considered to have medicinal attributes, and particularly anthelminthic properties (i.e. it can kill intestinal worms). On the downside, there are some indications that large quantities of mate may be considered one of the risk factors for oral and oropharyngeal cancer (Goldenberg, 2002).

It has been claimed that "mateine has the stimulatory effects of caffeine without the side effects: it does not seem to be addictive; it seems to regulate sleep patterns rather than interrupt them and promotes a better (deeper and more refreshing) quality of sleep; and it doesn't have the depressant letdown familiar to coffee drinkers" (Anonymous, 1998). Mate contains significant amounts of vitamins C, thiamine (B1), riboflavin (B2) and B complex, plus several forms of carotene precursors to vitamin A. But there's more – mate is especially high in potassium and magnesium and it has high levels of antioxidants (anti-ageing substances).

Picking up on these qualities, a variety of modern beverages have incorporated mate into their composition as fashionable stimulant sports drinks. But the ancient convention of hospitality and friendship, which is inseparable from the ritual of drinking mate in the traditional manner, is still one of its strongest attractions, over and above any physiological effects it may have. Probably for this reason, mate seems to have been adopted by many Māori in New Zealand. Although mate can be drunk as an infusion like any herbal tea, the tradition is to drink it in a gourd with a metal straw, which is passed around a circle of people as a form of communion.

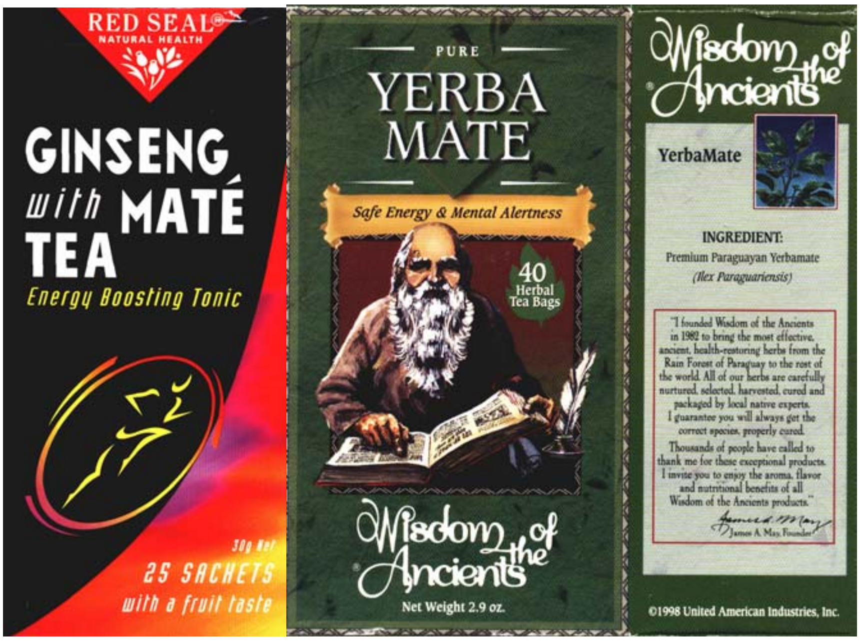

Figure 11.1: Some current mate products.

11.1 Why Grow Yerba Mate?

Well, if only half of the benefits claimed are true it would have to be a good bet!

The economic evidence strongly suggests that there is good potential for a mate producing industry in New Zealand – particularly if we can stimulate local consumption and do some exporting too. In the last decades, the admiration for mate's properties and history has spread to many areas including the Middle East, Germany and the United States. So internationally there is good market potential for a fledgling New Zealand industry that can produce good quality product. We'll look at the industry statistics shortly, but we should also note that compared to some new crops mate will have an advantage of being relatively easy to grow in the study district. We do have to make sure the leaves are processed carefully, and initially at least there will need to be a well-focused marketing drive ready for the first lot of product.

Mate fits well with the community groups' requirements for new crops. In particular, mate doesn't require a lot of special skills and money to grow, and it can be grown on a relatively small scale. We have to bear in mind though that it will not be a quick start crop – we need to multiply up the plant material available for plantations, and once planted it will take at least two years to establish a vigorous growing stock that can be harvested.

As with other products surrounded by mystique, mate production has an aura of the terroir. (Terroir is a concept of the whole growing environment of the plants and how it affects product quality, it is a much used word amongst the wine industry). Overseas, mate sells best when it is produced by sustainable growing and harvesting methods, and if it is grown from particular soil types. In this context, it is particularly important that, at present, over half of world production is harvested from the wild because plantations cannot produce enough to meet demand. As wild reserves diminish, new plantations are required to supply the demand. However, large scale mechanized plantations defeat the image of an environmentally friendly crop, and so fetch lower prices. There is an opportunity to develop small scale mate plantations with environmentally friendly methods in New Zealand. With these we need to emphasise the concept of clean and green production, good soils, ideal climates and socially-responsible procedures. This is just the image that the Hokianga and Western Kapaira community groups would like to use when marketing their produce.

11.2 Industry and Market Size

World mate consumption is increasing rapidly, from around 300,000 tonnes of dried leaf in the early 1990s to 890,000 tonnes by 2001 (FAO, 2002). The main producers are Brazil, Argentina and Paraguay. A testimony to the rapid growth of the market for mate around the world is the fact that it is traded in over 70 countries. More than 60,000 tonnes were traded internationally (export-import) in 2001. Over the last 15 years, the value of the international trade has more than doubled to around US$60 million. The overall value of mate production around the world is around US$1 billion. Apart from South American countries, where its popularity dates back many years, large importers include Middle East countries (particularly Syria, Lebanon, Israel), the United States and Europe (particularly Spain, Germany, France).

The bulk wholesale value of mate varied in 2001 from lows around US$250-1000 per tonne for countries in South America, Asia and Africa; up to US$3400-8000 per tonne in Japan, some European countries, Nepal and Bahrain. Because of its traditional image, retail prices of mate vary enormously according to quality, location, market target, packaging and promotion. In Argentina, one kg packages of loose mate sell for anywhere from two to seven New Zealand dollars. Argentinian mate exported to Europe can be retailed there at a middle price of NZ$6.50 per kg. In the US, however, loose mate can sell at around NZ$50-140 per kg (sold in ¼ kg bags), whereas in tea bags it can sell for NZ$120-150 per kg (see references). These prices have remained stable for the last five years at least.

In New Zealand, broken leaves rose in retail price from NZ$45 per kg in 1993, to NZ$52 in 1998. This compares to around NZ$10 per kg for common tea. However, the overall market in New Zealand is minuscule, with few people aware of this interesting tea. Marketing mate locally will require promotion and education about the plant's physical and cultural attributes.

11.3 Infrastructure

Growing the crop

Mate is produced under several very different production regimes. At one extreme, the crop is intensely managed in a typical conventional agricultural setting, planted as a monoculture in prepared soils, sprayed, pruned, and mechanically harvested. At the other extreme, mate is harvested from wild stands. In between, there are various semi-wild harvesting regimes where natural stands of mate are enriched with new plantings in amongst the native forest, to plantations interspersed amongst a few remaining native trees (agroforestry, e.g. Eibl et al., 2000). In semi-wild organic production systems harvests may be spaced out as much as 2 to 4 years.

For intensively managed plantations, plants are grown from seed, which take several months to germinate after stratification. Plants are also obtained from cuttings under appropriate conditions and tissue culture is also an option (Sansberro et al., 2000).

Mate requires at least two years to establish a vigorous growing stock. Depending on growing conditions, and the harvesting regime, reasonable harvests may be obtained from 3 to 5 years after planting. The plant will produce for at least 20 years, with each tree producing over 30 kg of leaf per year.

Mean yield varies considerably in different production areas, from less than 2 tonnes per hectare dry leaf in Argentina to well over 7 tonnes per hectare in Brazil (FAO, 2002).

Most harvesting is still done by hand, although mechanization is increasingly common in large plantations. Staff need to develop some skills in selecting the best material to harvest.

Processing the tea

In semi-wild plantations harvested leaves are flash dried over flames then are "roasted" in open sheds for 24 hours. The material is then ground and separated, according to quality, into either pure leaf or leaf plus bits of stems.

We expect that in Northland the processing will be closer to the procedure used in large plantations overseas. The main infrastructural requirements for this are some centralised buildings that several growers can use, some heating drums and staff that are well-trained in operating the process. Let's look at that process in a little more detail.

1. Leaves and twigs at around 60% moisture are subject to flash drying, a process called parching (at 400°C for 1 minute) in drums down to 25% moisture. The initial parching is performed to inactivate leaf enzymes, as in the manufacture of green and black teas.
2. Leaves are then pre-dried for another 1-2 minutes at 80°C in drums with a hot air current. This brings the moisture down to ~15%.
3. Then leaves are dried for another 4 hours at 80°C on a conveyor belt with a forced air current, bringing the moisture content down to 8-9%.
4. The next step is grinding with rollers and, depending on the quality desired, removal of the twigs.
5. This raw mate is then carefully fermented (as is black tea) and this takes patience. Fermentation is done either naturally (at room temperature, for 6 months - 1 year) or artificially (50-60°C hot air current, 30-45 days).
6. Often the final step is grinding, sieving and blending to produce green mate. Sometimes, a further roasting produces roasted mate (Stradella, 1997).

The conditions described above vary from one processing plant to another and are considered part of the carefully guarded trade knowledge leading to the particular taste of each blend. Quality of the product will depend on variations in each of the steps (Bertoni et al., 1992; Schmalko and Alzamora, 2001).

Sales and marketing

The infrastructural needs here are very similar to other crops under consideration. First off, choose the initial target markets: we suggest a combination of the local tourist and hospitality industries, retail in health food shops and supermarkets in the rest of New Zealand (especially Auckland and Wellington), and as you build experience in producing quality mate go for the export markets.

A key factor here will be to schedule your initial marketing efforts to match the production. It will be important to deliver good quality mate reliably as the marketing efforts kick in. If you start with the local tourism and hospitality industries you can take advantage of their already well established infrastructure. You will need to build and maintain good working relationships with these people, so they know they can rely on you for good quality product when they need it.

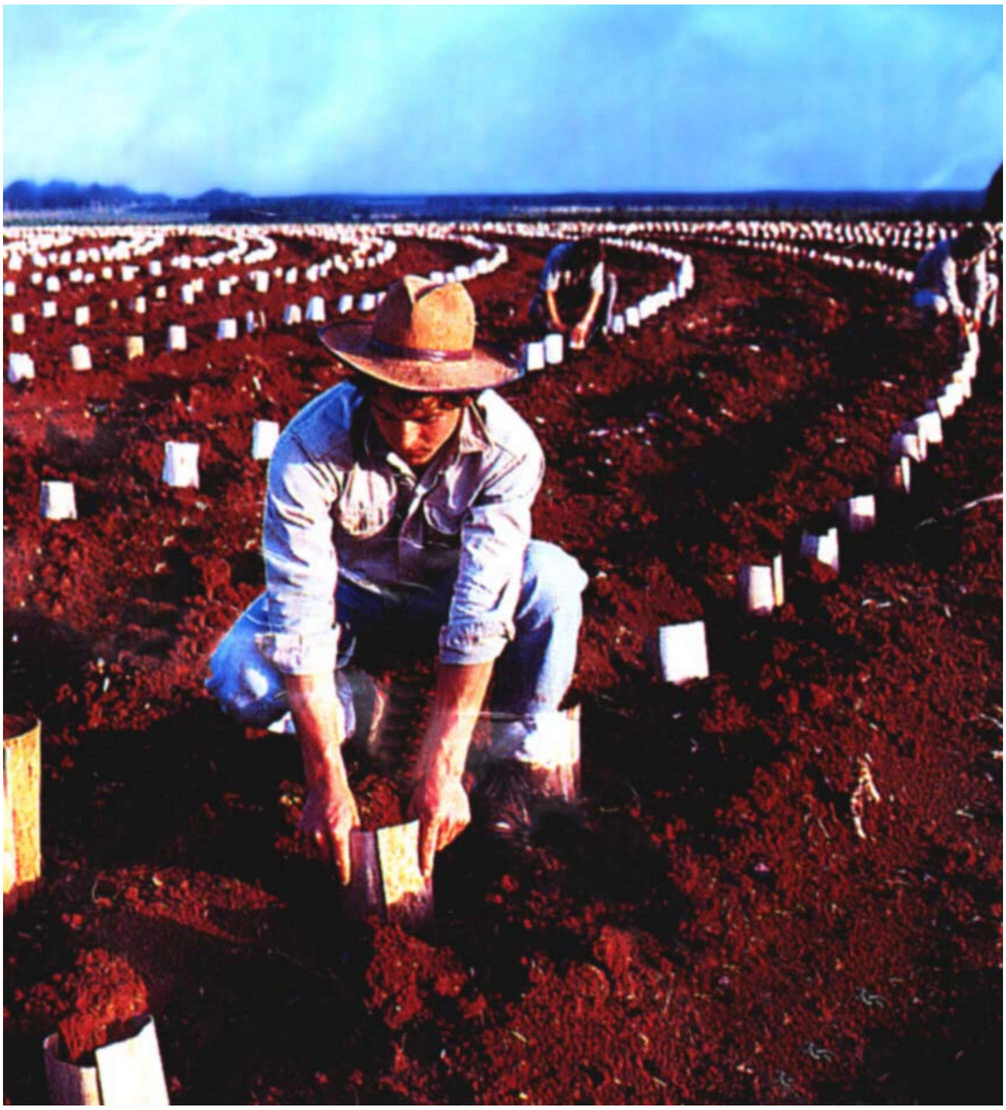

Figure 11.2: Establishing a monoculture mate plantation in northern Argentina.

Figure 11.3: Mate monoculture plantation in Misiones, Argentina.

Figure 11.4: Semi-wild mate plantation mixed with native Araucaria trees in Misiones, Argentina.

11.4 Experience Growing Mate in New Zealand

Mate has only recently been introduced into New Zealand. There is little New Zealand experience in growing this crop but careful extrapolations can be made on existing trials and on mate's growth range in South America. Trials show healthy growth in coastal Otago, although heavy frosts (below -5°C) can devastate young (less than one year) plantings.

At Invermay, near Dunedin, plants have been grown since 1993. They have produced healthy foliage each year and flowers since 1997, thriving in the Dunedin summer. Hardened leaves have tolerated winter temperatures down to -4°C and -6°C. Below this temperature, damage will occur in young plants. Plants are also growing on the Otago Peninsula and in several commercial trials in coastal Otago. They have also grown well (up to flowering stage so far) at Riwaka, Nelson.

Climate and soil comparisons suggest mate could produce good quality harvests in areas of coastal Otago and coastal Westland in the South Island and Taranaki up to Northland in the North Island. This range can be extended at the cost of higher investment in shelter and irrigation. Quality assessment trials are necessary in different New Zealand environments. We are not aware of any trials so far in the North Island.

Figure 11.5: Young mate growing at Invermay.

11.5 Basic Growing Requirements

Mate tolerates acid (low pH) soils; a pH range from 4.6 to 7.2 is adequate. At higher pH levels, mate growth rates and quality (mineral content) tend to decline (Reissmann et al., 1997). Soils should ideally be deeper than one metre, but mate often grows well on soils with impeded hardpans. Although good drainage is preferable on intensively managed plantations, semi-wild plantations do well with restricted drainage.

The natural home of mate is the Paranaense forests of eastern Paraguay, southern Brazil and north-east Argentina on the ancient basaltic plateau of the Paraná highlands. Mate occurs on slightly acid tropical oxysols high in iron content. These are often poorly drained and may have a hardpan with a pH down to 4.5. The climate is hot and very wet in summer (> 1000 mm precipitation) but dry and cool in winter. In spite of its tropical origins, mate has adapted to southern New Zealand, as mentioned above. This is because mate climbs into montane areas where mean annual temperatures are 15°C or less and where frosts are not uncommon in winter (Duke, 1986; Gepts, 1997; Giberti, 1994; Hueck, 1978).

The fact that mate already grows well in southern New Zealand suggests that it will do even better in Northland, which more closely approximates the climate and soil conditions of its native environment. Being a small tree, Mate is ideally suited to grow on slopes that are too steep for annual crops but can still be productive. Final leaf quality (particularly mateine or caffeine content) is also influenced by rainfall during the growing season (Bertoni et al., 1992).

11.6 Conclusions

- Mate is a popular and profitable crop overseas, local demand is growing but still small.
- There is good potential to establish a local industry producing mate tea for local sale and eventually for export.
- A large part of the study area appears to be well-suited for mate production (see Chapter 18).
- Setting up mate production is not a short-term proposition. Plants will take 3-5 years to get into full production, and then processing the tea itself can take up to 12 months.
- Plantations will be needed, and processing facilities. Physically, these are not particularly difficult to achieve.
- The most crucial requirement is building up the skills needed to process the mate leaves into a high-value tea.

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General information

For prices and top of the scale retailing on the web see for example www.dealtime.com; www.shopnatural.com; www.wisdomherbs.com

12. Growing avocado

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The avocado is a large evergreen subtropical tree that originated in the rainforests of Central America. There are three distinct types of avocados, Mexican, Guatemalan and West Indian, originating from different environments. Hybrids between these types are common, providing many hundreds of cultivars (cultivated varieties). Hass (a Guatemalan hybrid) is the most common cultivar overseas and the only cultivar grown for export in New Zealand. However there are other early and late maturing cultivars that may be grown to suit local market niches.

Figure 12.1: An avocado tree.

12.1 Why Grow Avocado?

Avocados have been grown commercially in New Zealand for many years. In recent years the industry has expanded rapidly, become well organised and focussed. Cultural techniques are well documented and advice for growers is readily available.

1. Avocado orchards are well established in Northland with commercial planting around Whangarei and in the Far North producing 30% of the national crop. Orchards in the Far North region have an advantage of early fruit maturation and harvest.
2. Avocado orchards need capital and time for development, but management of the crop is not as intensive as for example kiwifruit, citrus and apples.

3. Avocado fruit are unique and have positive health benefits. They contain monounsaturated fatty acids and Vitamin B, but very little saturated fat and no cholesterol.
4. The infrastructure required for producing, packing, processing and marketing avocado is already available in Northland.
5. Export and local markets for avocados are well established. The industry is expanding and seeking new markets in response to increasing market demand both within New Zealand and overseas. There is also a demand for fruit for processing to produce a high quality cooking oil.

12.2 Current Industry Status and Market Size

In New Zealand avocados are grown on around 2646 hectares of land, with 55% of plantings in the Bay of Plenty and 30% of the crop grown in Northland. The industry is expanding rapidly and the planted area is expected to increase to 4,500 hectares by 2008. As avocados take four of five years to begin bearing fruit and up to 12 years before full production is reached, it will be some time before current and anticipated plantings reach their potential. Less than half of the current plantings are old enough to bear fruit. However the industry has planning and market development underway to cope with the projected increase in production.

In 2001, two million trays of fruit, with a value of $28.3 million were exported from New Zealand. Export production has increased by 370% over the past 6 years and is expected to triple again to 6.2 million trays by the 2004/5 season. Exports from New Zealand have some advantages due to our high fruit quality and food safety standards. Approximately half of all exports are sold in California and the other half go to Australia, the traditional export market for New Zealand avocados. The Californian market is expected to expand as consumption increases from a modest 1 kg of fruit per capita. However the industry faces significant competition in this market from locally grown fruit as well as imports from Mexico, Chile and Peru. In Australia there is increasing local supply from orchards in Western Australia. Therefore new markets are being developed in Asian, European and Pacific countries.

Around 700,000 trays of avocado are sold on the local New Zealand market, and this is expected to double in response to vigorous campaigns promoting the health benefits and many uses for fruit. Facilities to produce high value avocado oil have recently been established in the Bay of Plenty and Kerikeri. The market for oil is increasing rapidly both in New Zealand and overseas, creating a demand for second grade fruit. New Zealand Dairy Foods has recently developed the world’s first avocado and olive oil spread and this is also expected to be popular.

12.3 Infrastructure

To produce high quality export fruit, avocados should be grown in well-maintained orchards. Trees need a high degree of care in the first few years after planting to establish a good framework for future production. Cultivation of avocados is moderately intensive and trees will need some shelter and may need mulching to maximise fruit yields. Avocados are susceptible to water stress during flowering, fruit growth and flushes of vegetative growth during summer and autumn and will need to be irrigated with high quality water during dry periods. Equipment will be required for mowing the orchard, mulching, weed, and pest and disease control. Fruit can be harvested from young trees from the ground or using picking ladders. However as the trees increase in size they are generally harvested using cherry pickers.

Packhouses play a key role in the marketing of avocado fruit. There are established packing facilities in both Whangarei and the Far North and the crop can be readily transported to them. The industry has developed standards for handling, packing and cool storing of fruit, to ensure that only the best quality fruit reaches market. Packhouses determine which exporter and local market outlets fruit are sent to. Avocado exporters include Primor Produce, Freshco, Global Fresh, Integrow, Team Avocado, Fresh Max, and Turners & Growers. There is a processing facility in Kerikeri (Olivado NZ Ltd), which uses poorer quality fruit to produce avocado oil.

The avocado industry is well organised. The New Zealand Avocado Growers Association (AGA) is a national organisation that promotes growers interests. While the Avocado Industry Council (AIC) manages the industry, sets industry standards, registers growers, licenses exporters, develops the export marketing strategy and manages research and development for avocado growers. The industry also has regional focus groups in both Whangarei and the Far North developing guidelines for avocado management practices, running field days, carrying out surveys and research and encouraging the exchange of information between growers.

12.4 Basic Growing Requirements

Avocados have a shallow and inefficient root system, which can't survive in waterlogged soils, even for short periods of time. In wet soils, trees are highly susceptible to the root disease *Phytophthora cinnamomi*, which causes rotting of actively growing feeder roots and eventually tree death. One of the key requirements for avocado trees is a deep, well-aerated and well-drained soil. Additional drainage will be required if there is any chance of the soil becoming waterlogged. Mature avocado trees are large and need to be planted in a soil with a good rooting depth (0.9m or greater) to ensure they are well anchored. Shallower soils may be considered (0.6-0.9m) if they have good physical properties and the trees are planted on raised mounds.

Avocado trees need to be planted on a site that is relatively flat or slopes gently to the North or North East. This allows easy access for machinery such as tractors and for growers to carry out cultural operations like pruning and harvesting fruit from ladders or cherry pickers. The maximum suitable slope for avocados, like many tree crops, is about 8.5% (equates to NZRLI slope class C).

Avocado trees also need a regular supply of water during the dry months in order to produce good crops of large fruit, and will generally need to be irrigated. Rainfall will need to be considered, together with soil properties in order to determine both drainage and irrigation requirements. The ideal soil pH for avocados is 6.0-6.5, although a range of 5.5-6.9 is satisfactory. Sites which have pH levels below this will require heavy additions of lime, incorporated throughout the root zone to prevent nutrient deficiencies and toxicities.

Avocados are subtropical trees and in New Zealand low temperatures will limit their growth. Flower buds are very susceptible to damage from frosts and low temperatures during spring (September-October). Successful fruit set only occurs when there are warm temperatures during flowering. Temperatures at this time must be above 17°C during the day and 11°C at night over two consecutive days to ensure flowers are pollinated and fruit set occurs (Hopping 1981). Frosts will damage the fruit and foliage of mature trees and may kill small trees.

Avocado trees require high light levels to produce high fruit yields. Trees perform best on NorthEast or North-facing slopes, which are warmer and have higher light levels than other sites. Trees should not be grown on shaded or South-facing slopes. Avocado trees need some shelter to prevent wind damage to trees and fruit and well-managed shelterbelts can also be used to increase temperatures in the orchard. Too much shading from shelter or other trees in overcrowded blocks will cause the trees to grow very vigorously and produce few fruit.

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13. Growing cherimoya

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The cherimoya belongs to a large family of subtropical and tropical fruit, including the atemoya or custard apple that is a significant crop in Queensland. The cherimoya is native to the cool dry upper highlands of Ecuador, Colombia and Peru where the fruit has been known since ancient times. The semi-deciduous tree produces large green fruit that mature in winter and early spring. The cherimoya is grown commercially in Chile, Argentina, California and Spain. Many cherimoya cultivars have been imported into New Zealand.

Figure 13.1: Cherimoya.

Source of photo: http://www.hort.purdue.edu/newcrop/morton/cherimoya.html

13.1 Why Grow Cherimoya?

Cherimoya is an unusual subtropical fruit crop that grows well in warm frost-free conditions. They have been grown commercially in New Zealand on a limited scale. Cherimoya were chosen for this project because:

1. Cherimoyas grow well in Northland.
2. Considerable research and development was carried out on cherimoya in Northland during the early 1990's and cultural techniques for commercial production have been established.
3. Cherimoyas are easy to grow and can be grown on a small scale with moderate capital input.
4. Cherimoyas are a favoured fruit in the USA and they have definite marked potential although export and local markets are not well established.

13.2 Current Industry Status and Market Size

The cherimoya industry is very small with an unconfirmed estimate of 5000 trees in New Zealand. A number of commercial plantings were established in the 1990's in Northland and the Bay of Plenty. High quality fruit were exported to niche markets in Japan and California and received excellent prices. For a few years there was little competition for New Zealand fruit, however when Chile gained access, the market for New Zealand fruit collapsed. There were few other efforts to develop the local or other export markets and many of the trees were removed. Currently, the local market, although undeveloped, is the main outlet for fruit.

Cherimoya fruit have many appealing and marketable attributes. They ripen in late winter - early spring when few other fruit are available. The fruit are known and there is a good demand for them in the USA and Asia. Cherimoyas are closely related to custard apples that are well known by consumers in Australia and Asia. Although New Zealand consumers are generally not familiar with the fruit, most local consumers (about 80%) like the fruit when they taste it and would buy it. However they need to be educated about cherimoya and what to do with it. To be successful growers would need to develop their own markets, for example restaurants and tourists.

Cherimoya are generally eaten fresh and not processed. In South America frozen cherimoya pulp, ice cream, sherbet and soft drinks are produced from the fruit. Cherimoya trees also contain high levels of alkaloids that have insecticidal and other properties.

13.3 Infrastructure

Cherimoya trees need to be carefully established and well maintained to produce a good crop of high quality fruit. Trees are very vigorous, although they have a weak root system. They need to be well pruned and may need to be supported by wires or a simple structure. The trees are very susceptible to wind damage and will need to be grown in well-sheltered blocks. During summer dry periods the trees need to be irrigated to ensure good fruit set and growth.

Limiting tree size and maintaining good structure is essential to provide access to trees for hand pollination, harvest and providing cover for the fruit so they are not exposed to extreme temperatures. Hand pollination of flowers is essential to ensure that trees produce a good crop of uniformly shaped fruit. Growers will need to ensure they have sufficient labour available in December and January to pollinate flowers. The fruit ripen during late winter and need to be harvested on a regular basis. Possums also like cherimoya fruit and may need to be controlled. Cherimoya trees have few pest and disease problems.

The fruit can be easily packed on an orchard. Cherimoya fruit have a relatively short shelf life (14-28 days) and need careful post-harvest handling and cool storage at 8-12^{o}C. They sustain significant chilling injury if they are stored at temperatures of 0-4^{o}C used for many other fruit and vegetables. There are no established export or local marketing systems for cherimoya fruit. Individual growers have organized niche markets for the fruit.

A considerable amount of research has been carried out on the culture of cherimoya in New Zealand. Practices have been established for key operations like propagation, hand pollination and pruning. Cultivars of cherimoya have been assessed and a number of these are available to growers. There is also considerable information available from overseas.

13.4 Basic Growing Requirements

Cherimoya trees will not tolerate poor soil conditions. The trees have a weak root system that is susceptible to bacterial root rot in waterlogged soils. Trees require a well-aerated, well-drained, deep soil (0.9m or greater) to perform well. They will grow satisfactorily on shallower soils with good physical properties that are mounded to increase soil depth. Cherimoya trees will not tolerate water logging and additional drainage will be needed where there is any possibility of this occurring. Optimum soil pH for cherimoyas is in the range of

6.0-6.5, where nutrients are freely available to plants. If soils have lower pH levels, lime should be incorporated throughout the root zone to modify soil pH and nutrient availability.

Cherimoyas should be grown on flat or gently sloping sites to allow easy access for equipment and to carry out tasks like pruning, pollination and harvest. Trees perform best on warm sunny sites, and should not be planted in shady conditions. North or NorthEast facing slopes are most suitable for planting.

Cherimoya trees are large, have soft wood, weak branch angles and weak roots. They are extremely sensitive to wind damage, and even moderate winds can cause tree failure, limb breakage and wind rub on fruit. Trees are particularly vulnerable to wind damage when they are carrying heavy loads of large fruit. Good shelter is essential for cherimoya orchards.

Cherimoyas come from areas with mild temperate or subtropical conditions and are sensitive to cold temperatures and frost. The best sites for cherimoya orchards are those that are frost-free and relatively warm. Mild frosts will damage leaves and small twigs on mature trees and may kill young trees, while temperatures below -4^{o}C will kill mature trees. Cherimoya fruit mature during the winter and cool temperatures (below 4^{o}C) near harvest will cause blackening of the fruit skin or splitting of the fruit. However trees do need winter conditions to co-ordinate leaf drop and bud break in spring. Warm temperatures during flowering (December – January) promote flower development, pollination and fruit set.

Uniform soil moisture levels are necessary during fruit set and fruit growth to ensure high yields of good-sized cherimoya fruit. Rainfall patterns throughout the year and soil properties need to be considered to determine irrigation and drainage requirements. High humidity enhances pollination and fruit set, but excessive rain during flowering can lead to fungal damage and lost of flowers.

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14. Growing fig

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Figs have been cultivated by man since ancient times (4000 BC) and are well known throughout the world. This unusual fruit grows on a deciduous subtropical tree, native to Western Asia. Commercial plantings of figs are mainly located in Mediterranean countries like Italy, Portugal, Spain, Turkey and Greece but some are also grown in California, Argentina and Australia. There are several types of fig, but only the Common and San Pedro types are grown in New Zealand. A large number of cultivars (cultivated varieties) of each type are available.

Figure 14.1: Figs growing in an orchard (left) and dissections of the fruit (right).

Source of photo: http://www.valleyfig.com/

14.1 Why Grow Figs?

Figs have been grown successfully in home orchards since early European settlers first brought them to New Zealand. The crop is relatively easy to grow and well known but has only recently been planted as a commercial crop. Figs were chosen for this project because:

1. Figs grow well in Northland and cultivars have been selected that are suited to growing conditions in the region.
2. Figs are easy to grow and can be grown on a small scale with only moderate capital input.
3. The fruit are nutritious with high levels of calcium and iron.
4. Figs can achieve good prices on the local market, but the fruit are not suitable for export because they do not have a long life after harvest. There are a number of processing options including drying, canning, or making the fruit into jams, pickles, other preserves, wines and liqueurs that can add to the value of the crop. Markets for fresh figs are not well established in New Zealand and would need to be developed. Currently most fruit is sold direct to hotels and restaurants.

14.2 Current Industry Status And Market Size

Figs have been grown commercially in New Zealand for a few years, but only on a small scale. Production of figs is increasing as trees mature and new plantings are made, but is expected to remain on a limited scale. Fruit have been sold on the local market for good prices, but demand and prices may change as production increases. Growers will need to establish their own niche markets for example to restaurants and other tourist outlets. Many consumers are familiar with fresh figs, however some will need to be introduced to the fruit and how to use them. Figs don't last for long after harvest and this limits the distance they can be transported and how long they can be held before sale. Suitable postharvest treatments may extend the keeping ability of figs.

Figs are very suitable for processing into a range of products and this can be done on a small scale. Traditionally figs have been dried to extend their useful life and allow them to be shipped to distant markets. They are also made into jams, pickles, chutneys and other preserves. In many countries fig paste is used to make cakes and sweets. Figs are also made into wine, brandy and other liqueurs.

14.3 Infrastructure

To produce high quality fruit, fig trees need to be well maintained and cared for after planting. The fig is a vigorous tree that can be easily propagated from cuttings. Trees will need shelter to prevent wind damage to the lush canopy and fruit. Although figs can tolerate dry conditions they need plenty of water during the growing season to produce large succulent fruit. Growers will need to have a good supply of water for irrigating trees during dry periods.

Fig trees are quite large and will need pruning to prevent shading of fruit, which delays ripening. Limiting tree size will also ensure that fruit are easy to harvest. The fruit, which ripen in February and March, need to be picked daily as they spoil quickly and will split if it rains. Figs are very popular with birds and growers may need to consider some form of bird protection. Although the crop has fewer pests and diseases than many other fruit crops, fig rust can be a problem and will need to be controlled with fungicides.

Since commercial production of figs has been on a small scale, there is no industry infrastructure and very little support available for growers. The Tree Crop Association has a grower group who are investigating appropriate cultural techniques and fig cultivars for New Zealand conditions. There is a large amount of overseas information on growing figs, although this information is often more relevant to areas with dry climates.

14.4 Basic Growing Requirements

Fig trees are surface rooted and will not tolerate waterlogged soils for more than a few hours. They should only be planted in well-aerated and well-drained soils. Additional drainage will be required if there is any possibility that the soil may become waterlogged. Fig trees are very vigorous and perform extremely well in deep soils. However they will grow in shallower soils (0.6-0.9m) and some restriction of the rootzone may help to reduce the vigour of trees. Figs should be planted on flat or gently sloping sites to allow easy access for equipment and cultural operations like pruning trees and harvesting fruit.

As with most tree crops, figs grow best at a soil pH of 6.0-6.5 where nutrient availability is not limiting. However sites with soil pH below this may be satisfactory if additions of lime are incorporated throughout the rootzone before the trees are planted.

Figs generally grow in warm, relatively dry climates. Trees may require a small amount of winter chilling (cool temperatures during winter) to ensure good flowering in spring. Although mature trees will tolerate very cold temperatures when they are fully dormant, temperatures below $0^{o}C$ will damage actively growing trees. Fig trees need warm temperatures and plenty of light to produce good fruit. They should be planted in full sun, preferably on warmer North or NorthEast facing slopes.

Fig trees require a steady supply of water throughout the growing season to produce large, juicy fruit. They will need to be irrigated during dry periods on most sites in Northland. Figs mature during February and March and will split if the weather is very wet during ripening. Birds can also cause significant damage to ripening fruit. Fig trees are more tolerant of wind than other fruit crops. However fruit and leaves may be damaged by wind and plantings should be sheltered.

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15. Growing blueberry

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Blueberries and their close relatives the cranberries and bilberries grow wild in North America and Europe on acid soils that would otherwise be unproductive. There are three major types of blueberry: the Highbush blueberry (Northern and Southern; are the main cultivated type), the Lowbush blueberry (the main wild type) and the Rabbiteye blueberry. In New Zealand blueberry production is largely based on the Northern Highbush and Rabbiteye cultivars which require a moderate to high amount of winter chilling (cool temperatures during the winter which promote growth and flowering in the following season). Most Highbush types do not receive sufficient winter chilling and will not crop well in Northland. However a number of recent releases from breeding programmes in both the USA and New Zealand have a much lower chilling requirement and are suited to the region. Rabbiteye blueberries, with their moderate chilling requirement will also grow and crop well in Northland, but their harvest overlaps with peak production in the Waikato.

Figure 15.1: Blueberry.

15.1 Why Grow Blueberries?

Blueberry production is well established in New Zealand with the majority of growers (over 80%) based in the Waikato area. New cultivars, suited to warmer regions, have recently been released and these provide opportunities for Northland growers. Blueberries were chosen for this project because:

1. Limited plantings of blueberries have been successfully established in Northland since 1994. Warm winter and spring conditions in the region allow growers to produce fruit for high value early domestic and export markets in October and November.
2. Good growing skills and moderate capital investment will be necessary to establish and manage blueberries. Although growing blueberries is not very intensive the fruit are picked by hand, so lots of labour will be required for harvest, grading and packing.
3. Blueberries have very high levels of antioxidants and other healthy components that help the body to resist infection and disease. These health benefits have increased demand for blueberries.
4. The blueberry industry is well organised, but few facilities are available in Northland.
5. Export, local and process markets are established and the industry is currently expanding to take advantage of new opportunities. Over the past few years demand for blueberries has exceeded supply.

15.2 Current Industry Status and Market Size

Blueberries are mainly grown in the USA (97,000 tonnes), Canada (33,000 tonnes) and Poland (14,500 tonnes), with smaller areas in Chile, Australia, Germany, New Zealand and Japan. They are a relatively new crop for New Zealand, with commercial production developing over the past 20 years. Blueberries are currently planted on about 350 hectares of land, with most of the crop (80%) in the Waikato region however there are significant new plantings in Hawkes Bay and Southland and smaller plantings in Horowhenua and Canterbury. The availability of new cultivars is providing opportunities for blueberries to be planted in other regions of the country.

Blueberries from New Zealand are mainly exported to Japan and the USA although some fruit also goes to Australia, Singapore, Hong Kong and Europe. Exports have been increasing steadily with fresh fruit returning $6.8 million and frozen fruit $1.5 million in 2000. New Zealand growers face competition from Chile in the USA, Japanese and European markets, and more recently from Southern Africa in Europe. Local demand for fresh berries is increasing, mostly because of their recognised health benefits though the presence of blueberries in many supermarket products (50+) is creating far greater awareness of the fruit. Growers often freeze blueberries at peak periods of production to ensure the market is not oversupplied and good fresh prices are maintained. Frozen fruit can then be sold later in the year when fresh fruit are not available. The berries are also made into pie and muffin fillings, jams, purees, yoghurt, ice cream flavouring, toppings, wine and liqueurs.

15.3 Infrastructure

Blueberries are relatively easy to grow in a well-chosen and prepared site. For Northland selection of the appropriate low chill cultivars will be essential. Plants will need a good supply of high quality irrigation water to ensure vigorous plant establishment and fruit development. Blueberry plants respond well to organic mulch that will help to conserve soil moisture, encourage root growth and prevent weeds. Birds can cause serious fruit losses, particularly early in the season, so netting the crop is generally recommended. One of the major requirements for growing blueberries is to ensure there is a large amount of labour to pick the fruit at harvest. Between 10-20 pickers are needed daily during harvest, for each hectare of mature blueberries. Fruit for processing can be hand harvested by this is increasingly done by machine.

The blueberry industry is well established in the Waikato region with modern packing and processing facilities. Growers in Northland would need to develop these facilities to meet quality standards for export and local markets. However it is possible for growers to pack and freeze fruit on a relatively small scale. A number of marketers including Freshco, Delica, Paragon International, New Zealand Gourmet, Intermax, Le Fresh, Turners and Growers and Produce Partners are involved in export and local market sales of fresh fruit.

1. The industry is well organised and has its own industry body, Blueberries New Zealand (BBNZ) funded by compulsory levies. They promote blueberries, look after the interests of growers, set quality standards and carry out research and development. HortResearch Ruakura has had a long association with the industry providing new cultivars, research and consultancy services. The latest cultivar, 'Island Blue', released by HortResearch in 2002 was chosen for its good performance in Northland over the past seven years.

15.4 Basic Growing Requirements

Blueberries are shallow-rooted compared to larger tree crops and perform best on moist, free draining, acid soils with a high organic matter content and pH range of between 4.0-5.5. Peat soils are ideal for blueberries, however other soils are satisfactory, as long as regular additions of organic mulch are made to help improve soil water holding and nutrient capacities and the soil pH is satisfactory. Blueberries will not survive if the soil they are planted in becomes waterlogged for even short periods of time or the soil dries out too much. They should only be planted on well-drained soils, or moderately well drained soils with artificial drainage. During the growing season irrigation will be necessary to ensure good berry development and ripening.

Blueberries are shallow rooted and can be planted on relatively shallow soils (0.45 metres or deeper), compared to larger tree crops. They should only be grown on flat or slightly sloping sites. This allows easy access for workers and equipment, limits the potential for soil erosion and simplifies the installation of irrigation and bird netting. Blueberries should be planted in full sun in order to produce high yields of quality fruit. Although blueberry bushes are not as prone to wind damage as larger tree crops they may require shelter on exposed sites.

Blueberries will only thrive in acid soils with a relatively low soil pH of 4.0-5.5. Outside this range they will suffer from nutrient deficiencies and toxicities. Soil pH can be reduced by incorporating sulphur throughout the root zone. Blueberries prefer quite low soil nutrient levels in soils and particularly do not like high soil calcium levels.

Blueberries are temperate plants and require cool temperatures in winter (winter chilling) to promote budbreak and flowering in spring. Several blueberry cultivars have been tested in Kerikeri and a number are suited to the comparatively warm winter conditions in the region. Selecting appropriate cultivars is essential in Northland. Although blueberries need cool winters they also need warm conditions in spring and early summer to produce good fruit. Late spring frosts will reduce yields. Warm spring conditions in the parts of the study area may allow growers to produce fruit for a high value early market niche in October and November.

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16. Growing hydrangea

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Hydrangeas are medium sized semi-deciduous shrubs, commonly found in gardens throughout New Zealand. The many species of hydrangea are native to Japan, China and North America. In New Zealand the main type grown commercially is the traditional mophead hydrangea (*Hydrangea macrophylla*). Each bloom is made up of many flowers with each tiny true flower surrounded by coloured sepals (leaves or scales which enclose the flower bud) which make the Hydrangea so attractive. There are a large number of cultivars with varying colours and size of blooms. Colours, ranging from white, to blue, purple, pink and red and colours can be modified by soil acidity levels.

Figure 16.1: Purple, cream, and red hydrangea.

Source of photos: http://www.flowernz.co.nz/catalogue/flowers/hydrangea/

16.1 Why Grow Hydrangeas?

Hydrangeas are a well known in Europe, USA and Asia. They are grown commercially as a cut flower and a potted plant in many countries, for well-established markets. Hydrangeas are an established commercial flower crop in New Zealand.

1. Hydrangeas grow well and are grown by a few commercial growers in Northland.
2. They can be grown on a small scale with moderate labour skills and limited capital investments.
3. Hydrangeas have established local and export markets for fresh and antique (semi-dry) blooms.
4. Currently hydrangea is a fashionable flower, although this, like most fashions, could change quite quickly.

16.2 Current Industry Status And Market Size

Hydrangeas have been grown in New Zealand home gardens for many years. Commercial production has increased over the past decade since the flowers have once again become popular and will continue to increase as new plantings come into production. Market demand for hydrangeas has recently been strong with good prices for blooms.

Hydrangeas are grown throughout New Zealand, with commercial growers in Northland through to Southland. High humidity in Northern areas allows hydrangeas to be grown in more open conditions, while in parts of the South Island more protection is required. It is essential that growers pay careful attention to environmental conditions to produce high quality blooms required for local and export markets.

Fresh hydrangea blooms can be harvested from November through to March depending on the cultivars (cultivated varieties) grown, plant management and location. Flowers are a luxury crop, and patterns of demand change regularly according to fashions. Although large blooms with long stems are generally preferred, demand for size and colour of blooms can vary with markets and special events like Christmas, Valentines Day, Easter and Mothers Day. Markets require a wide range of colours and sizes, so growing a range of cultivars, particularly in large plantings, are a good idea. High quality hydrangea blooms from New Zealand have a good reputation in overseas markets, as outdoor grown blooms are hardier than those grown in greenhouses overseas.

Another option for hydrangeas is to harvest blooms later in the season as semi-dry 'antique' blooms. These are blooms that are almost dry and have turned to deep blue, burgundy or green in colour. Not all cultivars produce attractive 'antique' blooms, and there is some risks producing them as they can be destroyed overnight by heavy rain. Foliage from hydrangea bushes is in limited demand on the local market.

16.3 Infrastructure

Hydrangeas are relatively hardy and easy to grow. However to produce high quality blooms suitable for export attention to detail and providing suitable environmental conditions is important. Before planting, growers need to select a range of cultivars with potential for various target markets. Good pruning technique is essential to produce large blooms with long stems. The crop will need some form of natural or artificial shade during the summer months, otherwise the intense sunlight will damage blooms. Hydrangeas also need lots of water, so a reliable source of high quality irrigation water is essential. Blooms must be disease and insect free, so growers must be able to control insect pests and diseases when necessary.

Hydrangeas can be harvested and packed by a grower or a group of growers with a few basic facilities. After harvest, blooms are stored in buckets of water in a cool shady place overnight, to maximize water uptake. Growers will also need space to prepare and grade blooms for export. Export blooms will also need to be fumigated because the large heads provide an ideal home for insects and spiders. If the material is to be held for any length of time before being dispatched some cool store facilities may also be required.

Transport firms in Northland collect packed flowers from growers and deliver them to wholesalers and exporters. Hydrangea blooms can be marketed through a number of companies who facilitate local or export markets sales e.g. Turners and Growers, Auckland Flower Exports, Auckland Flower Wholesalers and Metro Flowers.

16.4 Basic Growing Requirements

Ideally hydrangeas should be grown in a rich loamy soil with plenty of organic matter that can supply plenty of nutrients and water to support vigorous plant growth. The soil should be free draining, so water should not lie around for more than an hour or two, even after a real Northland downpour. Soil pH or acidity can be used to modify the colour of hydrangea blooms. Under acid soil conditions blooms will tend to be blue, while in more neutral soils they will be pink or red. Soil pH can be altered with lime or sulphate of ammonia.

The site should be relatively flat or gently sloping to provide easy access and simplify plant management. Hydrangeas need to be sheltered from the wind to prevent damage to plants and blooms. However some air movement around plants is beneficial in humid areas like Northland, where disease may become a problem.

Hydrangeas need overhead irrigation or misting to produce large, high quality blooms. During the hot summer months, blooms will quickly become dehydrated, bleached or burnt if they are exposed to full sun. Therefore plants will need to be partially shaded either by trees, buildings or artificial shade during the sunny, summer months. Blooms can also be damaged by heavy rain or hail. Hydrangeas are frost hardy and need cool temperatures during winter to ensure plants flower well during the following spring.

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17. How to read a crop potential map and methodology used

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Climate and soil factors, which are known to be of importance for crop growth, were identified for each of the ten crops. These are shown on the left hand side of the crop potential maps, while the crop potential maps themselves are shown on the right hand side of the page. As an example, 6 factors were identified as being very important for optimal fig growth (Map 44) – these were extreme minimum temperature, soil slope, winter chilling, soil pH, soil drainage, and soil potential rooting depth.

In each left hand side map, there is a range of 'suitability' given – optimal (shown in green), marginal (shown in cream), and unsuitable (shown in brown). The horticultural scientists outlined the limits of tolerance for fig for each of these left hand side factors. For example, it is known that Fig are frost-sensitive during growth, so that an optimal extreme minimum air temperature criterion is considered to be warmer than zero degrees (> 0 °C, no air frosts). Marginal extreme minimum temperature conditions were deemed to be between 0 °C and -2 °C, while totally unsuitable conditions were identified as cooler than -2 °C (< -2 °C).

In each left hand side map, each colour corresponds to a number – optimal (2), marginal (1), and unsuitable (0). For each 'pixel' or 500 metre by 500 metre square, the numbers from the smaller left hand side maps are added together, using a computer analysis tool called GIS, to achieve a total, shown in the right hand side map. Given that each left hand side map contains estimates (with associated uncertainty), a 'sliding scale' of suitability is presented in the crop potential map on the right hand side. That is, there are no areas labelled "suitable" or "unsuitable", just a *range* of suitability.

The highest possible total in the fig potential map is 12, and areas with this high potential for fig growth are coloured purple. The * symbol indicates the highest total actually obtained in the analysis, which just happens to be 12 in this map. You can see purple areas on the map, such as the valley near Taheke, which show high potential for fig growth.

On all the crop potential maps, purple always corresponds to the highest potential, green corresponds to the middle or medium point on the colour scale, and red colours always show low potential – no matter how many factors there are on the left hand side.

One final caution – there is no "global limiter" in this analysis. This means that for a place like Dargaville, which shows a medium (green) fig suitability rating, it may actually be quite difficult to grow figs well – because of one of the factors, soil drainage class. For this particular factor, the Dargaville township area was deemed as unsuitable (it was coloured brown in the left hand side drainage map) – soil drainage is poor there – and figs do not like wet feet! (See the section on fig for more detail). Therefore, the information contained in the left hand side maps becomes very important – we can see which factors limit the optimal growth of a crop. For example, it has, in the past, been a little too cold for fig at Dargaville on occasion (coloured brown in the extreme minimum temperature left hand side map), and that soil drainage and potential rooting depth are unsuitable (coloured brown).

In summary: it is advisable to look at the crop potential maps for broad areas which show "good potential" (above a medium suitability rating, e.g. green or blue or purple colouring). Consider which soil and climatic factors limit the crop, and how you are placed to deal with limitations. And confirm all crop potential maps at the farmyard scale, by soil testing and local climate data.

NB: Not all climate maps used on the left hand side during the crop potential analysis are displayed elsewhere in this document. For more information about what these maps actually are, please use the glossary. Additional maps, beyond the 28 climate maps necessary for the inventory, were required in the analysis, due to unforeseen, specific, crop sensitivities. A number of very specific climate maps were created by NIWA in order to achieve the crop potential analyses, but remain the property of NIWA. It is important to note, that in future crop potential analyses of this type, we would recommend that the public decide which crop they wish to look into *first*, before inventories of basic climate or soil maps are requested, so that climate and soil factors of importance can be assessed and a minimum number of climate and soil maps be created (more cost-effective).

18. Description of crop potential maps

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This section describes the main patterns present in the crop potential maps produced for the Kaipara/Hokianga area. Table 18.1 lists all the crop potential maps and gives them identifier numbers, which will be referred to in this section. The maps can be viewed by clicking on the associated hyperlink.

Table 18.1: List of crop potential maps produced for the Kaipara/Hokianga region.

Map identifier	Map description
37	Potential for growing peanut
38	Potential for growing Māori potato
39	Potential for growing manuka (for oil)
40	Potential for growing banana
41	Potential for growing mate tea
42	Potential for growing avocado
43	Potential for growing cherimoya
44	Potential for growing fig
45	Potential for growing blueberry
46	Potential for growing hydrangea

18.1 Peanut

There is potential for growing Peanuts over much of the low elevation parts of the study region (Map 37), as is indicated by the dark green colours in the crop potential map. Areas with the best potential are near Taheke and Otaua, the area from Rangiahua to Okaihau, along the Kaihu River north of Dargaville, on the Wairoa River plains, on the west coast between around Baylys Beach and Glinkes Gully, and the area around Lake Humuhumu (see Map 1 for location of place names).

Within the study area we found four main physical factors that are likely to limit the success of peanut crops. These factors are:

- *Rainfall* – in many areas there is quite a high risk of heavy rainfall close to harvest. This raises the risk of crop damage, difficulties with harvesting, and problems with plant diseases.
- *Subsoil acidity* – low pH values (high acidity) in the subsoil prevents root growth, making the crop very vulnerable to wind and drought. Surface soil acidity is relatively easy to cure using lime. Subsoil acidity is much harder to cure, because topsoil has an otherwise useful habit of getting between you and the subsoil. Lime does not move

quickly down through soil. Much of the land with subsoil acidity problems also has problems with slope, reducing the incentive to cure the acidity problem.

- *Profile Available Water (*see *Glossary)* – in a substantial part of the Western Kaipara district the soil holds insufficient water for the crop to get through dry periods without some yield loss. This is much less of a hindrance where irrigation is available, but it is made worse in places where the potential rooting depth is quite shallow.
- *Slope* – a large part of the study area has soils on slopes that are too great. Apart from affecting safe and convenient access and use of cropping machinery, slopes greater than about 15° increase the risk of soil erosion. Peanut cultivation requires much of the land to be bare early in the season, and heavy rainfall on such slopes can wash a lot of soil away.

Soil drainage class should also be looked at carefully when considering whether specific areas should be developed for peanuts. The flat land to the south-east of Dargaville is not especially well-drained, and this increases the risk of crop damage and harvesting problems in wet seasons. Thought should be given to installing artificial drainage where peanuts are to be grown there.

One potential factor to consider is the likelihood of significant salt spray close to the coast. Peanuts will not grow well if the soil has a lot of salt in it or if their leaves are frequently exposed to salt spray. Areas close to the coast may well be suitable if they are well sheltered.

Overall, there are many areas that are moderately to well suited for growing peanuts.

18.2 Māori Potato

There are several areas that stand out as having potential for growing Māori potatoes (Map 38). These areas are the Wairoa River plains, the western side of the Pouto Peninsula, the area near Taheke and Otaua, and the area from Rangiahua to Okaihau (see Map 1 for location of place names).

Within the study area the main physical factors that can limit the success of Māori potato crops are slope and drainage. Slope is a problem that you cannot do much about – growing potatoes on steep land brings a substantial risk of major erosion because the soil surface is left bare and exposed to rain for a substantial part of the year. A large part of the study area has soils that are poorly drained and so will be risky for growing potatoes. On some of that land you can lower the risk by installing artificial drainage (usually clay pipes at 60-120 cm depth, that empty into deeper open drains around the edge of the paddock). Such drains can be expensive to install. Often though the poorly drained land has other limitations, such as being too steep.

Like peanuts, you will need to consider the likelihood of significant salt spray close to the coast. Potatoes will not grow well (and potato quality can be poor) if the soil has a lot of salt in it or if leaves are frequently exposed to salt spray. Areas close to the coast may well be suitable though provided they are well sheltered.

18.3 Manuka (For Oil)

Several areas around the region show potential for growing Manuka (Map 39), although the stretch of the west coast from Lake Taharoa to the Kaipara Harbour shows quite low potential. The main physical limiting factors for growing Manuka are too high maximum temperatures, too low minimum temperatures, and slopes that are too steep. These temperature values were never so far from optimum, however, that manuka would not grow at least moderately well. The likelihood of salt spray was not mapped, but you should be careful selecting sites close to the coast that are exposed to salt spray.

The profile available water, soil drainage, and seasonal rainfall also limit the potential for growing Manuka in some regions. The area east of Tokatoka shows good potential, as do the Awakino river valley (north of Dargaville) and the area near Taheke and Otaua. The area around Lake Omapere and the area on the northern side of the Hokianga Harbour around Panguru also show good potential (see Map 1 for location of place names).

18.4 Banana

There is potential for growing bananas for most of the study region (Map 40), as indicated by the dark green and light blue colours present in the crop potential map. The main physical limiting factors, shown in the climate and soil factor maps, are soil-related and are shallow potential rooting depth, imperfect to poor soil drainage, and moderate to low profile available water. Good drainage is needed to avoid waterlogging problems that cause the banana root system to fail. The potential root depth and available water capacity factors point to the need for banana palms to have access to plenty of soil water provided that waterlogging does not occur.

Spring, summer, and autumn rainfall tends to be limiting in the southern part of the region. The areas that show greatest potential for growing bananas are around Waihue (north of Dargaville), Aranga (5km east of Maunganui Bluff), Otaua, Umawera, Waipoua, Waimamaku, and the area from Rangiahua to Okaihau (see Map 1 for location of place names). For the inland sites we suggest you look carefully at terraces above the level of the river flats, so that cool air drains away faster in winter. For the coastal sites be careful to select areas that are well sheltered from salt spray.

18.5 Mate Tea

The highest potential for growing Mate Tea within the study region is the area north of around Dargaville as well as along the western side of the Pouto Peninsula, as indicated by the dark green and light blue colours present in the crop potential map (Map 41). The choice of where and when it can be grown will be more strongly affected by infrastructural issues, like access to the land, and how easy it will be to set up shared drying and fermentation facilities.

The main physical limiting factors, shown in the climate and soil factor maps, are soil-related and are shallow potential rooting depth, low profile available water, and poor drainage. In addition, spring, summer, and winter rainfall totals are generally too low in the Dargaville area. Areas of particularly high potential include the area near and to the east of Panguru, the area from Rangiahua to Okaihau, and the area around Umawera (see Map 1 for location of place names).

18.6 Avocado

There are some small areas within the study region that show potential for growing Avocado (Map 42). These are near Taheke and Otaua, the area from Rangiahua to Okaihau, along the western side of the Pouto Peninsula, and the area around Lake Humuhumu near the town of Pouto (see Map 1 for location of place names).

Within the study area there are three main physical factors that can limit the success of avocado trees. These factors are:

- *Drainage* – Many of the soils in the study area are poorly drained and will be waterlogged for long periods after heavy rain and during the typically wet Northland winters. Avocado trees are very susceptible to rot root and will not survive in soils that are not well drained.
- *Temperature* – Avocados are subtropical trees and are damaged by frosts and cold temperatures. Trees and fruit may be damaged or killed by frosts at any time of the year. Warm temperatures are essential during flowering and fruit set to ensure trees will produce good crops of high quality fruit.
- *Slope* – The countryside in the study area is largely made up of moderate to steeply sloping sites. Avocados need to be grown on flat to gently sloping sites to ensure safe and convenient access for machinery and workers.

18.7 Cherimoya

There are several small areas within the study region where there is potential for growing Cherimoya (Map 43). These are near Taheke and Otaua, the area from Rangiahua to Okaihau, near Waimamaku, near Aranga (5km east of Maunganui Bluff), along the western side of the Pouto Peninsula, and in particular around Pouto where nearly all the climate and soil factors are optimal (see Map 1 for location of place names).

Within the study area there are three main physical factors limiting the potential success of cherimoya. These factors are:

- *Drainage* – Many of the soils in the study area are poorly drained and will be waterlogged for long periods after heavy rain and during the winter. Cherimoya trees have a weak root system and in poorly drained soils they will rapidly die from bacterial root disease.
- *Temperature* – Cherimoya trees are a subtropical crop and will be damaged or killed by any frosts. Cold temperatures during the winter will also damage ripening fruit.
- *Slope* – Land in a large proportion of the study area is moderately to steeply sloping. Cherimoya should be grown on flat to gently sloping sites to ensure safe and convenient access for machinery and workers to carry out cultural operations like mowing, pruning, pollination and harvest.

18.8 Fig

Map 44 shows that there is potential for growing Figs near Waimamaku, in the area along the western side of the Pouto Peninsula and around Pouto itself, as well as in the area along the Punakitere River near Taheke and Otaua (see Map 1 for location of place names). However, most of the rest of the region is probably unsuited to growing Figs, as is shown by the light green, yellow, and orange colours in the crop potential map.

Within the study area there are three main physical factors that limit the potential success of figs. These factors are:

- *Drainage* – Many of the soils in the study area are poorly drained and will be waterlogged for long periods after heavy rain and during wet winter conditions. Figs will not survive in soils that are not well drained.
- *Temperature* – Trees will be damaged by any frosts that occur during active growth. Although figs are subtropical trees they require a small amount of winter chilling for good flowering and this is satisfied throughout most of the study area.
- *Slope* – Much of the study area is moderately to steeply sloping. Figs should be grown on flat to gently sloping sites to ensure safe and convenient access for machinery and workers, particularly at harvest.

18.9 Blueberry

Map 45 shows that there is highest potential for growing Blueberry around Lake Omapere, near Kaikohe, and along the Punakitere River near Taheke and Otaua, on many of the lower slopes of the Parataiko and Tutamoe Ranges, near Aranga (5km east of Maunganui Bluff), and along the western side of the Pouto Peninsula (see Map 1 for location of place names).

Within the study area there are three main physical factors limiting the potential success of blueberries. These factors are:

- *Drainage* – Many of the soils in the study area are poorly drained and will be waterlogged for long periods after heavy rain and during the typically wet Northland winters. Blueberries are susceptible to rot root and will not survive in soils that are not well drained.
- *Temperature* – Blueberries require a period of cool temperatures or winter chilling during winter in order to flower well during the following spring. They will not produce good yields of fruit without sufficient winter chilling. In order to produce early fruit blueberries will need warm conditions during spring and early summer.
- *Slope* – The countryside in the study area is often moderate to steeply sloping. Blueberries should be grown on flat to gently sloping sites to ensure safe and convenient access for machinery and workers, minimal erosion and easy installation of irrigation and bird netting.

18.10 Hydrangea

As tends to be the case for many of the crops discussed above, the slope and soil drainage are the main physical limiting factors for growing Hydrangea (Map 46). Also, the soil acidity and potential rooting depth are not ideal in many locations. However, the only climatic factor important for growing Hydrangea, i.e. the winter maximum temperature, is non-limiting over almost the entire study region. Areas that show potential for growing Hydrangea are on the slopes of the Maungataniwha Range and to a lesser extent the Parataiko and Tutamoe Ranges, around Umawera, the area from Rangiahua to Okaihau, around Kaikohe, near Taheke and Otaua, near Donnellys Crossing, in the hills around Aranga (5km east of Maunganui Bluff), near Kairara (10km east of Lake Taharoa), along the west coast from Omamari to north of Lake Mokeno, and around Pouto (see Map 1 for location of place names).

Within the study area there are three main physical factors which can limit the success of hydrangea. These factors are:

- *Slope* – The slope of much of the study area is too great for easy cultivation of hydrangeas. The maximum slope suitable for many crops is 8.5% which equates to a slope class of C on the maps, while slope class A and B are flatter sites. Only relatively flat land should be considered to ensure easy access for cultural operations like pruning, mulching, pest and disease control, and harvesting. Using flat land also ensures that installing irrigation and artificial shade is relatively simple.
- *Drainage* – Although hydrangeas require plenty of water for good growth they will not tolerate 'wet feet', even for relatively short periods of time. Therefore only well drained soils or moderately well drained soils with additional artificial drainage should be used for the crop.
- *Soil pH* – Although the pH of soil over much of the study area is suitable for hydrangea production, soil pH will affect the colour of hydrangea blooms.

19. Where to from here?

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"The more information, the better".

For most people, more information, advice and support are probably required to get underway.

This document provides the best all-in-one source of soil and climatic information for the western Kaipara and Hokianga region to date. But it is important to confirm the information contained in the maps, provided at a scale of 1:250,000 (500 metres by 500 metres). It is possible to "ground truth" soil on your own property by a simple soil test (contact Landcare Research, or a local consultant). Assess your property's climate using local records or your own local knowledge, or accessing the NIWA National Climate Database to confirm with a nearby climate station (consider using a NIWA consultant if your proposed crop is extremely climate-sensitive).

Information about climatic and soil requirements for each of the ten crops is given in the document, along with relevant market and general information – but it does NOT explain how to grow a crop in detail. Try finding some more information through the library or the Internet – there are a lot of books and articles out there about crops, varieties, and growing methods. Growers' associations and Industry Councils often have extensive information about practical methods and scientific research, including networks of other growers or consultants you can approach for more advice. A good example of this is the Avocado Growers Association and Avocado Industry Council website, located at http://www.nzavocado.co.nz/

Following that, once you have researched all that you can, if you still have particular problems or questions regarding a certain crop, or a specific growing arrangement on your property, you might consider approaching a professional horticultural consultant (HortResearch, Crop & Food, etc).

Of course, there are other skills you would probably need when involved with a crop operation:

Business and planning skills
Staff management skills
The ability to train a labour-force
Marketing skills and the ability to network
People skills, etc.

Lastly, it is important to note that having 'good potential' to grow a crop is NOT the same as having a good business case. <u>There are no guarantees of a successful venture or of making a profit.</u>

19.1 Places to go for Further Assistance

Foundation for Research, Science, and Technology

The Foundation for Research, Science, and Technology, located at http://www.frst.govt.nz/, offers information and advice for business uptake of science and technology.

Technology New Zealand

http://www.frst.govt.nz/business/index.cfm

The Technology New Zealand (Tech NZ) web site is a consolidation of sources of technological advice and assistance available primarily on the Internet. Tech NZ brings together many schemes that promote the development and adoption of advanced technologies by business. Investment, by Tech NZ in the form of grants, is directed at supporting technical risk and technical advancement rather than supporting commercial risk or aspects of general business development.

Links to various funds and programmes can be found at http://www.frst.govt.nz/business/funding.cfm. One of these, called the Techlink programme, is a group of schemes focused on building awareness associated with technical innovation. Techlink removes the costs barriers for small to medium business for:

- technology appraisal services
- access to new technology
- access to sources of guidance and assistance for technology based projects

Details about these Techlink schemes (for example Current Position Analysis, TechNet Expert Access, Technological Consultancy Projects, and International Technology Acquisition) are available on the Tech NZ web site or by phoning 0800 TECHNZ (0800 832 469).

Industry New Zealand

http://industrynz.govt.nz

Industry New Zealand's role is to help create a strong, vibrant and progressive economy. Their fundamental goal is to help existing businesses grow, and to encourage the establishment of new businesses.

If you are starting a business, want to improve an existing business or have an opportunity to take advantage of a significant market opportunity, and you want advice, training or funding, Industry New Zealand is a good place to start. Their business assistance programmes are designed for small to medium sized businesses.

The BIZ programmes offer practical training, business advice and management upskilling for small businesses, or those wishing to start a business. BIZ is provided by business people for business people.

Advice, contacts, referrals and contestable funding up to $20,000 is offered by BIZ to help businesses improve management skills, conduct research, develop marketing and business plans, undertake product development and many more business activities.

BIZ can be accessed through 0800 4 BIZINFO (0800 42 49 46), or the website: www.bizinfo.co.nz. BIZ services are: BIZtraining; BIZenterprise awards; BIZinvestment ready; BIZinfo; BIZpublications.

Trade New Zealand

http://www.tradenz.govt.nz/page_Index

Trade New Zealand provides a wide range of services to help New Zealand businesses navigate every stage of the export process. They work with exporters of all sizes, sectors and experience levels to maximise their export potential, grow their bottom line and assist in reducing the cost and risk of doing business offshore.

Their services are all either fully or partially subsidised by Government, so it costs your business a lot less to work with them than to do it yourself or use another consultancy.

For more information on Trade New Zealand services and how they can help you improve your chance of succeeding in international markets, phone the Export Hotline 0800 555 888 or visit http://www.tradenz.govt.nz/page_Index/

20. Glossary

Anthocyanins: A family of natural pigments in plants. These give some plant parts their distinctive colours - usually red, purple, blue or yellow. For instance the red colour of beetroot is due to an anthocyanin called betacyanin.

Autumn: The season composed of the months of March, April, and May.

Available water (or "profile available water"): This is the amount of water that the soil can hold that we can reasonably expect plants to be able to use. The available water capacity of a soil is the difference between soil water content at field capacity and at permanent wilting point (see definitions of these terms).

Average monthly-mean daily maximum temperature: The average of all the monthly-mean values for maximum – usually there are about 30 years of monthly-mean data, (about 30 x 12 months, or about 360 months to choose from). E.g. this represents a fairly typical maximum temperature value over the long term.

Cultivar: A cultivated and commercially named variety of plant (see *Plant variety*).

Day of soil moisture deficit: A simple definition would be a day when there was not enough moisture in the soil for the pasture or crop to grow at its (full) potential rate.

Drainage class: Categories of soil drainage. The categories are described in Table 6.6.

Extreme minimum temperature: The coldest *minimum temperature* ever recorded.

Field capacity: The soil water content when drainage stops. If you saturate a soil and then leave it water will drain away and the water content decreases, initially quickly and then more and more slowly. Eventually the change in water content will be so slow that it is very difficult to measure over a period of a day. Field capacity is the water content at that time. Usually this takes two to seven days. If the soil is wetter than field capacity then we usually assume that the excess water is not available to plants – because most of it drains away before the plants get chance to use it.

Frost free period: The number of consecutive days with minimum temperatures above 0 °C, starting from the last frost of the year. The longer the frost-free period, the warmer and generally less frost-prone the area.

Growing degrees days base 10: The amount of heat *above* a base temperature (in this case, the base is 10 °C) accumulated during a day is termed the degree day accumulation. 'Growing degree days' are the accumulated degree days for a specified period, for example a 12 month growing season (September – August). High growing degree days correspond to a warm climate. Horticulturalists use growing degree days as a measure of plant maturity – a well known amount of accumulated warmth (growing degree days) is required for flowering, fruiting, etc.

Growing degrees days base 0: The same as above, except that the base temperature is 0 °C.

Growing degrees days base 14: The same as above, except that the base temperature is 14 °C.

Hectare (ha): An area of land equal to 10,000 square metres. A hectare is about two and a half acres.

Highest daily maximum temperature, also called the **extreme maximum temperature**: The warmest *maximum temperature* ever recorded.

Infrastructure: The facilities, services and equipment that are needed for an industry or region to function properly. The infrastructure for the horticultural industry includes: machinery and people needed to plant and manage crops; buildings and equipment to process the harvested material; transport services to get the material to market; and companies to sell the product if necessary.

Lower quintile, 20th percentile: The lowest 20 percent. It is the value that would typically be exceeded 4 out of 5 years. For example, 'lower quintile summer rainfall' is an indication of a "dry" summer – 4 out of 5 summers, it is wetter that the values shown on the lower quintile map.

Lowest monthly-mean daily maximum temperature: The coldest of all the monthly-mean values for maximum temperature – usually there are about 30 years of monthly-mean data, (about 30 x 12 months, or about 360 months to choose from).

Lowest monthly-mean daily minimum temperature: The coldest of all the monthly-mean values for minimum temperatures – usually there are about 30 years of monthly-mean data, (about 30 x 12 months, or about 360 months to choose from).

Lowest summer daily maximum temperature: The coldest summer *maximum temperature* recorded.

Maximum temperature: Each day, a maximum air temperature is recorded – it is the highest temperature recorded for that day, and often occurs in the afternoon.

Mean: The average, a typical value.

Mean November 10 cm soil temperature: An average soil temperature in November, at a depth of 10 centimetres below the soil surface.

Minimum temperature: Each day, a minimum air temperature is recorded – it is the lowest temperature recorded for that day, and often occurs around dawn.

Monthly-mean daily maximum temperature: For any month, take all 30 or so maximum temperatures recorded in that month, and take an average. This is the monthly-mean value for maximum temperature for that particular month.

Monthly-mean daily minimum temperature: For any month, take all 30 or so minimum temperatures recorded in that month, and take an average. This is the monthly-mean value for minimum temperature for that particular month.

PAW class (Profile Total Available Water): Categories of the amount of water available to plant roots in the soil. The categories are described in Table 6.7.

Permanent wilting point: This is the water content of the soil when the soil is so dry that plants cannot take up any more water. There is still some water left in the soil at permanent wilting point – more so in clay soils than in sands – but it is so tightly held that the plants cannot use it for themselves.

pH: This is an indication of acidity or alkalinity. Values of pH range between 1 and 14, where values below 5 are strongly acid and values above 10 are strongly alkaline.

pH class: Categories of sub-soil pH. The categories are described in Table 6.3.

Plant variety: A consistent type of plants. Crop plants can differ at the big scale – whereby we may call them different species (beans are a different species from peas although they come from the same family). Within a species though there can be a lot of variation. For example think of the differences between Granny Smith and Gala apples. Genetically, all Granny Smith apple trees are very similar, and although they are different from Gala both are recognisably apple trees. Granny Smith and Gala are different *varieties* of apple. Strictly speaking we should call them cultivars of apple. A cultivar is a cultivated (i.e. deliberately grown) and commercially-named variety.

PRD class (Potential Rooting Depth): Categories of soil depth to a layer that stops root extension. The categories are described in Table 6.5.

Rhizome: A plant stem that grows horizontally within the soil.

Seed potato: The potato tuber that is planted in the ground and from which the plant develops. To date most people growing Māori potatoes have used tubers from their previous crop as seed. However to get high yields and good quality, healthy virus-free seed potatoes from a certified potato seed crop should be used. The process of producing virus-free seed potatoes is not easy and it usually takes three years or more to produce enough for commercial plantings.

Slope class: Categories of land steepness. The categories are described in Section 6.3.

Spring: The season composed of the months of September, October, and November.

Summer: The season composed of the months of December, January, and February.

Taproot: This is the single main root that emerges from the seed of plants like peanuts, peas, carrots, and even trees like pines. Usually this root penetrates deep into the soil and many fine branches grow off it. Grasses (including crops like wheat and maize) do not have tap roots – instead two or more finer roots emerge from the seed, and these are replaced later on by roots that emerge from the base of the plant's stem.

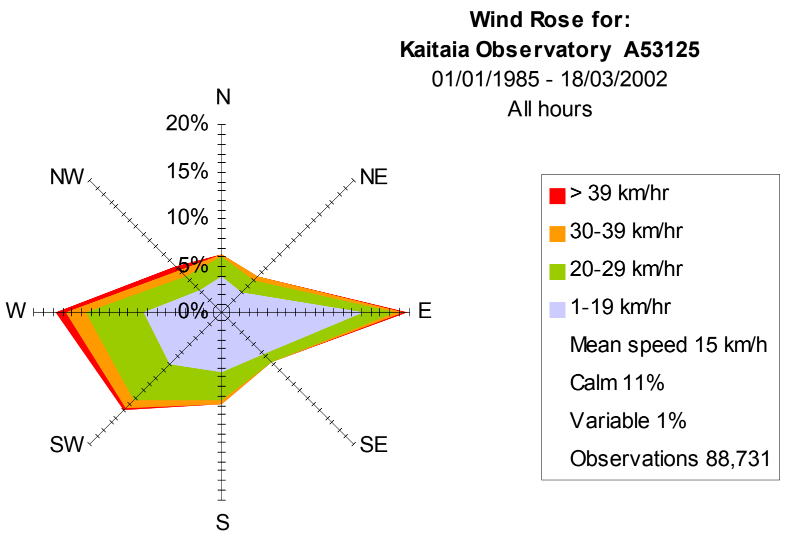
Tuber: An enlarged, short fleshy underground stem. These are usually used by plants to store food. The edible parts of potatoes and kumara are tubers.

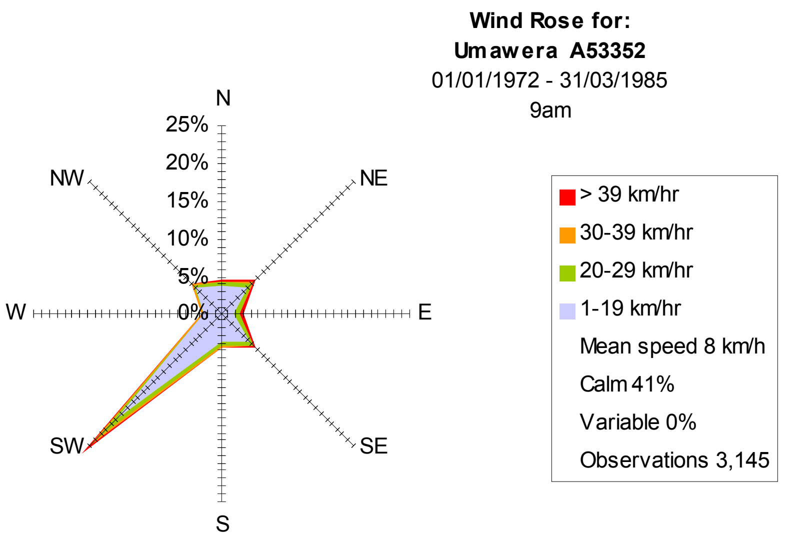
Upper quintile, **80^{th} percentile**: The highest 20 percent. It is the value that would typically be exceeded only 1 out of 5 years. For example, 'upper quintile summer rainfall' is an indication of a “wet” summer – only 1 out of 5 summers, it is wetter that the values shown on the upper quintile map.

Winter: The season composed of the months of June, July, and August.

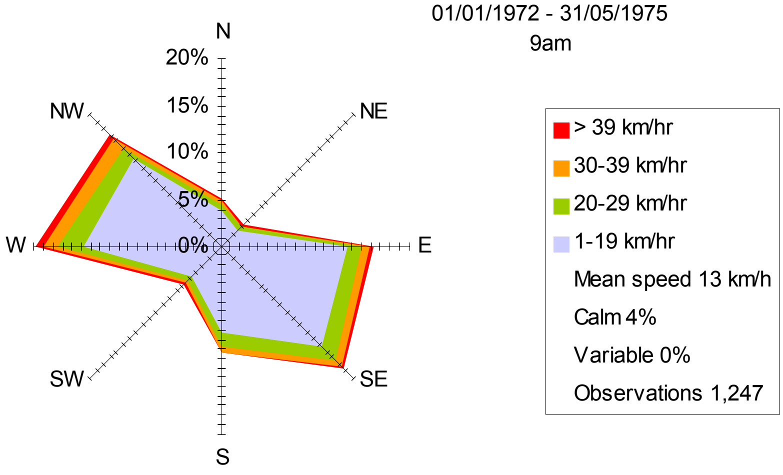
Winter Chilling (< 7 °C): The amount of chilling *below* a base temperature (in this case, the base is 7 °C) accumulated during a day is termed the chill day accumulation. ‘Winter chilling’ is the accumulated chill days for winter.

21. Appendix – Wind roses

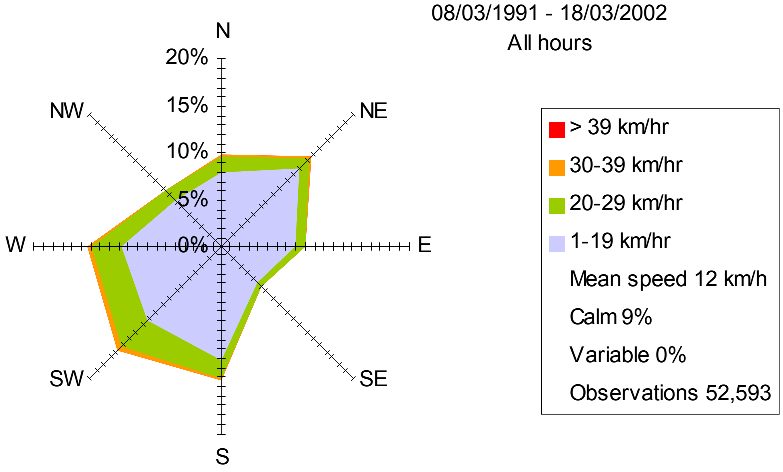


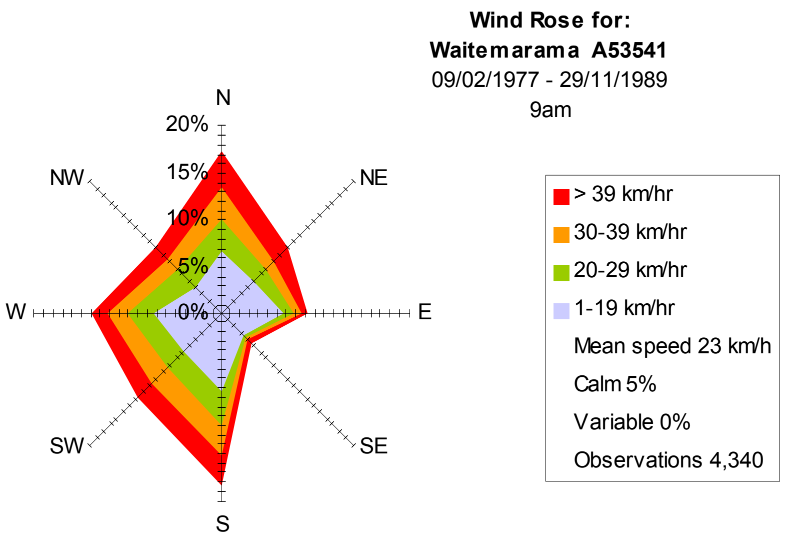


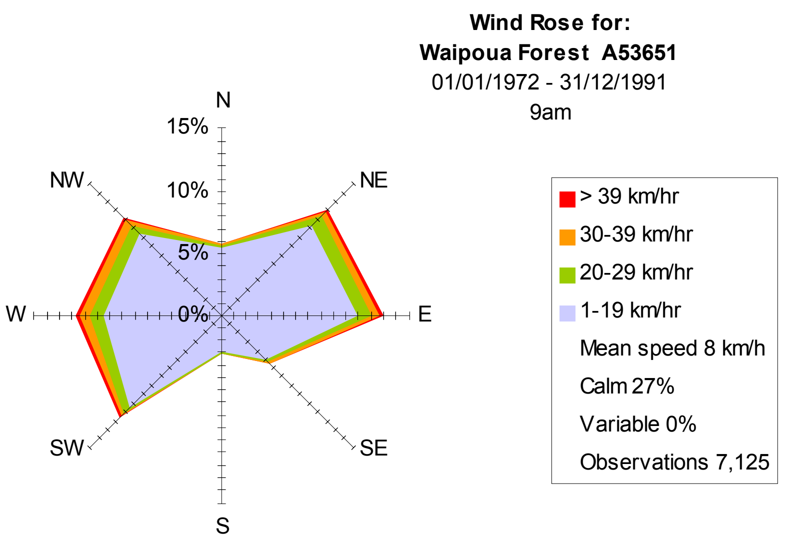
Wind Rose for:
Punakitere A53461
01/01/1972 - 31/05/1975
9am

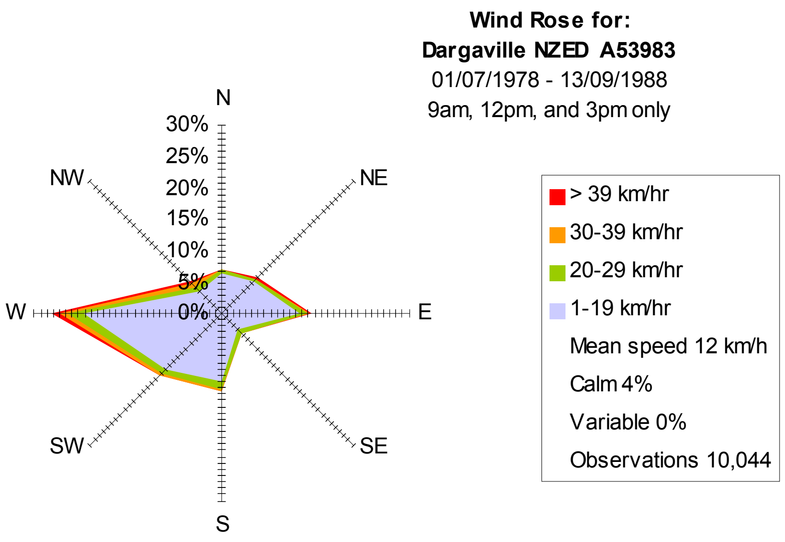


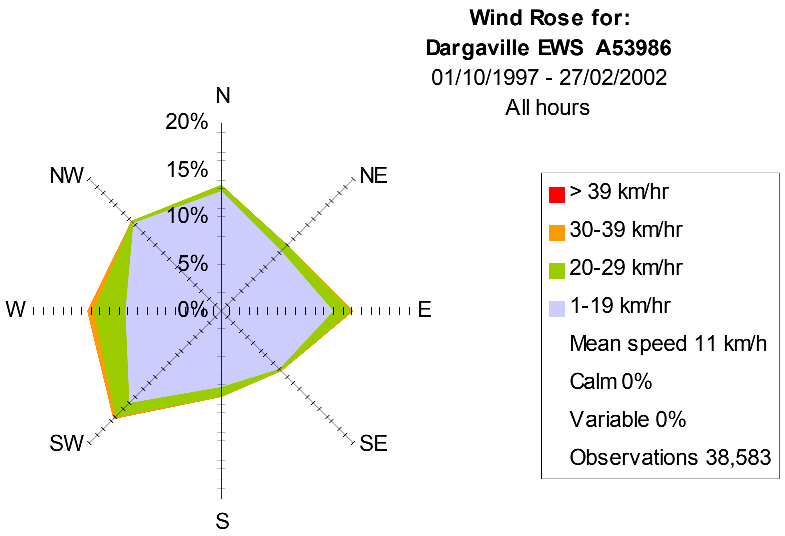
Wind Rose for:
Kaikohe EWS A53487
08/03/1991 - 18/03/2002
All hours



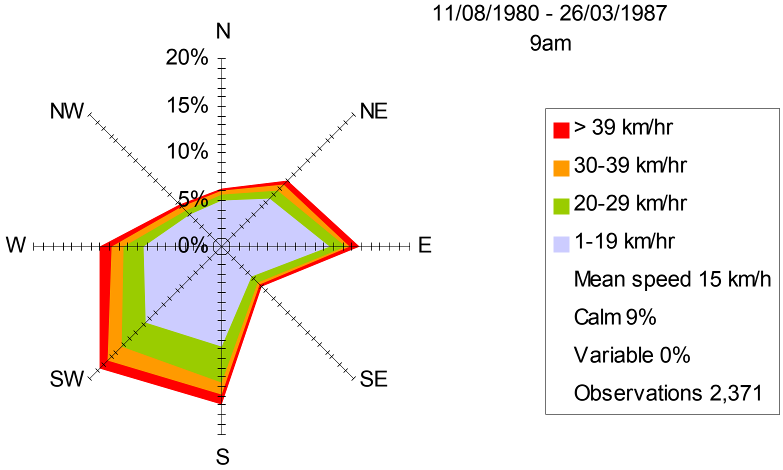

Wind Rose for:
Waitemarama A53541
09/02/1977 - 29/11/1989
9am
N
NE
E
SE
S
SW
W
NW
20%
15%
10%
5%
0%
> 39 km/hr
30-39 km/hr
20-29 km/hr
1-19 km/hr
Mean speed 23 km/h
Calm 5%
Variable 0%
Observations 4,340


Wind Rose for:
Waipoua Forest A53651
01/01/1972 - 31/12/1991
9am
N
NE
E
SE
S
SW
W
NW
15%
10%
5%
0%
> 39 km/hr
30-39 km/hr
20-29 km/hr
1-19 km/hr
Mean speed 8 km/h
Calm 27%
Variable 0%
Observations 7,125


Wind Rose for:
Dargaville NZED A53983
01/07/1978 - 13/09/1988
9am, 12pm, and 3pm only
N
30%
25%
20%
15%
10%
5%
0%
NW
NE
W
E
SW
SE
S
> 39 km/hr
30-39 km/hr
20-29 km/hr
1-19 km/hr
Mean speed 12 km/h
Calm 4%
Variable 0%
Observations 10,044


Wind Rose for:
Dargaville EWS A53986
01/10/1997 - 27/02/2002
All hours
N
20%
15%
10%
5%
0%
NW
NE
W
E
SW
SE
S
> 39 km/hr
30-39 km/hr
20-29 km/hr
1-19 km/hr
Mean speed 11 km/h
Calm 0%
Variable 0%
Observations 38,583

Wind Rose for:
Pouto A64212
11/08/1980 - 26/03/1987
9am



Wind Rose for:
Kaipara, South Head A64423
08/10/1982 - 29/07/1986
9am