Impacts of Climate Change on New Zealand Horticulture and the Effectiveness of Government Policy at Production Level:

A Case Study

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ABSTRACT

Climate change has a significant influence on New Zealand horticultural production and therefore, relevant adaptation responses should be taken to cope with the impacts of climate change. The New Zealand government has introduced several policies on climate change for the agricultural industry, such as the Emission Trading Scheme (ETS), Fund and technology development and transfer in order to mitigate greenhouse gas emissions and facilitate farmers' adaptation responses. However, many of these policies are related to dairy rather than horticultural production. Therefore, it is not certain whether these policies are being implemented effectively at horticultural production level or not.

The purpose of this research is to identify the impacts of climate change on horticultural crop production and how government policies on climate change have been implemented at horticultural production level.

The study used qualitative research methods and a case study approach to collect and analyse data. The case study was implemented at seven farms: a citrus orchard in Gisborne, a vineyard in Nelson, four vegetable farms in Manawatu, and an apple orchard in Hawke's Bay. Primary data were mainly obtained from semi-directive interviews with farmers and government officers and field observations. Secondary data were collected through literature reviews.

The literature reviewed showed that climate change is occurring in New Zealand. Annual average temperatures have increased by 0.9˚C over the last 100 years and annual rainfall has been changing with an increase in the west. However, field interviews revealed that most farmers felt that climate was not changing and didn't change their farming activities. Also, there was no significant impact of climate change on horticultural crops, including citrus, wine grapes, apples, and vegetables. As a result, most farmers interviewed had little concern about climate change and were not doing any particular adaptation responses for climate change.

In addition, from field interviews, government policies and activities seemed to be less effective at horticultural production levels. Many farmers interviewed had little knowledge on government policies on climate change and were not involved in those

government policies and activities. This is because the farmers tend not to pay strong attention to long-term issues or threats, such as climate change. And, many New Zealand government policies on climate change are focusing on mitigation of GHG emissions from livestock and pasture. Also, local councils' resources and finance are generally insufficient to meet the full demands around the issue. In addition, New Zealand policies on climate change have a limited comprehensive approach.

Thus, it is recommended that the Government needs to develop broader policies for enhancing horticultural industries' adaptability and resilience to climate change. Also, the Government needs to develop comprehensive and long-term strategies including considering relocation of production to new regions. In addition, the central government needs to provide more financial support to local government in order to improve their capability of undertaking adaptation activities to climate change.

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ABBREVIATIONS

Aws	Aero weather station
BMP	Best Management Practices
CAP	the Common Agricultural Policy
CDM	the Clean Development Mechanism
DP	the Direct Payment
ENSO	El Nino – Southern Oscillation
ETS	Emission Trading Scheme
GHG	Greenhouse Gas
GRAAGG	Global Research Alliance on Agricultural Greenhouse Gases
HortNZ	Horticulture New Zealand Incorporated
IPCC	the Intergovernmental Panel on Climate Change
IPO	the Interdecadel Pacific Oscillation
ME	Ministry for the Environment
MPI	Ministry for Primary Industries
NIWA	the National Institute of Water and Atmospheric Research
NZ	New Zealand
NZAGRC	New Zealand Agricultural Greenhouse gas Research Centre
PDSI	Palmer Drought Severity Index
PGP	Primary Growth Partnership
RMA	the Resource Management Act (1991)
SAM	the Southern Annular Mode
SFF	Sustainable Farming Fund
SLMACC	Sustainable Land Management and Climate Change Plan of Action
SOM	Soil Organic Matter
UNEP	the United Nations Environment Programme
UNFCCC	the United Nations Framework Convention on Climate Change

CHAPTER ONE: INTRODUCTION

1.1. Introduction

Climate change and global warming are likely to be one of the most significant and controversial issues in the world this century. People had little knowledge about climate change a couple of decades ago. However, recently many people worldwide have come to recognize climate change and are concerned about its impacts. It is not difficult to find evidence of climate change and global warming around the world. For instance, global surface temperatures have increased continuously since the Industrial Revolution (IPCC, 2007a). As a result, glaciers and ice in many cold regions have been gradually melting. The ecosystem of the Arctic and Antarctic regions has been changing rapidly due to global warming. Also, climate extremes, such as floods and droughts, extreme heat and cold events and strong hurricanes have occurred more frequently in recent decades and unexpectedly around the world (IPCC, 2007a). The marine ecosystem also has been changed due to rising sea water temperatures. In addition, there is considerable confidence that the sea level is rising gradually and as a result, people who live on some Pacific islands are worrying about loss of their living space.

Climate change can have a significant influence on agricultural crop production. This is because agricultural crop production depends on all the weather factors, especially temperature, sunshine levels and duration, rainfall, frost, and wind. The primary sector, including agriculture, horticulture, seafood and forestry represents around 70 % of New Zealand's (NZ) total product export revenue although it accounts for about 4.9 % of NZ's total GDP (MPI, 2011a; Statistics New Zealand, 2012c). Therefore, climate change will result in a profound impact on the NZ economy. In many cases, the adaptation response to climate change requires considerable resources and skills. As a result, some small farmers cannot afford to take the appropriate measures for addressing climate change. Thus, relevant government policies on climate change are required to help farmers respond to climate change. The NZ Government has introduced several policies on climate change. However, it is unclear whether current government policies on climate change are being implemented effectively at the farm production level. The research question of this study is drawn from in this context.

This chapter gives an introductory overview of the issues on climate change and agricultural crop production. The research problem is identified and the objective and the structure of this thesis are given.

1.2. Background

1.2.1. What is climate change?

Climate change is referred to as "*a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its property and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity*" (IPCC, 2007a; 2007b).

People often confuse climate with weather. Climate means the average of the meteorological conditions over many years. Whereas, weather can be defined as "*the meteorological conditions of the atmosphere at a particular place and time*" (Dessler & Parson, 2010). For example, the average values of daily temperature, precipitation and wind speed in September between 1990 and 2000 in a particular region constitute a particular 'climate' of that region in September. However, the high temperature last Monday can be defined as 'weather' (Dessler & Parson, 2010).

The Earth's climate system consists of the atmosphere, ocean and other water, land, snow and ice and living creatures (Solomon et al., 2007). The main energy of the climate system comes from solar radiation. Climate can be influenced by various natural and anthropogenic factors. Natural factors include volcanic eruptions, solar radiation, atmosphere-biosphere interaction, changes in the Ocean, and the change of the Earth's orbit (Mann & Kump, 2009; Solomon et al., 2007). On the other hand, the increase of greenhouse gases and aerosol emissions from human activities, such as the use of fossil fuel, transport, deforestation and land use change are well known as anthropogenic factors which affect climate (Mann & Kump, 2009).

1.2.2. Greenhouse effect

The greenhouse effect is referred as "a warming of the Earth's surface and lower atmosphere caused by greenhouse gases, such as carbon dioxide and water vapour" (NIWA, 2012). To understand the greenhouse effect, it is necessary to comprehend the Earth's energy balance (Figure 1). The main source of the Earth's energy is sunlight and about 342 Wm^{-2} of energy comes from solar radiation (Solomon et al., 2007). Then, 31 per cent (107 Wm^{-2}) of solar radiation is reflected by clouds, atmospheric gases, aerosol, and the Earth's surface. About 70 per cent (235 Wm^{-2}) of solar radiation is absorbed by surface and atmosphere. However, 235 Wm^{-2} of energy is emitted into space by atmosphere, clouds, and the Earth's surface by means of long-wave radiation. The Earth's surface emits 390 Wm^{-2} of energy and 83 per cent (324 Wm^{-2}) of surface radiation captured by greenhouse gases causes the greenhouse effect (Solomon et al., 2007).

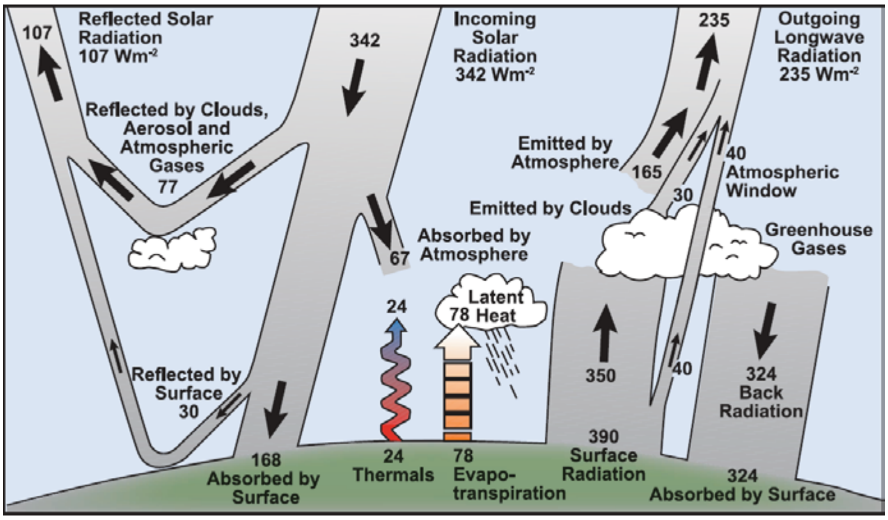

Figure 1 Earth's energy incoming and outgoing (Solomon, et al., 2007)

1.2.3. Greenhouse gases (GHGs) sources and sinks

A "greenhouse gas" is a gas that is known as a main cause of the greenhouse effect and global warming (Mann & Kump, 2009). Generally, water vapour, carbon dioxide, nitrous oxide, methane, and ozone are well known as greenhouse gases. Additionally, there are some anthropogenic greenhouse gases, such as hydrocarbons. Water vapour is the greatest greenhouse gas in the atmosphere. The second greatest GHG is carbon dioxide. Other gases, such as nitrous oxide and methane, have lower effects relative to water vapour. Several factors are related to the proportion of greenhouse gases in the atmosphere. For example, plants contribute to a decrease in carbon dioxide concentration in the air because plants convert carbon dioxide into carbohydrates through photosynthesis. Warm temperatures are likely to increase water vapour and carbon dioxide in the atmosphere. This is because in warm conditions, water vapour and carbon dioxide emissions from the ocean tend to increase (Solomon et al., 2007).

Among anthropogenic greenhouse gases, carbon dioxide represents about 77 per cent of man-made GHG emissions (IPCC, 2007a). Anthropogenic carbon dioxide emissions mostly come from fossil fuel combustion, deforestation, and land use change. Methane accounts for 14 per cent of total global anthropogenic GHG emissions and nitrous oxide cause about 8 per cent of them. Hydrocarbons, which are known as powerful greenhouse gases, represent only about 1 per cent of global anthropogenic GHG emissions (IPCC, 2007a, 2007b). Many greenhouse gases, such as water vapour, carbon dioxide, and methane have existed naturally. However, since the Industrial Revolution (1760~1830), the level of greenhouse gases in the atmosphere has increased rapidly due to human activities. Figure 2 shows atmospheric concentrations of main greenhouse gases over the last 2,000 years (IPCC, 2007b).

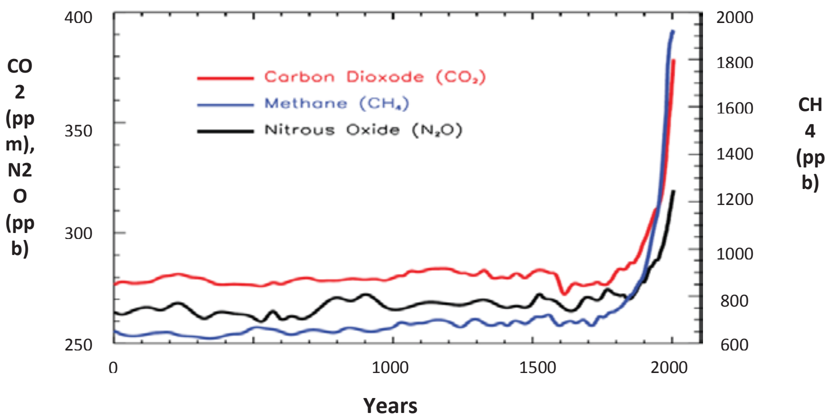

Figure 2 Atmospheric concentrations of man-made GHGs over the last 2,000 years (IPCC, 2007b)

Carbon dioxide concentration in the atmosphere has increased from 280 ppm to 379 ppm since the Industrial Revolution. The level of methane in the atmosphere also has doubled and nitrous oxide has increased from 276 ppb to 319 ppb at the same period. Total global anthropogenic GHG emissions have increased from 28.7 Gt CO_2-eq per year to 49 Gt CO_2-eq per year between 1970 and 2004 (IPCC, 2007b) and carbon dioxide emissions have increased by 80 per cent at the same period. With regard to GHG emissions by sector, energy supply was the largest source of global greenhouse gas emissions and caused about 26 per cent of total global GHG emissions in 2004 (IPCC, 2007b). Industry was the second largest source and represents around 19 per cent of global GHG emissions. Forestry was responsible for about 17 per cent and agriculture accounted for 14 per cent of global GHG emissions. The transport sector represented 13 per cent of GHG emissions. More than 50 per cent of global GHG emissions came from fossil fuels combustion in the areas of energy supply, industry and transport. In particular, in some emerging countries, such as China, India, and Brazil, GHG emissions in fossil fuel use have increased by up to 300 per cent between 1975 and 2002, while GHG emissions in EU have decreased at the same period (Dow & Downing, 2007).

GHG sinks are referred to as “natural or synthetic reservoirs which remove greenhouse gases, aerosols or precursors of greenhouse gases or aerosols from the atmosphere” (IPCC, 2007b). There are several GHG sinks, such as the ocean, the atmosphere, the soil, biotic pool, and fossil fuels. The ocean is the major sink of greenhouse gases and contains about 83 per cent of global carbon. It keeps 50 times more carbon dioxide than the atmosphere. About 50 per cent of man-made GHG emissions were assumed to have been absorbed by the ocean since the Industrial Revolution. The biotic pool, such as forest, is the other important sink. This is because forests and plants can sequester carbon dioxide from the atmosphere through photosynthesis and reduce the level of carbon dioxide in the air. In addition, the atmosphere is an important GHG sink. For example, methane in the atmosphere is converted into CH_3 and water through atmospheric oxidation. About 90 per cent of methane is removed by atmospheric chemical oxidation. Geological sinks, such as fossil fuels are both carbon sink and source. About 5 per cent of global carbon is stored in the geological sinks. However, storage in the geological sinks requires long periods of time. Fossil fuels were produced many millions of years ago and currently play a role as a GHG source not a sink. Soils store about 9 per cent of global carbon in a form of soil organic matter (SOM) (Lal, 2008).

1.2.4. Global climate change

Global warming and climate change is a reality. Global average surface temperatures have risen by 0.74°C between 1850 and 2006 (Figure 3). In particular, the increase of temperatures in the last 50 years is nearly twice as high as that in the last 100 years (IPCC, 2007b). An increase of average temperatures at higher northern altitudes was more dramatic. For example, since 1900, average temperatures of the Arctic have increased two times higher than global average temperatures. Sea water temperatures have also increased to a depth of about 3000m due to increase of global average surface temperatures (IPCC, 2007b).

Along with the increase of global average temperature, snow and ice covers over the world have gradually decreased. For instance, the Arctic sea ice has shrunk by about 2.7 per cent per decade for the last 100 years. In many mountains, glacial retreats are easily found. The snow peaks on the Mount Kilimanjaro have diminished rapidly and may disappear by 2025. Glaciers on most Alps have lost half of their volume (IPCC, 2007b).

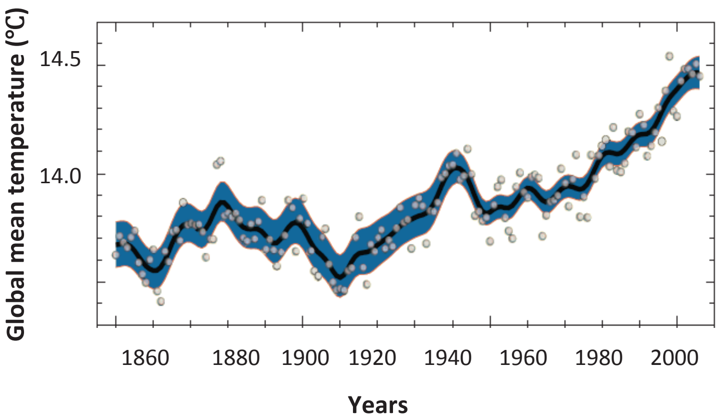

Figure 3 Global average surface temperature between 1850 to 2006 (IPCC, 2007b)

Global warming is likely to influence regional precipitation. Since 1900, precipitation in the Mediterranean, southern Africa and southern Asia has decreased and as a result, more droughts have occurred in these regions (IPCC, 2007b). Figure 4 shows the monthly Drought Severity Index (PDSI) from 1900 to 2002. Since 1900, PDSI has increased gradually, even though there was a little variation between 1950 and 1960 (IPCC, 2007a).

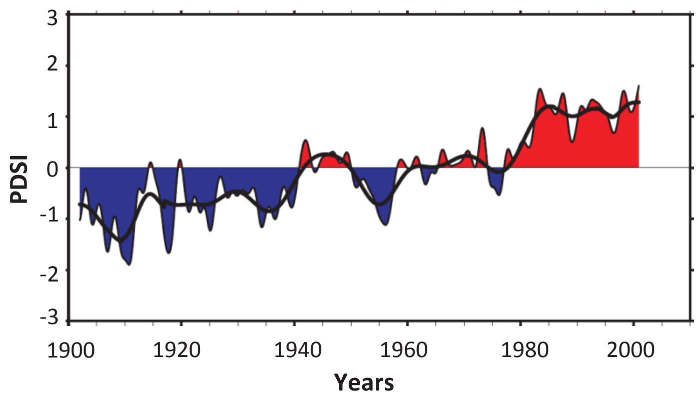

Figure 4 Monthly Palmer Drought Severity Index (PDSI) from 1900 to 2002 (IPCC, 2007a)

Sea levels have also risen with an increase of global surface temperatures. Between 1961 and 2003 average sea level rise was 1.8 mm per year. In particular, the sea level has risen by about 3.1 mm per year from 1993 to 2003. Several factors, such as thermal expansion of the ocean, glacial retreat, and the decrease of ice in the polar region are supposed to contribute to this recent rapid sea level rise (IPCC, 2007b).

Climate extremes are likely to happen more frequently due to global warming and climate change. For example, tropical cyclone activities in the North Atlantic have increased continuously since 1970. Also, heavy rain events in the mid-latitude regions have increased even though there has been no significant change in average precipitation in those regions. In addition, extreme events, such as heat waves and severe droughts, have occurred more frequently and unexpectedly. In 2003, Europe was faced with a severe heat wave and it caused about 35000 deaths. In 2006 a severe drought affected agricultural production in China and led to a decrease of 12 per cent in agricultural production (Mann & Kump, 2009).

Global warming and climate change can cause a change in the ecosystem. IPCC experts state that current changes in the ecosystem are related to global warming and subsequent climate change. For example, global warming has influenced biological systems and caused earlier blossom of many plants, earlier greening of vegetation and bird migration. Also, an increase of sea temperature leads to changes in habitats of many plankton and marine animals (IPCC, 2007b).

1.2.5. New Zealand's climate

New Zealand, located in the middle latitude of the Southern Hemisphere, is a long narrow island country surrounded by the South Pacific Ocean and the Tasman Sea. It consists of two main islands: the North Island and the South Island and many smaller ones. New Zealand's land area is 267,710 km^2 and 5.5 % of total land area is arable land (CIA, 2012; Statistics New Zealand, 2012c). New Zealand's climate is mostly dominated by the sea and mountains. It is sometimes defined as a maritime climate and is capricious or changeable.

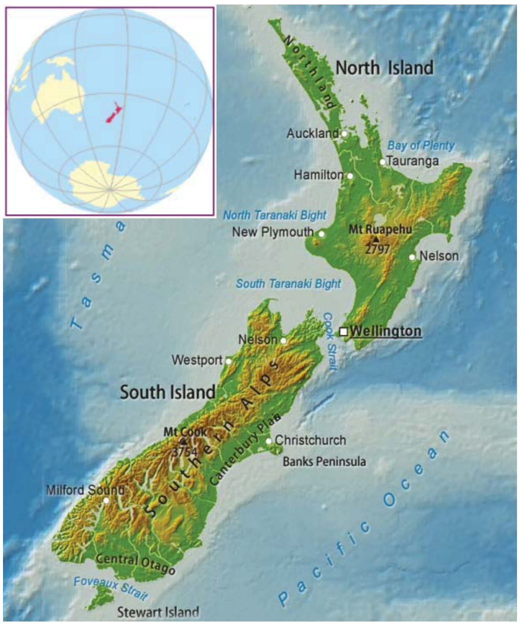

Figure 5 Map of New Zealand (Free World Maps)

New Zealand has a mild and temperate climate and average annual temperatures range from 10 °C to 16 °C. The difference in average temperatures between summer and winter are less than 10 °C in most regions due to its maritime climate (Climate Change Group, 2001). Rainfall is spread evenly throughout the year with average rainfall ranging from 640 mm to 1500 mm. However, annual rainfall varies with geographical location due to the prevailing westerly winds and high mountains in the middle of the country. While the eastern regions often experience semi-arid conditions, the western regions, such as the West Coast and the South Island, are often wet. In most areas of New Zealand, sunshine duration is more than 2000 hours annually. In particular, major fruit growing regions, such as Bay of Plenty, Hawke's Bay, Nelson, and Marlborough, receive more than 2350 hours annually (CIA, 2012; Warrick, Kenny, & Harman, 2001).

There is considerable evidence New Zealand's climate is changing. Annual average temperatures have increased by 0.9 °C in the last 100 years and sea surface temperatures showed a similar upward trend (Climate Change Group, 2001; Ministry for the Environment, 2008f). From the National Institute of Water and Atmospheric Research (NIWA)'s climate change projections, NZ's annual average temperatures are expected to increase up to 2.2 ℃ by 2090 with a faster increase in the North Island than in the South. Rainfall in the western regions such as Waikato, Manawatu, and West Coast

(South Island) are also predicted to increase by up to 20 per cent at the same period. However, rainfall is expected to decrease in the eastern regions, such as Hawke's Bay, Canterbury, and Central Otago. Sea levels are expected to rise by 24 to 34cm by 2100. Furthermore, more frequent climate extremes, such as heat and cold, droughts and floods, strong wind, and hail, are expected (Climate Change Group, 2001).

1.2.6. New Zealand horticulture

NZ horticulture is a NZ$ 6.3 billion industry as of 2012. It accounts for about 8 per cent of total NZ product exports and earns about NZ$ 3.3 billion annually from offshore. The kiwifruit and wine industries are the major exporters among NZ's horticultural industries. They earned about NZ$ 962 million and NZ$ 1.1 billion respectively in 2011. The pipfruit (apple and pear) industry earned around $ 326 million in the same period (MPI, 2011a).

The NZ apple industry produces about 1 % of world's apples and accounts for 3 % of global export trade. There are 431 apple growers and 95 apple exporters in 2010. New Zealand has a relatively good climate to grow apples. For example, NZ's winter is mild without extreme cold. The major apple growing areas have over 2300 hours of sunshine duration annually. There is also no significant issue on severe droughts due to adequate rainfall (Plant & Food Research, 2009; Pipfruit New Zealand, 2011).

In New Zealand, there are around 280 potato growers and about 10,670 hectares of arable land planted in potatoes (see Table 1). Potatoes can be divided into three categories by use: fresh, processing, and seed. Fresh potatoes represent about 33 per cent of total potato production in New Zealand. Processing and seed potatoes account for about 56 per cent and 11 per cent of total potato production respectively. Potatoes are mainly grown in Pukekohe, Ohakune, Hawke's Bay, Manawatu and Canterbury. Annually around 525,000 tonnes of potatoes are produced in New Zealand and about 10 per cent of total potato yields are exported (Plant & Food Research, 2009; The Potato Product Group of Horticulture New Zealand, 2010).

Citrus is grown on about 1,700 hectares of orchard areas and most of citrus orchards are located in warmer regions with high sunshine, such as Northland, Bay of Plenty, and Gisborne regions. There are around 450 to 500 citrus growers in New Zealand.

Annually around 45,000 tonnes of citrus fruits are produced and about 10 to 15 per cent of NZ citrus yields are exported to overseas markets, such as Japan, the USA, the United Kingdom, and the Pacific Islands (Table 2) (New Zealand Citrus Growers Inc, 2012).

Table 1 Potatoes production and export in New Zealand (The Potato Product Group of Horticulture New Zealand, 2010)

	Fact sheet
Area planted in potatoes	Approximately 10,670 ha (2011) - Fresh potatoes (3,548), Processing potatoes (5,926), Seed potatoes (1.194)
Annual yields	525,000 tonnes by volume NZ$ 143 million at the farm gate by value
Export	Frozen processed potatoes: 67,718 tonnes (2010) - Australia (70%), Japan (less than 5%) Fresh potatoes: 29,830 tonnes (2010) - Fiji (80%), the Pacific and Asia (20%)
Growing areas	All parts of the country, in particular Pukekohe, Hawke's Bay, Manawatu, and Canterbury
Varieties	Around 50 varieties are grown in New Zealand Main commercial varieties: Russet Burbank, Innovator, Rua, Nadine, Agria, Moonlight, Desires, Ilam Hardy, and Red Rascal

Table 2 Citrus production and export in New Zealand in 2009 (Plant & Food Research, 2009)

	Growers (No)	Planted area (ha)	Crop yields (tonnes)	Sales value (NZ$m)	
				Domestic	Export (FOB)
Citrus	**450**	**1834**	**44650**	**45.0**	**5.1**
- Grapefruit		41	1150		
- Lemons	100	332	13000	10.0	1.8 (Japan, USA)
- Mandarins	334	691	16000	21.0	2.8 (Japan, UK)
- Oranges	220	681	12000	11.0	0.4 (Pacific Islands)
- Tangelos		89	2500		

The wine industry is the main exporter in the NZ horticulture sector and earns more than NZ$ 1 billion annually. There are about 1000 wine grape growers and 700 wineries across NZ. The major wine producing areas are Marlborough, Hawke's Bay, Gisborne, and Central Otago. In particular, Marlborough accounted for 68 % of total NZ's wine production in 2009. The main wine varieties are Sauvignon Blanc, Chardonnay, and Pinot Noir. Sauvignon Blanc represented 63 % of total NZ's wine production in 2008. The main importers of New Zealand wine are Australia, the UK, and the USA. Those three countries accounted for about 81 % of NZ's wine export in 2008 (Plant & Food Research, 2009).

1.2.7. Impacts of climate change on agricultural & horticultural production

Agriculture and horticulture are vulnerable to climate change and global warming. This is because most crop yields are mainly determined by the amount of photosynthesis and accumulation and weather conditions, such as temperatures, sunshine duration, and rainfalls have huge influence on those photosynthesis and accumulation. For instance, changes in temperatures and water supply affect plant's photosynthesis and accumulation directly. Higher temperatures can cause inactivation of enzymes and genes which are related to photosynthesis. Also, plant respiration increases in warmer conditions. Droughts also have a negative effect on plant growth and development. Ainsworth and Ort (2010) indicated that high temperature affected yields of wheat, maize and barley worldwide between 1981 and 2002 and resulted in a loss of around $ 5 billion per year. Schlenker and Roberts (2009) predicted that If average global temperatures increase by 2°C to 4°C at the end of this century, production of USA maize and soybean are expected to decrease by 30 per cent to 46 per cent. Many climate extremes such as floods, droughts, and cold, also have significant influence on agricultural production over the world. In 2007, the world experienced a significant decrease in yields of some crops, such as wheat, corn and soybean due to severe droughts in the main growing areas. A modelling study estimated that global maize yield has decreased by 3.8 per cent due to climate change from 1980 to 2008 (D.B. Lobell & Field, 2011). Despite a weakness in many modelling results, such as a lack of accuracy, many modelling studies showed that climate change and global warming could have a serious influence on agricultural production

Several studies show that climate change has a significant influence on horticultural production. In particular, rising temperatures can affect breaking dormancy of many perennial crops, such as pip-fruit, kiwifruit and blackcurrants. Kiwifruit in New Zealand usually require 850 hours at optimum chilling temperature (usually 5°C to 7°C in Utah chill unit model) for breaking winter dormancy. However, recent warmer winters have caused a decrease of winter chilling hours and resulted in a delayed bud burst, a lower bud break rate, subsequent slower and weaker growth, and the decrease of fruit yields and quality (Rosenzweig, Phillips, Goldberg, Carrollh, & Hodges, 1996). According to the mid and upper warming scenarios by the Ministry for the Environment, the area suitable for growing kiwifruit in the Bay of Plenty is expected to disappear by 2090 (Climate Change Group, 2001).

With regard to potatoes, rising temperatures can cause accelerated development and earlier leaf area senescence of potatoes. As a result, tuber growth, tuberisation rate and crop yields can reduce because of higher temperatures. Also, warmer temperatures can lead to an increase of pest, weeds and diseases, such as late blight and virus infection of potatoes. In California, USA, citrus yields were expected to decrease up to 18% by 2050 due to high temperatures (Rosenzweig., Phillips, Goldberg, Carroll, & Hodges, 1996; The Potato Product Group of Horticulture New Zealand, 2010; Lobell, Torney, & Field, 2011; Medellín-Azuara, Howitt, MacEwan, & Lund, 2011)

1.3. Problem statement

There is an understanding that climate change can have a significant influence on crop production. All climate features, such as warmer temperatures, droughts and floods are closely related to crop physiology, development, and yields. An adequate adaptation response to climate change is required to help farmers meet climate change. However, it is not easy to encourage farmers' participation in any relevant adaptation response. This is because farmers without enough information usually have a tendency to ignore long-term and slow threats like climate change. Also, there are many small-sized farms and they often cannot afford to take adequate measures, such as expanding irrigation systems. However, as climate change is on-going, the risk of climate extremes which can cause serious reduction in crop production also increases. Therefore, adaptive responses to climate change may be become a prerequisite for farmers. With regard to adaptation to climate change, the Government role is important. This is because in many cases adaptation measures cannot be undertaken by a person or farmer alone. For example, to meet an increasing risk of floods, flood protection measures, such as raising stop-bank levels, should be undertaken. These measures can only be managed by the public sector and the Government. Also, farmers have little information and knowledge on the impact of climate change and adaptation technologies to their own particular situations. Thus, in order to help farmers address climate change government support is required. Many countries have introduced policies and measures to help farmers address climate change. The NZ Government have also implemented policies and measures in agriculture, such as, Emission Trading Schemes (ETS), developing and transferring technology, several funds (such as Sustainable Farming Fund, Community Irrigation Fund, New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) fund). (Ministry of Agriculture and Forestry, 2007). Many of those policies and measures mentioned above are related to dairy production not horticultural production. It is early days however and there is uncertainty whether those policies have been implemented effectively at farm production level or not.

1.4. Research objectives

The purpose of this research is:

- To define the impacts of climate change on New Zealand horticultural crop production, in particular potato and citrus production;
- To identify the main concerns of horticulturists and related industry on climate change;
- To explore adaptation responses to address climate change;
- To critically evaluate government policies on climate change at producer and industry levels.

The main aim of this research is to define how NZ government policies and measures are being implemented at production level in order to encourage farmers' adaptation responses to climate change. It will be difficult to define the effectiveness of government policies and measures in agriculture for meeting climate change, partly because most policies and measures are recent introductions and there is still uncertainty about the impact of climate change and the effectiveness of government action. Thus, this research will evaluate government policies and measures from farmer's perspectives, as it were, how farmers think about government policies and what policies and measures farmers need to meet climate change.

1.5. Research question

In order to achieve the purpose of the research, the following research questions are applied.

1. How is climate change affecting the horticultural sector in New Zealand and what responses or adaptation measures are being applied by producers?
2. How have New Zealand government policies on climate change been being implemented effectively at farm production level?

1.6. Thesis structure

This thesis is composed of six chapters. In the chapter one, background information on climate change is given and then the research problem statement, the research question and the objectives are introduced. The second chapter reviews the literature on climate change. Firstly, the present situation of NZ climate change is examined then the potential impacts of climate change on agricultural crop production and the adaptation options to meet climate change are studied. Finally, NZ government policies on climate change, NZ horticultural industry concerns, and the international issues on climate change are explored.

Chapter three explains the methodology of the thesis, including a research strategy, case study boundaries, questionnaire, and the methods of data collection and analysis. Chapter four presents the explanation of case study areas and the findings from the case studies. This chapter also focuses on the impact of climate change on the case study areas and the usefulness of government policies on climate change. In chapter five, the findings of the case studies are discussed and then suggestions for government policies are drawn out. Finally, in chapter six, the conclusion of this thesis and recommendations are presented.

CHAPTER TWO: IMPACTS OF CLIMATE CHANGE

2.1. Introduction

The aim of this chapter is to deliver information about New Zealand's climate change and the impact of climate change on horticultural production. While in the previous chapter, current global climate change and its impact on agricultural production were described generally, this chapter will give a more detailed account of how the NZ climate is changing along with global climate change and what impact of climate change is expected to have on horticultural production. The global climate systems which influence NZ's climate are defined and then observed and future changes in NZ's climate are explored. Section 2.4 explains how changes in climatic factors, such as temperature, carbon dioxide concentration and rainfall affect crop physiology, development and yields. The impact of current and future climate change on NZ's horticultural production will then be followed. Section 2.5 will illustrate potential adaptation measures to address climate change.

2.2. NZ climate – Present and future

2.2.1. Main climate features

New Zealand is located between longitudes 165º and 176 º E, and latitudes 29 º and 53 º S and is a long and narrow country surrounded by the ocean. NZ's climate is quite variable because it is influenced by the ocean, latitude and winds. For instance, NZ's climate is sensitive to influences from the Tropics and the sub-Antarctic due to its latitudinal location. The mid-latitude westerly winds affect weather patterns every 4-5 days. The sub-tropical highs which move southward or around New Zealand increase the uncertainty of NZ's climate. New Zealand mountainous orography is also one of the factors which affect the capricious NZ climate. The Southern Alps and mountainous ranges in the North Island result in weather variations. However, the main components which have significant influence on NZ's climate are the global-scale climate system and the wind circulation, such as the El Niño-Southern Oscillation (ENSO), the Interdecadal Pacific Oscillation (IPO), and the Southern Annular Mode (SAM).

El Niño-Southern Oscillation (ENSO)

The El Niño-Southern Oscillation (ENSO) is the global-scale climate fluctuation which is related to circulation of the trade winds and the surface ocean across the Equatorial Pacific. ENSO is comprised of two opposite extreme events, El Niño and La Niña (Renwick et al., 2010; Wratt, Basher, Mullan, & Renwick, 2012). During El Niño, the trade winds across the tropical Pacific wane and ocean temperatures in the Equatorial Pacific rise unusually compared with normal conditions. As a result, El Niño leads to global warming. On the other hand, during La Niña the trade winds strengthen and ocean temperatures in the tropic Pacific become cooler. This results in a decrease of global average temperatures (Spencer, 2010). ENSO can be predicted by the Southern Oscillation Index (SOI) which is measured from the difference in pressure between Tahiti and Darwin. El Niño usually occurs every 3-7 years (Renwick et al., 2010; Wratt et al., 2012). It is evident that El Niño and La Niña have a significant influence on NZ's climate (Figure 6). During El Niño, New Zealand experiences more westerly and south-westerly winds resulting in more rains in western regions and more droughts in eastern regions. Also, New Zealand becomes cooler than normal, partly because of south-westerly winds from the sub-Antarctic (Renwick et al., 2010). On the contrary, in La Niña years westerly winds weaken, and northerly and north-easterly winds tend to increase instead. As a result, New Zealand experiences warmer conditions. Also, the mean rainfall in the eastern regions increases while the west regions become drier than normal conditions. El Niño and La Niña usually begin in autumn or winter and continue for about one year with a peak in summer (Renwick et al., 2010; Wratt et al., 2012).

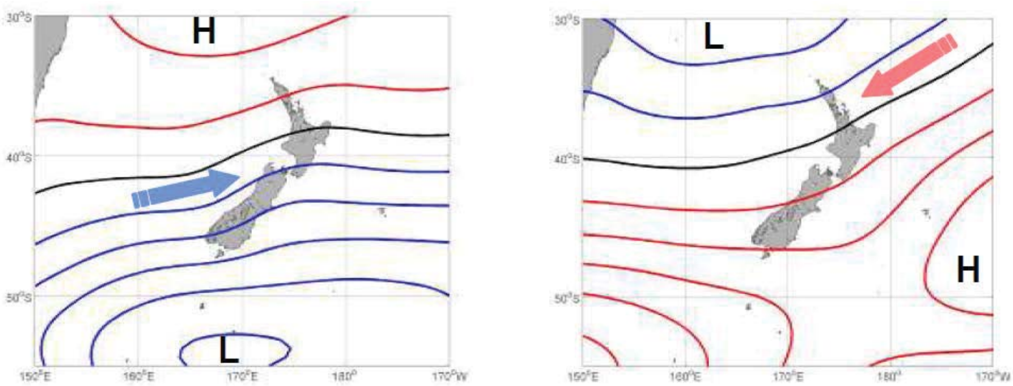

Figure 6 New Zealand's typical wind patterns during El Nino (left) and La Nina (right) (Renwick et al., 2010)

Interdecadal Pacific Oscillation (IPO)

The Interdecadal Pacific Oscillation (IPO) is "a long-lived El Niño-like weather pattern of Pacific climate variability" and changes its phase every 20 to 30 years (Mantua, 2002). The sea surface temperature change for the warm and cool phase of the IPO is illustrated in Figure 7. The sea surface temperatures tend to vary with the change of the different IPO phases.

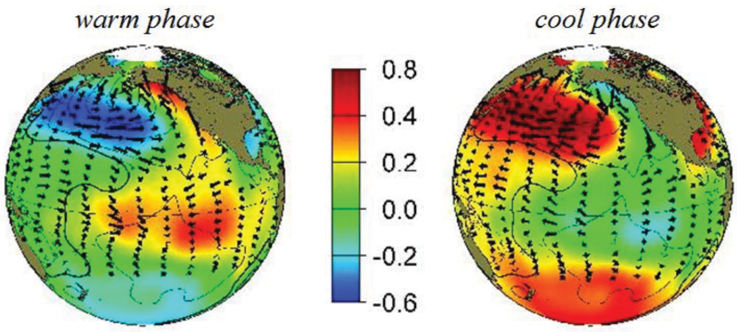

Figure 7 IPO phases and the Sea Surface Temperatures (Sea Surface Temperatures: colour, surface windstress: arrows) (Spencer, 2010)

Figure 8 shows changes in IPO Index from 1900 to 2008. During the positive IPO phase, El Niño events occur more frequently and therefore, strong westerly winds dominate New Zealand's climate. As a result, New Zealand experiences cooler conditions and more rain in western regions. However, during the negative phase of IPO, La Niña events have a significant influence on New Zealand's climate. As a result, westerly winds weaken and more northerly and north-easterly winds affect New Zealand. Then, mean rainfall in the north-eastern regions usually increases while south-western regions experience drier weather conditions. The IPO was at the positive phase between 1978 and 1999. However, recently the IPO has turned from the positive phase into the negative phase. Thus, New Zealand has experienced more La Niña events and warmer conditions with weak westerly winds (Renwick et al., 2010).

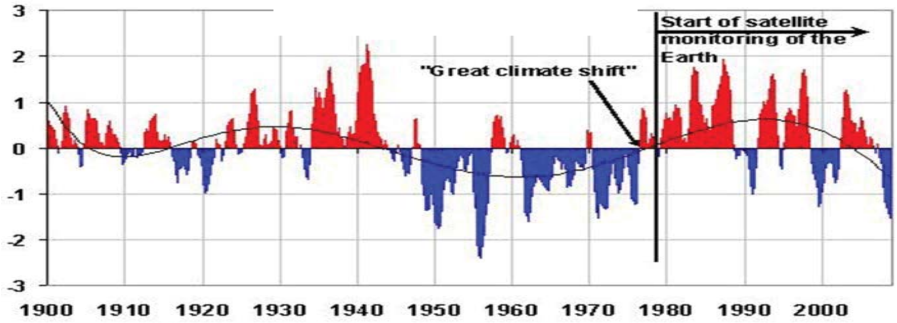

Figure 8 Changes in IPO Index from 1900 to 2008 (Renwick et al., 2010)

Southern Annular Mode (SAM)

The Southern Annular Mode (SAM) 0is hemispheric-scale climate changes which affect the westerly winds and storms from the middle latitudes (40ºS to 50ºS) to Antarctic sea (50ºS to 70ºS) (Renwick & Thompson, 2006). SAM changes its phases between positive and negative on a week to week basis. In a positive phase of SAM, westerly winds weaken with higher sea-level temperatures over New Zealand and often drier conditions are followed. During a negative SAM phase, stronger westerly winds dominate New Zealand with lower pressure and wetter conditions over New Zealand (Renwick et al., 2010; Renwick & Thompson, 2006; Thompson, 2007). The positive phase of SAM is likely to be related with La Niña and on the contrary El Niño may be associated with the negative phase of SAM. Recently, there has been a tendency that more positive SAM phases have occurred than normal conditions with more La Niña events in New Zealand. As a result, lighter westerly winds and warmer conditions over New Zealand have been observed more frequently (Renwick & Thompson, 2006).

2.2.2. Observed climate change

New Zealand has a moderate climate partly due to being a maritme climate. Average sea level temperatures range from 10 ºC in the South Island to 16 ºC in the North Island (NIWA, 2012a). Over most of New Zealand annual rainfall ranges from 600mm to 1500mm. However, annual rainfall shows significant variation from region to region due to the westerly winds and NZ's mountainous orography dominating NZ regional rain patterns. For example, annual rainfall in Central Otago is below 300mm while over 8000mm of precipitation is recorded in the Southern Alps (Warrick et al., 2001).

The NZ climate appears to be getting warmer. From the NIWA seven-station temperature series, New Zealand's mean annual temperature has increased by 0.9 ºC over the last 100 years even though there were year to year variations between 0.5 ºC and 1 ºC (Figure 9). Sea surface temperatures also have risen with a similar trend to mean annual tempreature (Mullan, Stuart, Hadfield, & Smith, 2010; Renwick et al., 2010).

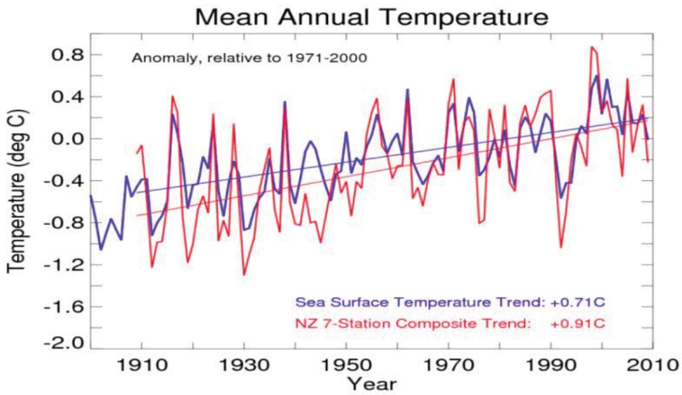

Figure 9 NIWA's seven-station temperatures (red) and NOAA sea surface temperatures (blue) for the last 100 years, expressed as anomalies relative to the 1971-2000 (Mullan et al., 2010)

Changes in mean temperatures also have a significant relationship with wind patterns. This is because the NZ climate is dominated by the westerly winds. Changes in NZ mean temperature and northerly winds over the last century are illustrated in Figure 10. During La Niña and the positive phase of SAM, the westerly winds tend to wane. Instead the northerly and the north-easterly winds influence NZ climate more frequently and result in warmer conditions than normal. Between 1990 and 2000 La Niña events have occurred more frequently and more northerly winds have been observed. As a result, the NZ climate experienced warmer than normal climate conditions. However, there has been a long-term decreasing trend in the northerly winds since about 1960. According to the IPCC climate scenarios, as global warming is going on, more westerly and south-westerly winds are expected over New Zealand. Therefore, the trend toward a less northerly flow is consistent with recent global warming (Mullan et al., 2010).

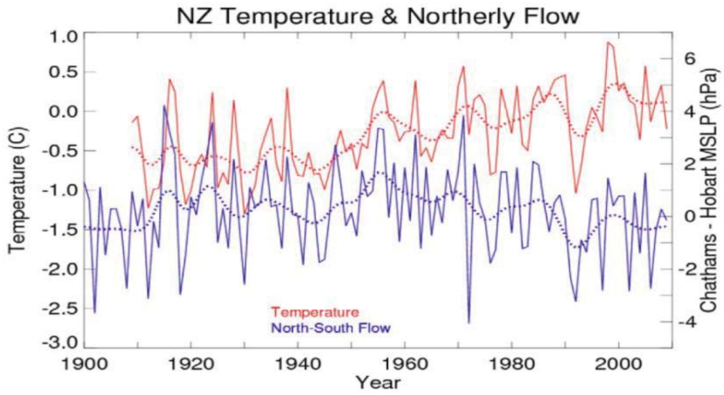

Figure 10 Changes in annual Tasman Sea Northerly Flow (blue line) and NZ mean temperature from NIWA's seven-station temperature series (red line), expressed as anomalies relative to the 1971-2000 climatological average (Mullan et al., 2010).

NZ rainfall has a significant variation between the western regions and the southen regions due to the prevailing westerly winds. Since 1950s, in the western regions of the North Island and the south-western regions of the South Island, rainfall has increased by 5 to 15 % due to the increase of the westerly winds over New Zealand. On the contrary, the east of North and South Islands, such as Gisborne, Hawke’s Bay, Wellington, and Canterbury have experienced less rainfall by 5 to 20 % (Renwick et al., 2010; Warrick et al., 2001). Table 3 illustrates the main features of NZ’s climate from 2004 to 2011 (NIWA, 2012a).

Niwa Data (2012a) presented in Table 3 shows that between 2004 and 2011 annual average tempeatures have been mostly above the average from 1971 and 2000. This pattern shows that New Zealand is getting warmer. Also, there is a tendency that recently El Niño and La Niña events have influenced New Zealand more frequently due to global warming. In addition, the more El Niño and La Niña have affected New Zealand, the more climate extremes have occurred. There is also some evidence that the westerly winds have increased over New Zealand because of global warming and climate change (Ministry for the Environment, 2008f). The northeastern regions of the North Island have become drier than normal conditions while the west and southwest of the South Island have been in wetter conditions partly due to increased westerly wind events. As a result, eastern regions of the North Island have experience more severe droughts. On the other hand, extreme rainfall events have increased in the west of the South Island (Ministry of Agriculture and Forestry, 2010c). There was a high confidence that these global-scale climate systems have affected New Zealand climate significantly and thus, lots of severe climate extremes, such as extreme heat waves, droughts & floods, unexpected snowfall events, strong winds and tornados, damaging hailstorms and electrical storms are likely to occur more frequently, partly due to uncertainty in global-scale climate systems and climate change.

In summary, New Zealand has become warmer and regional variation in rainfall events seem to have worsened partly due to changes in global-scale climate systems. Also, more frequent climate extremes have occurred over the country.

Table 3 Main features of New Zealand Temperature, Rainfall and climate extremes from 2004 to 2011 (NIWA, 2012a)

Year	ENSO/SAM	Temperature	Rainfall	Climate extremes
2011	Strong La Nina(spring to autumn) Negative SAM except for Feb, May, & Dec	0.3˚C above the 1971-2000 average	Wet: the North Island Dry: the east & southwest of the South Island	Heat wave (Feb),warmer (May, Jun) 2 snowfall events (Jul, Aug) 5 extreme rainfall events & floods
2010	Moderate El Nino → La Nina (Jul-Dec) SAM: strongly positive	0.5˚C above the 1971-2000 average	Wet: the northeasten regions Dry: other regions	Two droughts (Jan-May, Dec) Heat waves (Jan, Mar, Nov-Dec) Heavy rain & floods (Jan, Apr, May, Dec)
2009	La Nina → El Nino (end-year)	0.2˚C below the 1971-2000 average	Wet: Gisborne, Manawatu, Westland Dry: other regions	Heat waves (Feb) Floods (Ari, West Coast) Heavy rain & floods (Jun, Gisborne) Heavy snowfall (May, Oct)
2008	La Nina→ neutral (mid-year) → La Nina	0.3˚C above the 1971-2000 average	Wet: the north & west of the North Island, the north of the South Island Dry: Gisborne, Hawkes Bay, easter Otago	Severe droughts (Jan-Mar, Dec) Heat waves (Jan, Mar) Floods (Apr, Jul, Aug)
2007	Weak El Nino (Jan) → neutral (Feb-Aug) → La Nina (Sep-Dec)	0.1˚C above the average Warmer in the North Island	Wet: Northland Dry: other regions	Heavy rainfall events & 9 floods 14 damaging tonado Hot spell (early autumn, late spring) 2 severe hailstorms & 7 damaginf electrical storms
2006	Weak La Nina → El Nino (Sep-Dec) More the southeasterlies	0.2˚C below the average Warmer in the northeast	Wet: the northwest in the North Island, Canterbury Dry: Central Otago, Marlborough, the northeastern regions	Heavy rainfalls & 12 floods 9 notable snowfalls Summer heatwave 4 tornados, 3 severe hailstorms, & damaging windstorms
2005	Weak El Nino (Jan-Jun) → La Nina	0.5˚C above the average	Wet: Bay of Plenty, Hawke's Bay Dry: the South Island	Heavy rainfall events & about 13 floods Warmer months (Feb, Mar, May, Jul, Sep, Dec) & heat wave (Jan) Tornado (Greymouth), damaging hailstorms
2004	`Weak El Nino (all around the year) With strong westerly and south westerly winds	0.3˚C below the average	Wet: Bay of Plenty, Manawatu, Kapiti, Upper Hutt, Wairarapa Dry: Marlborough, eastern Otago	28 heavy rainfall events & 12 floods mainly in the North Island Storms (Feb) Many snowfall events (spring) 19 high wind events, tornado, & damaging hailstorms

2.2.3. Future climate

New Zealand's climate is likely to become warmer in particular the North Island, more westerly winds and wetter in the wester regions, and drier in the eastern regions over the next 100 years. Accroding to the IPCC 4th report, global averages of surface temperatures are expected to increase by 1.1 to 6.4ºC at the end of this century. Even though global warming may influence New Zealand less, and more slowly than the Northern Hemisphere because New Zealand is surround by the ocean, it is evident that New Zealand cannot be free from global climate trends.

The projected changes in average temperatures and rainfall for New Zealand regions are illustrated by Table 4. The mid-range climate scenarios by NIWA expect that NZ average temperatures will increase by about 0.9ºC by 2040 and 2.1ºC by 2090 with a faster increase in the North Island than the South. Also, an increase of average temperatures is expected in summer and autumn, relative to winter and spring. As a result, frost events are predicted to decrease over the next century whereas days above 25ºC are expected to increase, especially in northern regions (Ministry for the Environment, 2008a; Ministry of Agriculture and Forestry, 2010c).

Table 4 Predicted changes in seasonal mean temperature and rainfall (%) relative to 1990 (Ministry for the Environment, 2008f)

Region		Temperature (ºC)		Rainfall (in %)	
		Winter-spring	Summer-autnmn	Winter-spring	Summer-autnmn
Northland, Auckland	2040	0.8 ~ 0.9	1.0 ~ 1.1	-1 ~ -9	0 ~ 1
	2090	1.9 ~ 2.0	2.1 ~ 2.3	-1 ~ -16	-3 ~ 1
Western North Island (Waikato, Taranaki, Manawatu-Whanganui)	2040	0.8 ~ 0.9	1.0 ~ 1.1	-3 ~ 7	-1 ~ 3
	2090	1.8 ~ 2.1	2.2 ~ 2.3	-5 ~ 13	-3 ~ 4
Eastern North Island (Bay of Plenty, Gisborne, Hawke's Bay)	2040	0.8 ~ 0.9	1.0	-4 ~ -13	2 ~ 5
	2090	1.8 ~ 2.0	2.1 ~ 2.2	-3 ~ -16	2 ~ 9
Wellington, Nelson, Marlborough	2040	0.8 ~ 0.9	1.0	-6 ~ 4	0 ~ 5
	2090	1.7 ~ 2.1	2.1 ~ 2.2	-7 ~ 9	-1 ~ 6
West Coast	2040	0.7 ~ 0.9	1.0	5 ~ 11	0 ~ 3
	2090	1.7 ~ 2.1	2.1 ~ 2.2	8 ~ 21	-1 ~ 3
Canterbury, Otago	2040	0.7 ~ 1.0	0.9	-8 ~ 16	1 ~ 5
	2090	1.7 ~ 2.2	2.0 ~ 2.1	-11 ~ 29	0 ~ 6
Southland, Chatham Islands	2040	0.7 ~ 0.9	0.8 ~ 0.9	3 ~ 10	-1 ~ 4
	2090	1.6 ~ 2.1	1.9 ~ 2.1	6 ~ 18	-3 ~ 4

IPCC climate models expect that El Niño events in the Pacific ocean will happen more frequently due to global warming in the next 50 years. Consequentially, New Zealand are predicted to experience more El Niño events. The westerly and southwesterly winds in winter and spring are also expected to increase by 10% to 20%. On the other hand, in summer and autumn the westerly winds will decrease by 5% to 20% (Ministry of Agriculture and Forestry, 2010c). NIWA's climate scenarios showed that in the west of New Zealand annual rainfall is expected to increase up to 5% by 2040 and 10% by 2090 partly due to strengthen westerly wind patterns. In contrast, eastern regions, such as Gisborne and Hawke's Bay are expected to experience a decrease of about 5% in precipitation (Table 4). In particular, rainfall in eastern regions will decrease significantly in winter and spring while in summer and autumn rainfall in those regions are expected increase slightly (Ministry for the Environment, 2008f).

In the next 50 years, New Zealand is expected to experience more frequent and unexpected climate extremes, such as droughts and floods, heat waves and extreme colds, heavy rain and snowfall events, damaging strong winds and storms. For instance, drought risk will increase over the country, in particular eastern regions, such as Gisborne, Hawke's Bay and Canterbury. Also, extreme rainfall is expected to occur two times more frequently than now and thus, New Zealand will experience more floods. Frost risk and snow cover will decrease with increase of average temperature. However, unexcepted snowfall and late spring frost events may influence crop production (Ministry of Agriculture and Forestry, 2010c).

2.3. Impacts of climate change

According to the IPCC's climate scenarios, global average temperatures are expected to increase by about 2.8°C at the end of this century. Also, global precipitation patterns are predicted to change around the world. Agriculture is highly susceptible to weather conditions, such as temperature, sunshine hours, and rainfall. This is because basically plant physiology, development and photosynthesis are dependent on them. This section will describe the impacts of climate change on agricultural crop production. In particular, the effects of high CO_2 concentration, warmer temperatures and water stress are mainly explored.

2.3.1. High carbon dioxide (CO_2) concentration

High levels of carbon dioxide in the atmosphere are expected to be beneficial to crop production, in particular C_3 plants. Carbon dioxide is essential for plants to survive.

Plants use carbon dioxide as the primary carbon source during photosynthesis. Plants absorb carbon dioxide via stomata in the leaves and emit water vapour out of the leaves through transpiration. Carbon dioxide fixation by photosynthesis is determined by several factors, such as light intensity and carbon dioxide concentration in the leaves. Carbon dioxide concentration in the leaves depends on the diffusion gradient between in and out of the leaves and photosynthesis resistance: the boundary layer resistance, the stomatal resistance, the mesophyll cell resistance, and the biochemical resistance. According to the IPCC's estimates, atmospheric carbon dioxide concentration is expected to increase from 380 ppm in 2007 to 450 ppm by 2050. High carbon dioxide concentration in the air is expected to have a positive effect on photosynthesis and crop production. This is because high atmospheric carbon dioxide concentrations cause higher diffusion gradient. This results in the increase of carbon dioxide absorption and subsequent photosynthesis. However, the effects of high carbon dioxide concentration may vary with different plant types, such as C_3 plants and C_4 plants. This is because C_3 plants have different photosynthetic mechanism from C_4 plants. For example, the initial carbon dioxide fixation enzyme in C_3 plants is Rubisco (Ribulose biphosphate carboxylate oxygenase). Ribulose biphosphate (RuBp) of C_3 plants binds with CO_2 and is converted into 3-Phospho-glyceric acid by Rubisco. However, Rubisco has a low affinity with CO_2 and therefore carbon dioxide compensation point of C_3 plants is higher (about 40-100 ppm) than that of C_4 plants (Sage & Monson, 1999). High carbon dioxide concentration in the air leads to higher level of carbon dioxide in the chloroplast of C_3 plants and it stimulates photosynthesis of C_3 plants. However, high carbon dioxide concentration in the atmosphere has little effect on C_4 plants relative to C_3 plants. This is because the initial fixation enzyme of C_4 plants is Phospho-enyl pyruvate (PEP) carboxylase and has a high affinity for carbon dioxide. The carbon dioxide compensation point of C_4 plants is low (about 0 to 5ppm). Therefore, the effects of elevated concentration of atmospheric carbon dioxide on photosynthesis are limited. Table 5 shows the effects of a doubling of carbon dioxide concentration on plant physiology and yields using enclosed chambers and free-air carbon dioxide enrichment (FACE) experiments. Enhanced carbon dioxide concentration had significant positive effects on photosynthesis and yields of C_3 plants (e.g. bean, peanut, rice, soybean, wheat). Leaf photosynthesis of C_3 plants was improved by 50 per cent. Also, yields of C_3 plants increased by 44 per cent. On the other hand, the effects of high carbon dioxide concentration on C_4 plants, such as maize and sorghum were less than C_3 plants. For example, leaf photosynthesis and grain yield of maize increased slightly by 3 per cent and 4 per cent. Grain yields of sorghum also showed a little increase of 8 per cent (Hatfield et al., 2011). Another study indicated that enriched carbon dioxide concentration could increase C_3 plants growth by 41 per cent, C_4 plants growth by 22 per cent and CAM plants growth by 15 per cent (Poorter, 1993)

Table 5 Effects of a doubling of carbon dioxide concentration on plant physiology and yields (Hatfield et al., 2011)

Crops	Leaf photosynthesis	Total biomass	Grain yield	Leaf stomatal conductance	Canopy evapotranspiration
	% change				
Maize	3	4	4	-34	
Sorghum	9	3	0, 8	-37	-13
Bean	50	30	27		
Peanut	27	36	30		
Rice	36	30	30		-10
Soybean	35	37	34-38	-40	-9, -12
Wheat	35	15-27	31	-33 to -43	-8

High carbon dioxide concentration is supposed to increase photosynthesis of plants through several processes as follows; firstly, high carbon dioxide concentration in the air increases the level of carbon dioxide in the chloroplast in the leaves. Secondly, high carbon dioxide concentration reduces photorespiration in C_3 plants. This is because Rubisco in C_3 plants is usually exposed to low carbon dioxide and high oxygen concentration conditions. Under these circumstances, photorespiration, an oxygenation reaction of Rubisco, is stimulated to produce carbon dioxide. However, under high carbon dioxide concentration, photorespiration of Rubisco is not necessary and therefore this oxygenation reaction is reduced. Thirdly, high CO_2 concentration can reduce photo-inhibition by active oxygen species. This is because under high oxygen concentration conditions, active oxygen species increase and have negative influence on cellular membranes, enzymes and photosynthesis. High carbon dioxide concentration can reduce those oxygen species and alleviate their detrimental impacts on plant physiology. Finally, high carbon dioxide can increase water use efficiency due to an increase of the stomatal closure(Pritchard & Amthor, 2005).

High carbon dioxide concentration has a positive effect on potato growth and yields. For example, tuber dry weight and tuber yield increased by 34 to 40% and 39 to 44% respectively under enriched carbon dioxide concentration condition (740 to 1000ppm) (Sicher & Bunce, 1999; R. M. Wheeler, Tibbitts, & Fitzpatrick, 1991). Jaggard, Qi, and

Ober (2010) expected that if atmospheric carbon dioxide concentration increased from 380 ppm to 550 ppm by 2050, as IPCC scenario predicted, yields of potatoes would increase by about 36 per cent. Also, high carbon dioxide concentration was suggested to mitigate a negative effect of warmer temperature on crop yield (Rosenzweig. et al., 1996).

A long term carbon dioxide enrichment experiment on orange trees indicated that high carbon dioxide concentration could have significant effects in yields of oranges (Kimball, Idso, Johnson, & Rillig, 2007). The experiment was conducted to investigate the effects of enriched carbon dioxide on crop yields and plant growth for seventeen years. Table 6 shows the changes in yields and plant growth

Table 6 Changes in biomass of orange between enriched and ambient carbon dioxide conditions during 17 years experiment (SE: Standard Errors) (Kimball et al., 2007).

Item	Enriched		Ambient		Changes between enriched and ambient (%)
	Mean	SE	Mean	SE	
Biomass at final harvest (spring 2005 after 17 years)					
Fruit biomass (kg/tree)	32.9	2.1	10.9	0.6	202
Leaf biomass (kg/tree)	33.6	0.9	26.2	1.1	28
Twig biomass (kg/tree)	30.1	1.2	26.8	1.6	12
Branch biomass (kg/tree)	124.6	6.4	78.8	5.1	58
Trunk biomass (kg/tree)	110.0	10.9	80.4	2.0	37
Stump biomass (kg/tree)	41.0	2.6	26.3	0.3	56
Large root biomass (kg/tree)	40.6	1.7	27.7	2.2	47
Total biomass (kg/tree)	413.8	16.7	274.8	9.0	51
Miscellaneous parameters at final harvest					
Above-ground biomass (kg/tree)	332.3	13.8	220.9	6.9	50
Below-ground biomass (kg/tree)	81.6	4.2	53.9	2.5	51
Root/shoot ratio	0.246	0.010	0.244	0.006	1
Number of fruits/tree	863	62	311	19	177
Average fruit weight (g/fruit)	39.2	1.4	38.3	0.5	2
Number of leaves/tree	78300	2500	66000	2700	19
Leaf area/tree (m^2/tree)	249	8	223	8	12
Area per leaf (cm^2/leaf)	31.8	1.1	33.7	0.9	-6
Cumulative parameters					
Harvested fruit biomass (kg/tree)	518.2	26.4	280.8	11.5	85
Number of fruit per tree	13840	350	7660	180	81
Fruit size (kg/fruit)	37.3	0.9	36.4	0.7	2
Total cumulative biomass (kg/tree)	1127	35	664	25	70

Fruit biomass increase by about 200 per cent due to enriched carbon dioxide concentration in the air. The increase in biomass mostly came from an increase in the number of fruits but there was no significant change in fruit size (Kimball et al., 2007). To sum up, high carbon dioxide concentration in the air may increases C_3 plants yields significantly resulting from enhanced carbon dioxide concentration in the chloroplast. However, the effects of enriched carbon dioxide concentration on C_4 plants are likely to be not as strong as C_3 plants.

2.3.2. High temperature

At higher latitudes or in the cold regions, global warming and rising average temperatures may be beneficial to agricultural crop production because rising temperatures can be helpful to expand cultivated areas in these regions. Crops can be grown in further northern regions or at high altitudes with longer cultivated periods (Wheeler & Kay, 2010). However, in many temperate regions, where most agricultural production for human consumption occurs, an increase of average temperatures can have negative effects on plant physiology, development and photosynthesis.

Higher temperatures can affect plants in several ways. Firstly, high temperatures can affect photosynthesis in plants and impact on crop yields. In fact, the impacts of high temperature vary with the species and the life-cycles of crops. In general, high temperatures have less negative impacts on C_4 plants than C_3 plants. This is because C_4 plants have higher optimum temperature for photosynthesis pathway than C_3 plants. For example, the optimum temperature of wheat for photosynthesis is between 15ºC and 30ºC. Photosynthetic CO_2 assimilation of wheat decreases rapidly over 30ºC. However, the optimum temperature for photosynthesis in maize is between 30 and 40 ºC. Therefore, maize, a typical C_4 plant, is able to maintain its photosynthetic ability even under higher temperature conditions compared with C_3 plants. The reason that the optimum temperatures for photosynthesis vary with C_3 plants and C_4 plants can be explained partly by quantum yields of C_3 and C_4 plants. Quantum yield means "an amount of carbon dioxide assimilated per photon absorbed" (Pritchard & Amthor, 2005).

Figure 11 shows the quantum yields of C_3 and C_4 plants. Quantum yields of C_4 plants show no significant change with an increase of leaf temperatures. On the other hand, quantum yields of C_3 plants decrease rapidly compared with C_4 plants. Therefore, C_4 plants result in better quantum yields than C_3 plants under higher temperature. However, chloroplasts are sensitive to high temperature. They can be damaged when temperatures rise over 40ºC. This results in the reduction of photosynthesis (Pritchard & Amthor, 2005).

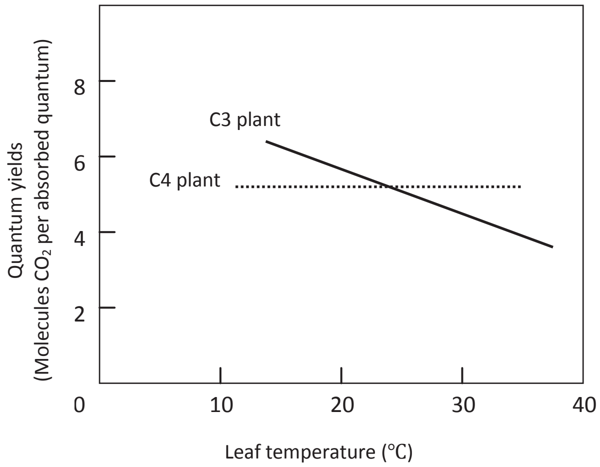

Figure 11 Quantum yields of C_3 and C_4 plants against leaf temperature (Pritchard & Amthor, 2005)

High temperatures are likely to have a negative effect on photosynthesis of C_3 plant. On the other hand, no significant influence of high temperatures on C_4 plants can be found. However, under extreme high temperatures, such as over 40 ºC, even C_4 plants can be detrimentally impacted.

Secondly, higher temperatures can affect plant development, physiology and respiration rate. With respect to annual crops, higher temperatures may result in faster plant development and crop cycling. Faster plant development can cause the reduction of crop yields due to the shorter life cycle. Usually a short life cycle leads to smaller plants and leaf areas. The reduction of leaf area means the decrease of light interception and crop photosynthesis (Hatfield et al., 2011). For instance, crop duration of wheat can decrease by 21 days with only a 1ºC increase in temperature. Also, in rice production, higher temperature conditions (34/27/31ºC; day/night/paddy temperature) can result in 10 days decrease of flowering time compared with lower temperature conditions (25/18/21ºC) (Pritchard & Amthor, 2005). The reduction of growth duration appears to have significant effects on crop yields because the amount of biomass is reduced with a decrease of plant growth duration. Furthermore, high temperatures can have more significant effects on the reproductive stage than other development stages. In particular, the effects of temperature extremes during the pollination stage or the fruit set stage can have a fatal impact on pollen viability, fertilization and fruit formation (Hatfield et al., 2011). In addition, high temperatures can stimulate crop respiration in short-term periods. However, the effects of high temperatures over long-term periods were relatively smaller compared with short-term periods. This is because crops can adapt better to high temperature over long-term periods (Pritchard & Amthor, 2005).

High temperatures can influence breaking dormancy in many perennial crops. Most perennial crops, such as pip-fruit, kiwifruit and black currents, require sufficient chilling duration for breaking dormancy. For example, apples (*Malus domestica*) in New Zealand require 1100 to 1700 hours at optimum chilling temperature (usually 5 to 7 ºC in Utah chill unit model) and blackcurrants (*Ribes nigrum*) need 2000 hours. Insufficient winter chilling can cause a delayed bud burst, lower bud break rate and subsequent slower and weaker growth. As a result, yields and quality of fruit may decrease due to insufficient chilling. Hence, sufficient winter chilling is important for perennial crop production. However, recent rising temperatures cause warmer winters and also shorten winter chilling duration. Hydrogen Cyanamide has been widely used to break dormancy in New Zealand and is effective on many perennial crops, such as kiwifruit and grapes (Kenny, 2008). However, current warmer winters have added to farmers' difficulties and consumers may not want an extra chemical application in system. In addition, warmer temperatures can cause earlier flowering of apple. For example, in Germany, flowering of apples has occurred 4.6 days earlier with an increase of 1ºC in average temperature (Chmielewski, Muller, & Bruns, 2004). In Japan, apple blossom began 3.8 to 4.6 days earlier with an increase of 1 ºC in temperature (Fujisawa & Kobayashi, 2010). Fujisawa & Kobayashi (2011) indicated that frost damage of apple in spring could increase due to earlier flowering.

Warmer temperatures have a negative effects on crop production even though C_4 plants maintain its photosynthetic potential up to 40ºC. According to a study by Muchow, Sinclair, & Bennett (1990), maize production in cool regions was higher than warm regions. Also, an increase of 2 ºC in average temperatures resulted in the reduction of maize yields by 5 to 8 per cent in the central Corn Belt. The study by Pritchard & Amthor (2005) also indicated that in most cases, high temperatures had negative influence on wheat production and yields of wheat decreased up to 48 per cent due to high temperature (Table 7).

Table 7 Effects of experimental warming on wheat yield (Pritchard & Amthor, 2005)

Temperature treatment	Effect of warming on yield (%)	Notes	Source
1.1-1.6℃ above ambient	-7	cv. Hartog	(Rawson, 1995)
1.1-1.6℃ above ambient	-0.5	cv. Late Hartog	(Rawson, 1995)
1.5-2.2℃ above ambient	-43	cv. Hartog	(Rawson, 1995)
1.5-2.2℃ above ambient	-30	cv. Late Hartog	(Rawson, 1995)
2.1-2.3℃ above ambient	-16	cv. Hartog	(Rawson, 1995)
2.1-2.3℃ above ambient	+3	cv. Late Hartog	(Rawson, 1995)
4℃ above ambient	-18	448 kg N per ha	(Mitchell et al., 1993)
4℃ above ambient	-22	83 kg N per ha	(Mitchell et al., 1993)
+2℃ (whole season)	-22	cv. Galahad	(Batts et al., 1998)
+2℃ (whole season)	-6	cv. Hereward	(Batts et al., 1998)
+2℃ (whole season)	-31	cv. Merica	(Batts et al., 1998)
+2℃ (whole season)	-36	cv. Soissons	(Batts et al., 1998)
+2℃ (whole season)	-48	cv. Hereward, 1995	(Batts et al., 1998)

Lobell, Schlenker, and Costa-Roberts (2011) estimated that global yields of maize, wheat, and soybean between 1998 and 2009 would be reduced by 0.8 to 4.9% due to an increase in global temperatures (Table 8). However, rice yield increased by 0.1 per cent because usually rice is cultivated in warmer regions and in deep watered fields. Therefore, warmer temperatures may have relatively lower impact on rice production than other crops production.

Table 8 Median estimates of global impacts of temperature and precipitation trends, 1980-2008, on average yields for four major crops (Lobell et al., 2011)

Crop	Global production, 1998-2002 average (millions of metric tons)	Global yield impact of temperature trends (%)	Global yield impact of precipitation trends (%)	Subtotal	Global yield impact of CO_2 trends (%)	Total
Maize	607	-3.1	-0.7	-3.8	0.0	-3.8
Rice	591	0.1	-0.2	-0.1	3.0	2.9
Wheat	586	-4.9	-0.6	-5.5	3.0	-2.5
Soybean	168	-0.8	-0.9	-1.7	3.0	1.3

In general, potatoes are sensitive to temperatures and cool temperature is one of the natural factors inducing tuber formation. Theoretically, it is true that high temperatures can have a negative influence on potato growth and photosynthesis. However, the effects of high temperatures on potato yields are not easily to be predicted because they may vary with natural factors, such as geographical and weather conditions. A simulation study at 12 sites in USA showed that yields of autumn potatoes were estimated to decrease up to 19.2% with increase of 1.5 ºC in temperature (Table 9). The highest decrease (71.6 %) in yields was observed at Indianapolis (USA) with an increase of 5ºC (Rosenzweig. et al., 1996). This is partly because warmer temperatures cause a decrease in potato growth duration (Nottage, Wratt, Bornman, & Jones, 2010). However, potential yields of potatoes in eastern Scotland were predicted to increase by 34-39% over the 47 years due to warmer temperatures and the increased duration of the green canopy (Gregory & Marshall, 2012).

Table 9 Change (%) in yields of autumn potatoes with increase of temperature at 12 sites in USA (Rosenzweig. et al., 1996)

Site	Base yield	Percentage change from base at		
	(*t/ha*)	+ 1.5 ºC	+ 2.5 ºC	+ 5.0 ºC
Yakima, WA	80.4	- 1.4	- 3.8	- 18.5
Medford, OR	81.0	- 6.1	- 11.0	- 28.1
Pendleton, OR	81.4	- 6.8	- 11.9	- 30.6
Boise, ID	62.6	- 7.1	- 13.5	- 34.1
Maribou, ME	46.6	- 2.0	- 6.0	- 21.6
Buffalo, NY	43.1	- 12.1	- 21.5	- 48.8
Fargo, ND	43.0	- 10.3	- 18.9	- 44.4
Muskegon, MI	44.8	- 11.3	- 20.1	- 45.5
Madison, WI	42.6	- 10.7	- 19.9	- 45.9
Scottsbluff, NE	36.9	- 17.0	- 29.5	- 64.0
Alamosa, CO	52.7	- 5.2	- 10.1	- 26.3
Indianapolis, IN	34.8	- 19.2	- 33.4	- 71.6

Warmer temperatures have significant effects on citrus yields. Rosenzweig et al. (1996) suggested through their simulation study that high temperatures could increase yields of citrus up to 47% at 10 current cultivated sites in USA. Tubiello et al. (2002) also showed that simulated yields of citrus in Tucson (Arizona, USA) increase by 20 to 50% by 2090. Duan et al. (2010) also found that citrus temperature risk in the south subtropics of China decreased between 1975 and 1991. But no significant changes in citrus temperature risk at the time could be found in mid and north subtropics of China. In Cordoba and Murcia regions of China, citrus yields were expected to increase up to about 40% by 2100 with increase of temperature (Iglesias, Quiroga, & Schlickenrieder, 2010). However, citrus is also vulnerable to extreme high temperatures even though it is cultivated in the tropical and subtropical regions. For example, extreme high temperatures during flowering and fruit setting can cause fruit abscission and result in the reduction of fruit production and yield. High temperatures also affects fruit quality, such as sugar levels and colour, In addition, tree storage duration decreased resulting from temperature rise (Rosenzweig. et al., 1996). Medellin-Azuara et al. (2011) suggested that simulated yields of citrus in California, USA, are expected to decrease by about 19% by 2050 due to higher temperature and reduced water supply.

In summary, warmer temperatures have a significant influence on crop production both directly and indirectly. However, the impact of higher temperatures on crop production cannot be predicted easily whether it is positive or negative. This is because many natural variables are related to crop production.

2.3.3. Water stress

It is difficult to predict a future trend of precipitation. It is also premature to conclude that global warming causes lower precipitation over the world. This is because precipitation can vary with natural factors, such as temporal and geographical conditions. However, it is true that recent severe droughts have occurred frequently over the world and climate change has aggravated water shortage in many regions, such as southern Australia and Africa (IPCC, 2007b). Water is essential to maintain plant growth and development. Firstly, water is one of the important constituents of plant and represents 80 to 90 per cent of the fresh weight of most herbaceous plants. Also, water is used as a solvent for gases, minerals and other solutes. Water is a reactant in many physiological processes, such as photosynthesis and plays an important role to maintain turgor pressure in plant cells. Therefore, sufficient water supply is essential for plant growth and photosynthesis, otherwise, a lack of water supply can cause disruption to photosynthesis and result in a decrease in plant growth and crop yields.

Plants emit water vapour via stomata through transpiration. 95 per cent of water absorbed from the soil is lost through transpiration and just 5 per cent of water remains in the plants (MacAdam, 2009; Taiz & Zeiger, 2010). The amount of water loss through transpiration depends on the water supply, the energy supply, resistance and the difference in vapour pressure deficit between the leaves and the air. In general, the difference in vapour pressure deficit is influenced by internal leaf water vapour pressure that is related to leaf temperature. Increasing air temperatures due to climate change and global warming can cause an increase in leaf temperature and leaf water vapour pressure. As temperatures increase, the air can hold more water vapour. As a result, warmer temperatures can lead to more water loss via stomata due to an increase in vapour pressure deficit in the air (Hatfield et al., 2011). However, the relationship between high temperature and water loss is complicated. For instance, high temperature may shorten plant growth duration and result in the reduction of total plant water requirement. Also, a high carbon dioxide concentration in the air also affects crop water use directly. Increasing carbon dioxide concentration in the air causes stomatal closure and results in the decrease of stomatal conductance and water loss. In several studies, the reduction of stomatal conductance due to elevated carbon dioxide concentration was observed. Kimball and Idso (1983) found that stomatal conductance was reduced by about 34 per cent with doubling carbon dioxide concentration. Another study showed that increasing carbon dioxide level in the air caused the reduction of stomatal conductance by 39 per cent in C_3 plants and 29 per cent in C_4 plants (Wand et al., 1999). Hatfield et al. (2011) estimated that increase in carbon dioxide concentration by 450 ppm, which the IPCC report (IPPC, 2007b) suggested, could reduce stomatal conductance by 10 per cent.

However, in many cases climate change and global warming seem to aggravate water stress. In east and south-east England, the production of water-intensive crops, such as potatoes may need to shift northward due to an increase of water shortage in dry summer seasons (Knox, Morris, & Hess, 2010). Potato canopy growth decreased even under high carbon dioxide concentration due to lack of water supply but total biomass – which includes tops and tubers – of potatoes grown under enriched carbon dioxide concentration and decreasing irrigation conditions was similar to that of potatoes under ambient and irrigation conditions (Fleisher, Timlin, & Reddy, 2008). For soft fruits, such as strawberry and blackberry, increased water shortage may influence crop yields. For instance, the potential soil moisture deficit (PSMD) is expected to increase by 28% to 51% by 2050 with low and high-emission scenarios in the major strawberry cultivated regions, UK (Else & Atkinson, 2010). Kapur et al. (2010) found that the net irrigation requirements (NIR) for citrus and olive trees will increase by 48% and 65% by the end of this century in the Apulia region, Italy.

In summary, global warming and climate change is highly likely to deepen water shortage in many regions. Water shortage could result in the severe reduction of crop yields including potatoes and citrus.

2.3.4. Outbreak of pests, disease and/or weeds

There is no doubt that pest, disease and weed management plays an essential role for increasing crop yields since the Green Revolution. However, it is true that plant pests, disease, and weeds continue to cause negative impacts on crop production. Chakraborty and Newton (2011) indicated that plant pests and diseases attributed to a decrease of about 10 to 16 per cent in global crop yields annually and if sufficient management were not followed, yields of major crops would be reduced by 50 per cent. They added that average loss of rice between 2001 and 2003 was about 37 per cent of total rice production due to pests, disease and weeds (pests 15 %, pathogens 11%, viruses 1%, and weeds 10%).

Warmer temperatures and humid conditions are expected to promote the spread of pests, disease, and weeds. Climate change and global warming can have influence host-pathogen interactions and potential outbreaks of pests, disease and weeds. For instance, warmer temperatures can stimulate insects' activities and result in the increase of insect population and the expansion of insects' habitats or extend their life cycles. Pritchard and Amthor (2005) indicated that warming and high humidity can cause an increase of key pests and disease. *Fusarium Head Blight* (FHB) is a good example that shows the impacts of climate change on disease. FHB is one of the serious diseases in wheat. Between 1998 and 2000, FHB caused $ 2.7 million loss in the northern Great Plains and central USA (Chakraborty & Newton, 2011). As outbreaks of FHB tend to increase under warm and wet conditions, recent global warming and climate change has influenced severity of FHB. For instance, *Fusarium* and *Microdochium* species usually cause FHB. In the cooler climate of Europe *Fusarium culmorum* and *Microduchium nivale* are the dominant species which cause FHB. However, *Fusarium graminearum*, which produces more mycotoxin than *F. culmorum* and *M. nivale*, has become more prevalent species in the Netherlands due to climate change and global warming. This is because *F. graminearum* likes warmer conditions more than other species. Furthermore, the growing carbon dioxide concentration in the air may increase FHB inoculum. Chakraborty and Newton (2011) showed that under high carbon dioxide concentration, *Fusarium* biomass per unit wheat tissue increased. It is not clear why *Fusarium* biomass increases. One potential explanation is that the increase of plant biomass leads to increase of FHB inoculum. Bale et al. (2002) indicated that temperature was the dominant factor deciding insect proliferation and outbreaks of insect herbivores could be stimulated by warmer temperature and longer growing seasons. Hakala et al. (2011) also expected that eye-spot, which was a serious disease of wheat and rye, could increase in Finland resulting from rising temperatures. Also, powdery mildew infections of wheat and barley were predicted to increase due to warmer temperature. On the other hand, Aurambout et al. (2009) estimated that in Australia, the risk of the Asiatic citrus psyllid (*Diaphorina citri* Kuwayama), which caused citrus greening, was expected to decrease with increasing temperatures due to reduced interval of new citrus growth. However, they predicted that the southern coastline of Australia would be more suitable areas for *D. citri* in the future resulting from warmer temperature. Warmer temperatures and enriched carbon dioxide concentration in the air may contribute to an increase of weeds. This is because most weeds are C_4 plants which are less affected by warmer temperature than C_3 plants. Even, warmer temperature can stimulate photosynthesis and growth of C_4 weeds. Also, weeds have a more varied gene pool compared to crops. Hence, under new environmental conditions, such as high temperature, salt and ozone stresses, and rising carbon dioxide concentration, weeds are able to adapt themselves to this new circumstance more quickly than commercial crops (Chakraborty & Newton, 2011). In summary, in many cases outbreaks of pests, disease, and weeds are expected to increase in response to warmer temperatures and enriched carbon dioxide concentration in the atmosphere.

2.3.5. Others

Pollination is an important element which determines crop yields and quality, and pollinators, such as bees and butterflies, play a crucial role for pollination of plants and reproduction. In fact, Ecosystems and crop production are highly reliant on pollination and pollinators. Actually, 75 per cent of global crop production is determined by insect pollination and the value of insect pollination in the world was predicted to be about €153 billion (9.5 per cent of total value of global crop production) in 2005 (Potts et al., 2010). Honey bees are the most common pollinator and are responsible for 96 per cent of animal-pollinated crops (Potts et al., 2010). However, recently honey bees have been reduced in many countries and in NZ the varroa mite has decimated bee colonies in last decade. For example, In the USA, the colonies of honey bees have decreased by 59 per cent between 1947 and 2005. Also, 25 per cent loss of honey bees' colonies has been found in central Europe from 1985 to 2005. The number of bumblebees has also decreased quickly in some countries, such as Belgium and the UK (Potts et al., 2010).

The recent decline of pollinators is likely to be generated by several factors such as habitat loss, introduction of alien plants and pollinators, increase of pests and pathogens, and climate change. Habitat loss and change in land-use are known as important factors which influence the decrease of pollinators. Introduction of alien plants may cause the reduction of native pollinators which rely on native host plants. Alien pollinators can also lead to outbreaks of new diseases (Potts et al., 2010).

Several studies have shown the relationship between pollinators and climate change. Hickling et al. (2006) investigated the distribution of 16 taxonomic groups and 329 species in the UK. They found that most species (275 species) of these taxonomic groups including 29 species of butterflies moved their habitats northwards and to higher regions due to global warming. Williams et al. (2007) found that bumblebees generally had a narrow climate niche and were highly vulnerable to climate change and global warming. Settele et al. (2008) predicted that future change of distribution of butterflies by climate change would be more serious than ever.

High ozone concentration in the air due to climate change can also affect crop production. Generally, ozone is generated from photochemical reactions of several chemicals; carbon monoxide, methane, nitrous oxide and volatile organic compounds (IPCC, 2007a). Figure 12 shows the change of tropospheric ozone concentration. Since the pre-industrial age, tropospheric ozone concentration has increased by 38 per cent (20-50 per cent) and most increase in tropospheric ozone seems to come from human activities (IPCC, 2007a).

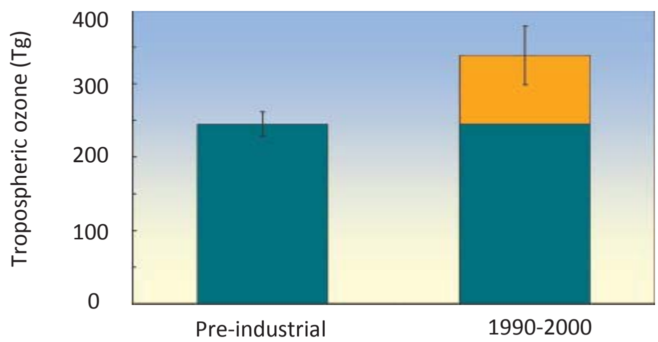

Figure 12 Change in tropospheric ozone concentration (IPCC, 2007a).

Several studies showed that high ozone concentration in the atmosphere can cause the significant reduction of photosynthesis of sensitive crops. For example, photosynthesis of barley decreased by 17 per cent under higher ozone concentration (180 ppb) compared with lower ozone concentration condition (10 ppb) (Plazek, Rapacz, & Skoczowski, 2000). Also, in soybean, the leaf photosynthesis rate was reduced by 20 per cent due to higher ozone levels in the air (70ppb) compared with lower ozone level (carbon filtered air) (Morgan, Ainsworth, & Long, 2003). The reduction of photosynthesis rate under high ozone concentration conditions can be explained by several mechanisms. Elevated ozone concentration leads to stomatal closure and a decrease of stomatal conductance. In addition, it causes oxidative damage to chloroplasts and also stimulates leaf senescence. Furthermore, high ozone concentration influences Rubisco and photosynthetic pigments, such as chlorophyll. As a result, rising ozone concentration may reduce photosynthesis and crop yields significantly.

Salinization is often overlooked because in most well irrigated areas, salinization is not a serious problem. However, in arid and semiarid areas salinization is one of the most significant issues for crop cultivation. Salinization is usually accompanied by droughts. All irrigation water has some salts. When sufficient water is not supplied to the soil, salts are accumulated on the surface of the soil with increase of water evaporation. This accumulation causes salinization. Table 10 shows estimates of cultivated, irrigated and salinized areas in the world in 1985 and 2000 (Pritchard & Amthor, 2005). Salinized areas in the world have increased from 45-60 million ha in 1985 to 62 to 82 million ha in 2000 even though irrigated areas have increased from about 225 million ha to 272 million ha at the same period. The most significant increase in salinized areas was found in the arid and semi-arid countries, such as Australia, India, Pakistan and South Africa.

Table 10 Estimates of cultivated, irrigated and salinized areas in 1985 and 2000 (Pritchard & Amthor, 2005)

	Cultivated areas (Mha)		Irrigated areas (Mha)		Salinized areas (Mha)	
	1985	**2000**	**1985**	**2000**	**1985**	**2000**
Argentina	25.0	25.0	1.6	1.6	0.5-0.6	0.5-0.7
Australia	47.2	50.3	1.7	2.4	0.1-0.2	0.1-0.3
China	121.0	124.0	44.6	54.4	6.7-7.0	7.0-8.0
Egypt	2.3	2.8	2.5	3.3	0.8-1.0	0.9-1.1
India	163.2	161.8	41.8	54.8	7-20	10-30
Iran	14.9	14.3	6.8	7.5	1.5-2.0	1.5-2.5
Pakistan	20.2	21.3	15.8	18.1	3.2-4.3	3.5-5.5
South Africa	12.4	14.8	1.1	1.5	0.1	0.1-0.2
Thailand	17.7	14.7	3.8	5.0	0.4	0.4-0.5
United States	187.8	177.0	19.8	22.4	4.1-5.2	4.5-6.0
USSR (former)	227.0	204.1	19.5	19.9	2.5-3.7	2.5-4.5
World total	1372.8	1364.2	225.1	271.7	45-60	62-82

High salt concentration can cause damage to cellular membranes and stomatal closure. Growing salt concentration in plants has negative effects on electron transport in mitochondria and chloroplast. It may lead to an increase of active oxygen species (AOS). Increased AOS can cause severe damages to cellular membranes and result in the increase of leakiness and the inhibition of Na+ uptake (Pritchard & Amthor, 2005). As a result, Anions such as Na+ are moved out of the guard cells and stomata in the leaves are closed. In addition, salinity can cause the reduction of plant photosynthesis. Salt stress can lead to the decrease of leaf area and shortened growth duration. Hence, total crop photosynthesis and yields may decrease with high salt concentration.

2.4. Predicted impacts on NZ horticulture

New Zealand's climate is changing. Furthermore, in the next 100 years, New Zealand is expected to experience a more severe climate change, such as warmer temperatures, wetter or drier conditions, and unpredicted climate extremes. More frequent droughts will occur in the east, in particular, eastern Bay of Plenty, Gisborne, and Hawke's Bay. As a result, water availability will be a challenging issue in those regions. On the other hand, an increase of the westerly winds and heavy rainfall events are expected in the west and thus, land drainage, floods protection, and wind shelter will be required (Ministry for the Environment, 2008f). Also, as global warming occurs, populations of pests, disease and weeds are expected to increase. Warmer temperatures will accelerate the spread of insects and pests. Horticultural crop production is sensitive to climate change. This is because crop production is highly dependent on natural weather conditions. Generally, climate change will have both benefits and costs for temperate fruits, such as kiwifruit and apple. Otherwise, some subtropical fruits, such as avocado and citrus are expect to benefit from climate change.

2.4.1. Kiwifruit production

Kiwifruit is one of the important horticultural crops in NZ horticulture. Annually, more than 100 million trays of kiwifruit are produced and most of them are exported to the countries, such as EU, Japan, China, and South Korea (Plant & Food Research, 2012). The cultivated area of kiwifruit in New Zealand is about 13000 ha in 2011 with a small decrease of 1.7 per cent, relative to 2009 (Table 11). The major planted area of kiwifruit is in the Bay of Plenty where about 78 per cent of kiwifruit is grown (Statistics New Zealand, 2012b).

Table 11 Area planted in kiwifruit by region (Statistics New Zealand, 2012b).

Region	Cultivated area (ha)		Change (%)
	2009	2011	
Bay of Plenty	600	510	0.1
Waikato	790	660	-16.2
Tasman	640	540	-14.6
Northland	600	510	-15.0
Auckland	S	440	12.1
Gisborne	270	320	17.6
Hawke's Bay	240	210	-14.6
Total New Zealand	13,290	13,070	-1.7

The major impact of climate change on kiwifruit production will be through insufficient winter chilling hours due to warmer winter temperature. In general, kiwifruit require about 800 chill hours between 0 ºC and 7 ºC for breaking dormancy. However, in the Northland region, such as Kerikeri where is a marginal region to grow kiwifruit, it is getting harder to satisfy the winter chilling requirement for adequate bud break (Kenny, 2001, 2008). Even in the Bay of Plenty, sufficient winter chilling and breaking dormancy is becoming a significant challenge to kiwifruit growers. The projected area suitable for growing kiwifruit in the Bay of Plenty under low, mid, and upper-end warming scenarios is illustrated in Figure 13. Under mid and upper end scenario, over the next 50 and 90 years a significant decrease in suitable area for growing kiwifruit is expected in the Bay of Plenty due to warmer winter and insufficient winter chilling for breaking dormancy and subsequent flowering (Kenny, 2001). In particular, Hayward variety production in Northland and the Bay of the Plenty will be reduced significantly in response to warmer winter and less winter chilling. Also, Hayward variety bud break is expected to be delayed by 12 days under NIWA's high-end scenario (Clark et al., 2012; Ministry of Agriculture and Forestry, 2010c). On the other hand, Hawke's Bay and Nelson can satisfy the winter chilling requirement and are expected to be more suitable regions for growing kiwifruit in the next 50 years even though those regions have a risk of late frost damage. However, in Hawke's Bay and Nelson water availability for irrigation will be a significant limiting factor to expand current areas planted in kiwifruit (Kenny, 2001).

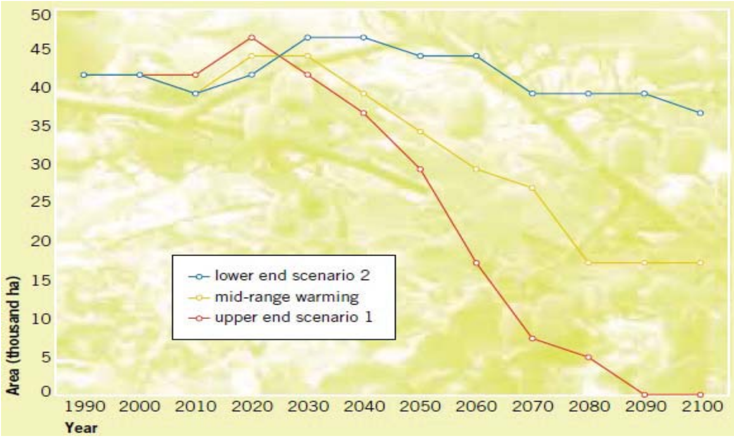

Figure 13 Projected areas suitable for growing kiwifruit in the Bay of Plenty (Kenny, 2001)

2.4.2. Pipfruit production

The planted area in apple trees is about 9,000 ha across NZ. Table 12 illustrates apple growing areas by region in New Zealand. Hawke's Bay is the predominant apple producing region producing about 60 per cent of total New Zealand apple production. Tasman and Nelson is the second growing region and represents around 30 per cent of total NZ apple production. The Otago region produces about 5 per cent and there are other minor apple growing regions, such as Auckland, Waikato, Gisborne, Marlborough, and Canterbury (Statistics New Zealand, 2012b).

Table 12 Area planted in apple trees by region in New Zealand (Statistics New Zealand, 2012b).

Region	Cultivated area (ha)		Change (%)
	2009	2011	
Hawke's Bay	5410	5140	-5.1
Tasman	2380	2450	2.7
Otago	570	470	-18.1
Canterbury	180	220	20.7
Waikato	220	160	-27.2
Auckland	120	140	18.7
Gisborne	120	110	-9.1
Nelson	C	90	
Bay of Plenty	C	10	
Marlborough	30	C	
Total New Zealand	9280	9000	-3.1

Average temperatures in Hawke's Bay are expected to increase by about 2˚C over the next 100 years under mid-range climate scenario. However, rainfall will decrease up to

16 per cent in winter and spring while in summer and autumn rainfall is predicted to increase slightly (Ministry for the Environment, 2008f). Sufficient access to water resources for irrigation will become a major constraint for growing apples in New Zealand in the next 100 years. In Hawke's Bay, water resources are already fully allocated and development of new water resources is necessary to meet future water demand in response to global warming. In Nelson, water availability also becomes a limiting factor for crop production (Ministry of Agriculture and Forestry, 2010a). Therefore, sufficient water supply will be crucial to expand apple production in those regions.

Apple production is expected to increase due to climate change. Royal Gala dry matter production will increase by 17.5 % by 2050 under the high-end scenario (Clark et al., 2012). Also, warmer temperatures are expected to increase apple fruit size even though the effects of warmer temperature are likely to be insignificant relative to current seasonal variations. The impacts of climate change on apple production are likely to be less than that on kiwifruit production. However, rising temperatures will influence bud breaking and flowering. According to a recent MPI report (2012), climate change has already caused an increase of flower numbers on apple trees. Also, climate extremes, such as hot and dry summers are expected to lead to an increase of sunburn and water-core in some sensitive apple varieties. In addition, strong winds and late frost will affect apple production more unexpectedly and result in severe damage in fruit (Ministry of Agriculture and Forestry, 2010a, 2010e).

There is a tendency for pests, disease and weeds to increase under warmer temperatures. In New Zealand apple production, insects and pests, such as scale and mealy-bug, codling moth, leafroller and apple aphid, are expected to increase with a southward spread. Therefore, in order to meet the increase of pests and disease, growers and apple industry need to develop new strategies for controlling pests and disease with potentially adding costs to production and impacting economic returns.

2.4.3. Others

Subtropical crops, such as citrus, are expected to benefit from warmer conditions in Northland, Auckland and Gisborne. However, in the northeast regions, such as Gisborne, as rainfall is expected to decrease over the next 100 years due to global warming and climate change, sufficient water supply will be a key constraint to producing these crops.

Warming temperatures are expected to affect budbreak in grapes. Sauvignon Blanc's budbreak in Marlborough predicted to break 4 days earlier than it does now. In addition, yield of Sauvignon Blanc is expected to decrease slightly from 12.6 ton/ha to 11.8 ton/ha under the high-end climate change scenario. Water availability will become a significant challenge to wine grape production also (Clark et al., 2012).

In terms of vegetable production, climate change could have both positive and negative impacts. Warmer temperatures are expected to increase vegetable growing seasons with earlier planting and late harvest. Warmer temperatures could also reduce growth duration due to rapid growth. Also, pest, disease, and weeds could increase under warmer conditions. As a result, vegetable quality could be affected because of the decrease of growth duration (Clark et al., 2012). In addition, frequent rainfall and strengthened winds could increase soil erosion and encourage crop health issues and difficult access for equipment, such as soil/seedbed preparation in the northern and north-western vegetable growing regions, such as Pukekohe (Ministry of Agriculture and Forestry, 2010a).

Maize production is expected to benefit from global warming because higher temperatures could make cooler regions suitable for maize production. As a result, the area planted in maize in some cooler regions, such as Canterbury, is predicted to increase (Kenny, 2001). However, under warmer and wetter conditions, a potential increase of pests and disease will become significant limitations for growing maize in the north, particularly in Waikato (Ministry of Agriculture and Forestry, 2010a).

2.5. Adaptation measures

Horticulture crop production is vulnerable to the impacts of climate change and global warming. Hence an adequate adaptation response is necessary to avoid negative impacts of climate change, as well as to utilize positive effects of climate change, such as high carbon dioxide and fertilization. There are many adaptation measures to meet climate change and some have already been implemented at farm production level. Adaptation measures can be classified into two groups: short-term and long-term responses.

2.5.1 Short-term adaptation measures

Short-term adaptation measures can include changing sowing and harvest dates, selection of adequate varieties, alternate tillage and rotation practices, and relevant fertiliser and pesticide use (Olesen et al., 2011). Changing sowing and harvest dates is a common and easy way to address climate change and global warming. Knox et al. (2010) indicated that earlier sowing and later harvest could be effective to reduce drought-related loss during hot and dry summer season. Changing varieties has also been widely used to meet warmer temperatures. For example, recently introduction of new varieties and crops has been observed in Europe. In particular, the area planted in maize has increased in the East-Central Europe countries, such as Romania due to rising temperatures. Olsen et al. (2011) suggested that even longer duration cultivars could be planted in the northern regions in response to global warming. In addition, there is a growing attention to water-conserving and soil erosion-protecting tillage and rotation practices to meet climate change. In general, higher temperature, droughts, and strong winds can deteriorate water shortage and soil erosion. Thus, adequate tillage, such as no or less till, can be effective to reduce water loss and soil erosion. Also, introduction of a cover crops rotation is useful for soil protection. This is because cover crops result in an increase of soil organic matter which can help reduce soil erosion. Otherwise, climate change can cause changes in crop growth and the outbreaks of pests and disease. Hence, an adequate use of fertilisers and pesticides is important to decrease pests and diseases. Olsen et al, (2011) recommended a use of Best Management Practices (BMPs) to address an increase of pests and disease.

2.5.2 Long-term adaptation measures

Long-term adaptation measures can include breeding of new cultivars, improving water availability, developing new technologies, changing land use and farming systems, such as relocation (Knox et al., 2010). In particular, improving water irrigation and drainage systems are important to meet climate change. This is because climate extremes, such as severe droughts and floods have more serious influence on crop yields than warmer temperatures. Therefore, in order to address unanticipated climate extremes, sufficient irrigation and drainage systems are crucial. Long-term measures often need considerable investment which small farms often cannot afford. Therefore, government support is often required in order to implement those long-term measures.

2.5.3 NZ farmers' adaptation responses

Table 13 is a summary of the result of farmers' workshops about climate change and show NZ farmers perspectives on the impacts of climate change and adaptation responses (Kenny & Fisher, 2003). Many NZ farmers acknowledged that climate change, such as warmer temperature, changes in wind patterns, heavy rainfall events and droughts would result in significant influence on NZ agriculture. They predict that the main impacts of climate change would be a decrease of water availability, an increase of pests and disease, soil erosion, and more frequent and unpredicted climate extremes, such as floods and droughts. They suggested adaptation measures to meet climate change as follow; improving water supply and adequate allocation, breeding of resistance varieties for warmer temperature and disease, increased use of soil organic matter, wind shelter, planting trees, soil protection management, Developing sustainable farming systems, and introducing of new varieties and crops suitable for warmer conditions (Kenny & Fisher, 2003).

With regard to kiwifruit, Kenny (2001) indicated that short-term, medium-term, and long-term measures are needed to adapt to climate change. As a short-term measure a new alternative, which would replace Hydrogen Cyanamids (HiCane), should be developed to break winter dormancy and lead to adequate flowering. By the means of the medium-term, it would be necessary to breed new varieties which have a lower chill requirement. Relocation toward the south with sufficient winter chilling hours, such as Hawke's Bay and Nelson, could be a potential long-term measure to meet climate change. However, relocating the infrastructure requires considerable investment and thus, the industry is reluctant to consider it as a reliable solution. Kenny (2008) illustrated current management tools or systems to meet climate change as follows:

- Microclimate management: canopy shelter, frost protection with sprinklers and frost fans/machines, irrigation and water storage, adequate water allocation

- Orchard and vine management: selection varieties, use of dormancy breaking chemicals (e.g. Hydrogen Cyanamids (HiCane)), canopy management, trunk girdling, biennial cropping, soil biological management
- Biodiversity
- People management: developing new ideas, adopting innovative practices
- Postharvest: Covering storage areas in the orchard, new packinghouse and cool stores with better insulation and power-saving ability.

Apple production is less susceptible to higher temperature than kiwifruit. However, less water availability and climate extremes, such as hot summers, can cause serious damage to apple production. In Hawke's Bay and Nelson, the lack of water supply will become a significant constraint to growing apples over the next 100 years. Therefore, as adaptation measures, efficient water use, adequate water allocation, monitoring of soil moisture, and developing new water supply would be taken to address water shortage. Also, in order to avoid damages by hot summers, relevant canopy management, such as overhead shelter, is recommended. In addition, developing new pest and disease management programmes will be required to protect plants from harmful attacks through increased pest and disease incidence (Ministry of Agriculture and Forestry, 2010a).

From MPI's stakeholder report (Clark et al., 2012), adaptation responses can be classified into 3 groups: Tactical, Strategic, and Transformational adaptation responses (Table 14).

Table 13 Farmers' perspective on climate change and adaptation (Kenny & Fisher, 2003)

Region	Main climate features	Impacts of climate change	Adaptation response
Hawke's Bay	During north-westerlies & wet easterlies Droughts on coastal hills and hill tops Heat waves in summer Heavy rainfall events	Increase of pests, disease and weeds More pressure on water supplies Greater risks of erosion	Increase of water supply and adequate allocation, selection and breed new varieties with pest & disease resistance, use of soil organic matter, soil protection management, and wind shelter
Bay of Plenty	Frost Winds (SW/SE & W/NW) Inconsistent rainfall & temperature Surface runoff	Potential increase of crop production due to suitable climate More sub-tropical grasses (weeds), insects and pests Strain on water reserves Floods and erosion	Relocation, application of soil organic matter, planting trees, more shade & shelter trees, biological control of pests and weeds, and adjusting plant crop types for warmer conditions
Nelson & Marlborough	Rainfall from north-easterly or northerly winds Dry north-westerly winds Heavy rainfall and landslips Dry summers and autumns	Less reliable water supply Erosion by wind and rainfall Changes in pests and diseases Change of pasture species and plants	Planting trees and regenerating native forest Water storage Sustainable farm management plans Better genetics and breeding
Canterbury	Droughts Extremes of temperature and rainfall Long winter and later spring Drying NW & wet SW winds	Longer growing season Less snow Less reliable water supply More weather extremes, such as droughts More weeds and pests Increased biosecurity issues	Monitoring and planning for sustainability Using resources responsibly Planting trees
South Canterbury	Summer droughts, Cold winters, cold/dry springs Extremes of temperature and rainfall Winds (W/NW and S) Out of season frosts	Less water availability Flooding, droughts and winds Stress on animals, plants and humans	Irrigation projects Topoclimate study Biodiversity Developing sustainable farming systems New crops and pastures
Wairoa & Gisborne	Heavy rainfall Drying and warm W/NW wind, cold and wet S/SE wind, and E/NE winds with heavy rains Summer dry Extremes (floods, droughts, winds, heavy rainfall)	More erosion Less water availability More damaging insects and new weeds Positive for crop production	Securing water supplies Farming in two climate zones Closed canopy-perennial plant production system Erosion control plantings Preserving native bush Address biosecurity Incorporating proven research and development into farm management systems

Table 14 Potential adaptation responses in NZ horticulture (Clark et al., 2012)

	Apples	Grapes	Kiwifruit	Vegetables
Tactical	Winter pruning Summer pruning Sunburn protection Overhead netting for protection Enhanced irrigation management	Winter pruning Summer pruning Overhead netting for protection Enhanced irrigation management	Winter pruning Summer pruning Girdling Chemical enhancement of flowing Overhead netting for protection Enhanced irrigation management	Planting new cultivars Shift locations of crop sites Adjust sowing and harvesting schedule
Strategic	New cultivars and new irrigation schemes			
Transformational	Contraction in existing areas and expansion into new regions			

2.6. Summary

New Zealand is located in the middle of the Southern Hemisphere and surrounded by ocean. As a result, NZ's climate is typically dominated by global-scale climate systems, such as El Niño and La Niña events, the Interdecadal Pacific Oscillation (IPO), and the Southern Annular Mode (SAM). There is high confidence that New Zealand has become warmer. Observation data from NIWA shows that New Zealand's average temperatures have increased by 0.9 ºC over the last 100 years. Under the mid- and high-range of climate scenarios by NIWA, New Zealand's average temperatures are expected to increase by 0.9 ºC by 2040 and by 2.1 ºC by 2090 (Ministry for the Environment, 2008f).

New Zealand will experience more frequent hot summers and autumns. Regional variation in rainfall has already occured with an increase of rainfall in the west and a decrease of rainfall in the east. However, climate extremes, such as droughts and floods, have occurred more frequently and unexpectedly over the country despite changes in precipitation. Recently, as the IPO has turned into the negative phase, New Zealand has experienced more frequent La Niña events and warmer condition with less westerly winds. However, IPCC's climate scenarios predict that in the next 50 years more frequent El Niño and will happen due to global warming. As a result, New Zealand will experience El Niño events and westerly winds more frequently. NZ's annual rainfall patterns are also expected to be changing with an increase of rainfall in the west of New Zealand partly due to an increase of the westerly winds. On the contrary, in the eastern regions, annual rainfall is expected to decrease. In addition, New Zealand will experience climate extremes, such as severe droughts and floods, more frequently and unexpectedly (Ministry for the Environment, 2008f).

Climate change is expected to affect crop production significantly. High carbon dioxide concentration in the air will be beneficial to crop production, in particular C_3 plants. However, in most temperate regions, warmer temperatures are expected to have negative effects on crop production. Warmer temperatures and more frequent climate extremes, such as droughts and floods, are expected to increase water stress, especially during spring and summer seasons. As a result, crop production will be affected significantly, particularly in the semi-arid regions over the world. In addition, rising temperatures and humid conditions might result in the outbreaks of pests and disease. Furthermore, there is some evidence that pollinators, such as bees and butterflies have decreased due to climate change and global warming (Bale et al., 2002; Pritchard & Amthor, 2005; Hickling et al., 2006; Williams et al., 2007; Settele et al., 2008; Aurambout et al., 2009;; Potts et al., 2010; Chakraborty & Newton, 2011; Hakala et al., 2011) .

Climate change is predicted to have a significant influence on NZ’s future horticultural production. In the main kiwifruit growing areas, such as the Northland and the Bay of Plenty, meeting sufficient winter chilling requirement will be a challenge to growers, as a result of warmer winters. On the other hand, in Hawke’s Bay and Nelson warmer temperatures will help growers increase kiwifruit growing areas. However, a lack of water supply will be a major constraint to growing kiwifruit in those regions due to climate change and global warming. Apple production is not likely to be affected significantly by warmer temperatures relative to kiwifruit production. This is because apples have lower winter chilling requirement and therefore, warmer winters have no significant effects on breaking dormancy. However, like kiwifruit, water availability will be a major limiting factor in apple production in most apple growing areas. Warmer temperatures will be beneficial to subtropical fruits, such as citrus. In the near future, citrus production in New Zealand is expected to increase as a result of global warming. Warmer temperatures are likely to have significant influence on NZ’s potato production. However, rising temperatures and high carbon dioxide levels in the air are expected to cause a decrease in potato growth duration and potential loss of yields. Increasing risks of climate extremes, such as droughts and floods will be a great challenge to NZ crop production (Kenny, 2001, 2008; Ministry of Agriculture and Forestry, 2010a, 2010c, 2010e; Clark et al., 2012).

CHAPTER THREE: POLICIES AND MEASURES (INTERNATIONAL)

3.1. Introduction

This chapter aims to illustrate international issues relative to climate and to explore some international policies and measures on climate change, including NZ government policies. Since the Intergovernmental Panel on Climate Change (IPCC) published the first assessment report on climate change in 1990, intergovernmental discussion and negotiation on climate change has been proceeding under the United Nations Framework Convention on Climate Change (UNFCCC).

This chapter will illustrate the role of IPCC and UNFCCC. Next, current international issues on climate change, including the Emission Trading Schemes (ETS) and carbon labelling will be briefly explained. This chapter will also illustrate several developed countries' policies and measures for GHG emission reduction and adaptation to climate change. Finally, NZ government policies and measures on climate change will be introduced and explored.

3.2. International issues

Global warming and climate change are key urgent issues which influence ordinary human life around the world. People have generally recognized that climate change will affect our day-to-day lives. Even, CEOs who participated in the Davos Forum in 2008 didn't hesitate to choose climate change as a world's top priority agenda (World Economic Forum, 2008). However, climate change is not one country's challenge alone. Instead, global collaboration is essential to reduce GHG emissions and meet climate change for securing sustainability of the Earth. Climate change has been widely discussed as a central agenda at various intergovernmental discussion and negotiation fora. Also, many countries have actively sought solutions through the IPCC and the UNFCCC as the central point..

3.2.1. International positions

It is evident that the IPCC has played an important role to inform the world of the impacts of climate change since its first assessment report released in 1990. IPCC was established in 1988 by the United Nations Environment Programme (UNEP) and the

World Meteorological Organization (WMO). IPCC is a scientific body that aims at giving people scientific knowledge and advice on climate change and its potential impacts. The IPCC consists of three Working Groups and a Task Force: Working Group I (the physical science Basis), Working Group II (climate change impacts, adaptation and vulnerability), Working Group III (mitigation of climate change), and Task Force on national greenhouse gas inventories. From 1990 to 2007 the IPCC has published four assessment reports and contributed to notifying the significance of impacts of climate change to the world through its many reports on climate change (IPCC, 2012).

The UNFCCC has been at the centre of global discussion and led to important momentum for GHG mitigation, such as the Kyoto Protocol. The UNFCCC was adopted at the Earth Summit in Rio in 1992 and enacted by 1994. The aim of the UNFCCC is to prevent dangerous impacts by human beings on the global climate system. Now, about 195 countries, including OECD member countries, participate in the UNFCCC (UNFCCC, 2012d). The UNFCCC has various bodies, such as the Conference of the Parties (COP), the subsidiary bodies (advise the COP), and the COP Bureau in order to coordinate discussion. The Kyoto Protocol adopted in 1997 and entered into force in 2005 was a first step to reduce global GHG emissions. Under the Kyoto Protocol, 37 developed countries set their goal for GHG emission reduction by 5 per cent below 1990 levels between 2008 and 2012. However, even though the Kyoto Protocol set emission reduction targets for developed countries, it also allowed flexible market mechanisms, such as the Emission Trading Scheme (ETS) and the Clean Development Mechanism[1] (CDM) (UNFCCC, 2012c). In 2007, UNFCCC adopted the Bali Road Map which suggested a framework of the negotiating process for beyond 2012. The Bali Road Map became a momentum for all member Parties to participate in emission reduction as well as 37 industrialized countries under the Kyoto Protocol. Also, adaptation was identified as an essential future response to meet climate change under the Bali Action Plan in 2007 (UNFCCC, 2012b). In 2010, the Cancun Agreements were accepted. The Cancun Agreements tried to make a decision on several controversial issues, such as including developing countries into binding emission reduction targets

[1] "The *CDM* allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol" (UNFCCC)

and developed countries' emission reduction targets by 2020 compared to 1990. However, the Cancun Agreements fail to conclude and postpone the decision to the next negotiating process (UNFCCC, 2012a).

3.2.2. Emission Trading Scheme (ETS) and Carbon Labelling

In many countries, various policies and measures have been introduced to reduce GHG emissions and address climate change. The ETS and carbon labelling are usually the major policies on climate change. The Emission Trading Scheme (ETS) is one of the main policies for reducing GHG emissions. The Kyoto Protocol allows that countries which have emission units to spare can sell their excess emission units to other countries and this is called as "Emission Trading". As a result, carbon could be traded as a new commodity in the carbon market (UNFCCC, 2012c). Recently, many countries have introduced an Emission Trading Scheme (ETS) by putting a price on GHG emissions in order to activate businesses and consumers' participation in reduction emissions (Table 15). The EU has implemented the ETS since 2005 and the EU ETS is now the biggest carbon market worldwide (European Commission, 2009). In USA, several ETS, such as Chicago Climate Exchange and Regional Greenhouse Gas Initiative, have been implemented. In Australia, the Carbon Price Mechanism entered into force from July 2012. New Zealand introduced the ETS for forestry in 2008. In the Republic of Korea, the ETS will be implemented from 2014. Japan launched their local ETS in Dec 2011. China and Brazil will introduce the ETS in the near future (Ministry of the Environment, 2012). In 2011, about US$ 149 billion of carbon units were traded in the global carbon market and more than 99 per cent of them were exchanged by the EU ETS (Kossoy & Guigon, 2012) (See Table 15).

Table 15 Global carbon market at volumes and values between 2010 and 2012 (Kossoy & Guigon, 2012)

	2010		2011	
	Volume ($MtCO_2e$)	Value `(US$ million)	Volume ($MtCO_2e$)	Value (US$ million)
	Allowances market			
EUA (EU Allowance)	6,789	133,598	7,853	147,848
AAU (Assigned Amount Unit)	62	626	47	318
RMU (Removal Unit)			4	12
NZU (New Zealand Unit)	7	101	27	351
RGGI (Regional Greenhouse Gas Initiative)	210	458	120	249
CCA (California Carbon Allowance)			4	63
Others	94	151	26	40
Total	7,162	134,935	8,081	148,881

Also, with EU as the centre, carbon labelling has been implemented to mitigate man-made GHG emissions. Carbon labelling is one of the main environmental policies. Since the UK launched the first voluntary carbon labels by Carbon Trust in 2007, many countries have introduced similar carbon labelling and now various businesses are putting carbon labelling on their commodities (Table 16). For example, Tesco, the largest retailer company in UK, started carbon labelling on four products in 2007 and has now expanded carbon labelling to 100 products (Carbon Trust, 2012). Marks & Spencer, another retailer company in the UK, has also established Eco-Plan, a campaign to reduce its carbon emissions. In France, Groupe Casino, retailer group, has conducted carbon labelling since 2008. Japan has started its carbon offset labelling schemes in 2009. Other countries, such as the USA, Canada, Switzerland, Germany, Korea, Holland and Sweden have also implemented various carbon labelling schemes (See Table 16) (Saunders, Guenther, & Driver, 2010). For example, Japan has started its carbon offset labelling schemes in 2009. Other countries, such as the USA, Canada, Switzerland, Germany, Korea, Holland and Sweden have also implemented various carbon labelling schemes. Carbon labelling has influenced NZ's agricultural exports, not directly but indirectly, through changing consumer behaviour. Saunders et al. (2010) indicated that about 68 per cent of consumers in 22 countries had a higher concern about global warming and climate change and 60 per cent of them were willing to buy more environmental products.

Table 16 Carbon labels by country in 2009 (Saunders et al., 2010)

Labels	Public/Private	Countries	Accounting Method	Companies	Products
Carbon trust (Tesco's)	Public+	U.K.	PAS-20503	20	Unknown
Climatop	Private	Switzerland	Unspecified LCA	3	15
Thailand carbon reduction label	Public+	Thailand	PAS-2050	Unknown	23
Carbon connect	Private	Canada	Unspecified LCA	Unknown	Unknown
SGS Carbon neutrality	Private	France.	Unspecified LCA	Unknown	Unknown
Climate conscious	Private	U.S.	Unspecified LCA	Unknown	Unknown
Carbonlabels.org	Private	Canada	Unspecified LCA	Unknown	Unknown
Germany: PCP pilot project	Public+	Germany	Unspecified LCA	8	10
Korea: carbon label	Public+	Korea	Unspecified LCA	Unknown	Unknown
Casino carbon index	Private	France	Bilan Carbone	1	237
E.Leclercs carbon label	Private	France	Unspecified LCA	1	<800
Certified carbon free	Private	U.S.	Unspecified LCA	11	Unknown
Eosta climate neutral	Private	Holland	ISO 14040/14044	Unknown	Unknown
Pilot Californian carbon label	Public+	U.S.	Unspecified LCA	Unknown	Unknown
KRAV Sweden carbon label	Private	Sweden	Unspecified LCA	1	Unknown
Japan carbon label	Public+	Japan	Unspecified LCA	20	Unknown

Vandenbergh, Dietz, and Stern (2011) also suggested carbon labelling could influence consumer behaviour by encouraging them to buy more eco-friendly products. Their study indicated 33 per cent of consumers in eight countries had an intention to purchase eco-friendly products. As a result, carbon labelling is likely to have a negative impact on NZ exports. This is because if consumers were to take carbon labelling into account to buy their foods and all conditions (e.g. price and quality) except for carbon dioxide emissions were equal, many consumers would purchase foods with lower carbon dioxide emissions. Recently, the NZ wine industry has taken a rapid action to cope with carbon labelling in the UK market and produced the first carbon-labelled wine in the world (the Guardian, 2010).

3.3. The industry and farmers' concerns about climate change

From the literature review, the New Zealand horticultural industry and farmer concerns about climate change were the Emission Trading Scheme (ETS), water supply and floods, soil erosion and increased pest, disease, and weed problems.

The NZ government introduced The ETS in 2008 in order to mitigate GHG emissions and agricultural sectors will enter the ETS in 2015. However, most farmers believe the ETS would cause more cost to their farming. For instance, MPI's Climate Change Peak Group indicated a severe impact of the ETS was on greenhouse growers in South Island (Horticulture NZ, 2012). The Horticulture NZ President (Fenton, 2010) commented that "implementing ETS in New Zealand will without doubt make us less competitive internationally".

It is evident that the ETS will increase input costs in horticultural production. Government estimated that the price of petrol, electricity, and natural gas will increase by 3.5 %, 5 %, 13 % respectively because of the ETS. Fertiliser price is also expected to go up because most components of fertiliser are imported from overseas and shipping costs are partly dependent on the price of fuel (Ministry for the Environment, 2011; Ward, 2010). Table 17 shows estimates of additional costs by sector in NZ due to the ETS. As at 2011 Horticulture New Zealand assumed that the horticultural industry will pay $11 million of additional costs due to the implementation of the ETS (Ward, 2010). In terms of total ETS costs per hectare by sector, the tomato sector which grows greenhouse tomatoes using coal as heating energy source is the biggest loser and expected to pay $44,121 per hectare of additional costs. In fact, there is huge difference in additional ETS costs between greenhouse tomatoes and outdoor tomatoes and most difference in additional costs is likely to come from the amount of energy used to heat greenhouse (Fairfax NZ News, 2010; Ward, 2010).

Secondly, the capsicum sector and $31,330 per hectare of additional costs (2011 assumption) will be required due to the ETS, also for fuel costs. Additional costs per hectare of fruit crops, such as kiwifruit, pipfruit, and citrus are usually higher than those of vegetable crops, including onion, potatoes, and sweetcorn (Ward, 2010). This is partly because fruit crops are perennial, compared with annual vegetable crops and also, they require more management activities such as pruning and thinning (See Table 17).

Table 17 Estimates of additional costs by horticultural sector due to the ETS (Ward, 2010).

Crop	Area (ha)	Total ETS Costs to farm gate and post farm gate but excluding shipping ($)	Total ETS Costs per hectare by sector ($)
Capsicums	56	1,754,502	31,330
Onion	4,657	152,905	33
Peas	10,720	361,800	34
Potatoes	9,787	550,519	56
Squash	6,601	226,834	34
Sweetcorn	5,800	237,800	41
Tomatoes Greenhouse tonnes gas	65	1,170,747	18,011
Tomatoes Greenhouse tonnes coal	35	1,544,247	44,121
Tomatoes Outdoor	757	32,551	43
Kiwifruit	12,337	1,393,230	113
Pipfruit	8,988	1,434,335	160
Citrus	1,834	176,675	96
Total NZ Horticulture	89,984	10,909,386	

Water (and water salinity) is also one of the biggest concerns of the industry and farmers in terms of climate change. Water issues include both water supply and drainage. In fact, New Zealand is considered fortunate in terms of water availability because there is sufficient water in the most regions of New Zealand. However, from projections of NIWA's climate scenarios, the eastern regions will become drier while the western regions will be wetter (Ministry for the Environment, 2008f). More frequent climate extremes, such as droughts, heavy rainfall and floods are expected. Thus, water management & availability and flood protection will be a challenge in the future.

There have been growing concerns about water availability in the horticultural industry in recent. For example, water availability is an issue in some dry regions, including Canterbury and Central Otago during hot summer seasons. Also, in the Waimea Plains, Nelson water supply has become a significant challenge to the horticultural industry. This is because in drought conditions farmers can be allocated water only by about 20% of their water requirement. In an attempt to increase water supply, the Tasman District Council launched a plan to build the Lee Valley Dam (Gillham, 2011). The industry also has a growing concern about water security. For instance, Bedford (2010) indicated that "there has been increasing tension around several aspects of freshwater management, including allocation, a perceived diminishing resource, lack of a national directions".

Furthermore, the NZ government introduced water metering systems in order to monitor and promote efficient use of water over the country. Under the Resource Management

Act (the RMA 1999) and the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010. all consented water takes of 20 L/sec should be metered from November 2010 and water takes of more than 10 litres a second by 2014 and more than 5 litres a second by 2016 (Ministry for the Environment, 2012c). As a result, unlimited water use by farmers is expected to be restricted and reduced due to strict water metering.

Flood protection and poor drainage also becomes a challenge to growers due to increasing heavy rainfall events and floods. In 2011, Hawke's Bay had about 1000 mm of annual rainfall and this rainfall was more than the average annual rainfall of 800mm and considered unusual. Furthermore, the bulk of annual rainfall in 2011 fell in January and February (NIWA, 2012a). That year, most farmers experienced wetter and cooler summers than normal condition and potentially poor soil drainage is an issue alongside increasing tree diseases (Wilton, 2011; NIWA, 2012a).

From the result of a two year project, 'Adapting to climate change in eastern New Zealand', local farmers thought that the main impacts of climate change would be water supply, floods, increased erosion and increased pest, disease and weed problem (Kenny & Fisher, 2003). According to the survey investigated by FAR (Foundation for Arable Research), Horticulture NZ, and LandWise [2], the main concerns of farmers in Canterbury, Hawke's Bay and Gisborne were drought and rain. In fact, these three regions are all located in the east of New Zealand and therefore insufficient rainfall will likely become an issue due to climate change. Rain was also a challenge to farmers during harvest periods, especially as wetter conditions can cause grain germination and an increase of fungal diseases. In addition, as strong winds and heavy rainfall are expected to increase due to climate change, soil erosion through runoff and wind will become a challenge to farmers, in particular in the hill country.

[2] LandWise is an extension group based out of Hawke's Bay, New Zealand

3.4. Policies and measures on climate change

3.4.1. European Union (EU)

The European Union consists of 27 Member States. EU's GDP was about €12268 billion in 2010 and bigger than USA's GDP (European Union, 2012). The EU set the goal of GHG emission reduction by 20 per cent compared to 1990 levels by 2020. In order to meet this goal, the EU has adopted a package of policies in 2008 and measures on climate change. This package includes two key pillars: an increase of renewable energy use and the Emission Trading Scheme (ETS). The EU is expected to supply 20 per cent of current energy consumption from renewable energy sources and reduce total primary energy consumption by 20 per cent by 2020. The EC ETS entered into force in 2005 and the second phase (2008 ~ 2012) of the EC ETS is now being implemented. In the third phase (post 2013), the aviation industry will be included into the ETS. Under the Kyoto Protocol, the EU-15 countries set binding emission reduction by 8 per cent below 1990 between 2008 and 2012. And they have achieved their goal by reducing their emissions by 9.2 per cent in 2010 (European Commission, 2009; European Union, 2012).

Climate change is likely to have significant influence on EU agriculture. The mid and northern Europe region will benefit from climate change due to higher CO_2 concentration in the air and warmer temperature. In particular, crop yields in the northern countries, such as Finland and Sweden, are expected to increase and growing areas are predicted to move northward. In southern Europe region crop yields are expected to decrease due to heat waves and lower precipitation. Hence, adequate policies and measures in agriculture are required to meet climate change (European Commission, 2009). The EU reformed the Common Agricultural Policy (CAP) in 1999 and in 2003-2004 in order to adopt new rural development policy in agriculture. There were various policies and measures in agriculture on climate change under the CAP reforms. Table 18 illustrates policies and measures of the CAP reforms related to climate change. Most of these policies and measures under the CAP reforms are related to GHG mitigation rather than adaptation to climate change. Reduction in the Direct Payment (DP) was a major measure to reduce GHG emissions in agriculture. Actually, the DP had the effects of encouraging farmers to increase target crop production and therefore, abolishment of the DP could lead to reduction in intensified production. However, in order to increase carbon sequestration, the CAP reforms maintained the DP for conservation and also, increased supports for set-aside land (European Commission, 2009).

Table 18 CAP's Policies and measures in agriculture related to climate change under the CAP reforms (European Commission, 2009)

Policies and Measures	Expected effect
Decoupling of single farm payment from production	Reduced incentive for intensified production
Cuts in direct payments of up to € 5 billion	Increase of supports for Agri-Environmental Measures
Partial or entire reduction of direct payment excepting: - Statutory management requirements in areas such as environment, plant health, animal welfare etc. - Maintenance of land in good agricultural and environmental condition - Cross-compliance	Provides additional incentive to protect the environment
Carbon credits: € 45 per ha for energy crops	Incentives for energy crop production
Set aside scheme	Increases carbon sequestration
€ 45 per ha support for Non-food crops grown on set-aside land	Incentives for non-food crops including energy crops
Support for participation in food quality schemes	Less intensive production
Support to help farmers adapt to new more demanding standards within Community legislation	Better compliance with environmental standards
Farm advisory systems	Raises awareness of potentially superfluous and negative input in agricultural production
Market measures – intervention price cuts for rice reducing incentive for intensified production. Abolition of intervention for rye	Less incentive for intensive production
Integration of support for dried fodder into single farm payment	Less incentive for energy consuming drying techniques
Support for Organic Farming Action Plan	Less intensive production, lower fertiliser use, higher content of organic matter in soil
Increased community support for agri-environmental measures	Incentives for uptake of measures such as soil conservation, organic farming, etc.

In 2008, the EC proposed another CAP reform known as “the CAP Health Check”. The CAP Health Check included modifications of three areas of the previous CAP reforms: Direct aid system, Market instruments, and rural development policy. For example, under the CAP Health Check, direct payments for energy crops and set-aside land from 2007 were eliminated. Rural Development Policy (2007-2013) included measures for facilitating renewable energy and energy efficiency in agriculture, manure management for reducing methane emissions, and practices for reducing fertilizer use. Under the Soil Directive, the Commission accepted the Soil Thematic Strategy which included measures to protect soil and improve soil carbon sequesterisation (See Table 19).

Table 19 Recent policies and measures on climate change under the CAP Health Check and other regulations (European Commission, 2009)

Policies and Measures		Expected effect
CAP Health Check	Abolishment of direct payments for energy crop production	Less incentive for energy crop production
	Abolishment of set-aside land from 2007	Negative impacts on the environment
Rural Development Policy	Measures to promote renewable energy and energy efficiency in the agriculture sector	Less CO_2 emissions
	Manure management measures	Less CH_4 emissions
	Practises to reduce fertilizer use	Less N_2O emissions
Soil Thematic Strategy	Establishment of a common framework to protect soil on the basis of the principles of preservation of soil functions, prevention of soil degradation, mitigation of its effects, restoration of degraded soils and integration in other sectorial policies	Soil protection
	Identification of areas of at risk of erosion, organic matter decline, salinization, compaction and landslides, and establishment of national programmes of measures	Less soil erosion
Nitrate Directive	Reduction of the application of nitrogen fertilisers to land	Less N_2O emissions

EU policies in agriculture on adaptation to climate change have consisted of measures for adaptation and water management including adequate supports for sustainable production, efficient use of water and examination of the capacity of the Farm Advisory System to improve knowledge and adoption of new technologies on adaptation (European Commission, 2009).

In summary, the EU's policies and measures in agriculture under the former CAP Reforms had focused on reduction in the Direct Payment in order to decrease intensified production that increased GHG emissions. Also, the CAP Reforms encourage soil conservation and set-aside in order to increase carbon sequestration. In addition, the CAP reforms encouraged energy crop production. However, under the recent CAP Health Check, the EU's policies on climate change have been changing towards more market-oriented than the CAP Reforms. The DPs for energy crop and set-aside were abolished. Also, the CAP Health Check increase support to management tools, such as efficient use of energy, manure management and adequate use of fertilisers in order to reduce GHG emissions from crop production. The EU's adaptation policies have focused on water management and technology transfer.

3.4.2. Australia

Australia ratified the Kyoto Protocol in 2007. Australia's GHG emissions in 2007 excluding land use, land use change and forestry (LULUCF) sector were approximately 541.2 million tonnes CO_2e. Table 20 shows the contribution to Australia's GHG emissions by sector in 2007. The stationary energy sector, such as coal-fired and gas-fired electricity generation, represented 54 per cent of Australia's GHG emissions. The agricultural sector was the second contributor and caused 16 per cent of Australia's emissions.

Table 20 Contribution to total GHG emission in Australia in 2007 (Department of Climate Change, 2010)

Sector	Contribution to total GHG emissions (%)
Stationary energy sector	54%
Agriculture sector	16%
Transport sector	14%
Fugitive emissions from fuels	7%
Industrial processes	6%
Waste	3%

Australia set the emission reduction targets of 5 per cent to 15 per cent and 25 per cent below 2000 levels by 2020. In order to achieve the goal, Australia developed the special climate change strategy which consists of three main pillars: reducing emissions, adapting to unavoidable climate change, and helping to shape a global solution (Table 21). The Australian Government's key policy for mitigation of GHG emissions is the Carbon Pollution Reduction Scheme (CPRS), a emission trading system. The CPRS entered into force from July, 2012. Also, the Government adopted laws to expand renewable energy supply by 20 per cent of total electricity supply by 2020 (Department of Climate Change, 2010).

Table 21 Main policies and measures on climate change in Australia under the Climate Change Strategy (Department of Climate Change, 2010)

Pillar	Policies and measures
Reducing emissions	Carbon Pollution Reduction Scheme (CPRS) – emission trading system Expanding of renewable energy supply Clean energy initiative Climate change action fund Supporting energy efficiency
Adapting to unavoidable climate change	Building capacity through research initiatives, research facilities, and risk assessments
Helping to shape a global solution	Funding and supporting adaptation for developing countries Developing mechanisms for GHG mitigation from forests in developing countries Active participation in the global conversations on climate change, such as UNFCCC

In Australia, the agriculture sector represents less than 4 per cent of Australia's GDP but contributes about 16 per cent of total GHG emissions. Agricultural GHG emissions mainly came from methane emissions by cattle and sheep, and nitrous oxide emissions from soils (Australian Greenhouse Office, 2005). The agricultural sector has been excluded from the CPRS. Table 22 shows the Australian government's policies and measures in agriculture which were reported in the Australian 4th National Communication on Climate Change in 2005. In order to coordinate greenhouse action and build the capacity of the agriculture and land management sectors, the Australian Government invested $ 20.5 million in research and development under the Greenhouse Action in Regional Australia (GARA) Programme. This programme included the previous policies and measures reported in the 3th National Communication, such as the Greenhouse Challenge Agricultural Strategy and the Agriculture Sector Work Programme. Also, the Programmes supporting Environmental Management Systems (EMS) implemented to encourage farmer's implementation of EMS.

Table 22 Australian Government's policies and measures in agriculture on climate change reported in the 4th National Communication on Climate Change (Australian Greenhouse Office, 2005)

Name of policy or measure	Objective and/or activities
Greenhouse Action in Regional Australia (GARA) Programme	• Funding: $ 20.5 m, over four years from 2004 ~2005 • Objective: to coordinate greenhouse action and build the capacity of the agriculture and land management sectors for reduction of GHG emissions. • Activities - Investing in research and development in order to reduce GHG emissions from livestock and agricultural soils - Government-industry partnerships to encourage development and implementation of management practices or tools for reducing GHG emissions - Also includes some policies and measures which have been implemented previously, such as the Greenhouse Challenge Agricultural Strategy, the Agriculture Sector Work Programme, research on methane emission reduction from livestock, and initiatives for improving the efficiency of nitrogen use
Programmes supporting Environmental Management Systems (EMS)	• Funding: $ 31.2 m, over 4 years from 2002~2003 • Objective: to support farmer's implementation of EMS • Activities - The EMS Incentive Programme - The EMS National Pilot Programme - The Pathways to industry EMS Programme • Expected effects - Conservation and restoration of habitat for native plants and animals - Increasing soil sink capacity - Reducing GHG emissions from land

From 2006 to 2009, the Australian government has implemented the National Agriculture and Climate Change Action Plan (NACCAP) in order to enhance coordination climate change between the central government and the local government to meet climate change (see Table 23) (Department of Climate Change, 2010).

Table 23 Policies and measures in agriculture on climate change reported in the Australian 5th National Communication on Climate Change (Department of Climate Change, 2010)

Area	Policies and Measures
Mitigation Policy	• Allowing offset credits for abatement from the agricultural sector to facilitate methodology development for emission reduction • Monitoring best practices for emission reduction with industry
Research and development	• Supporting of research, development, and on-farming testing to reduce emissions from livestock and enhance bio-sequestration ($ 50m) • Green Carbon Fund: investing in agricultural research and development to monitor and plan for the impact of climate change on biodiversity and to encourage environmental management ($ 40m) • The Australia's Farming Future Initiatives: Under the initiatives, the Climate Change Research Programme funded research and on-farm demonstration projects to build adaptable and resilient producers and industry and reinforce their management ability for climate change
National Agriculture and Climate Change Action Plan (NACCAP) 2006-2009	• NACCAP: agreement between federal government, state and territory governments • Objective: to improve coordination for climate change policy in agriculture • Activities: - Adaptation strategies to climate change - Mitigation strategies - Research and development - Communication with producers and rural communities

In summary, the main causes of agricultural emissions in Australia are methane emissions from livestock and nitrous oxide emissions from soils. Therefore, Australia's policies and measures in agriculture focused on research, partnership, and investment to reduce GHG emissions from livestock and soils. Also, the Government has provided financial supports to enhance soil carbon storage, soil conservation and protection (Australian Greenhouse Office, 2005). However, recently the Australian Government has introduced policies on adaptation with support for research, development, and on-farm demonstration projects related to adaptation. The government has also adopted policies and measures on bio-sequestration, bio-diversity, and environmental management to reduce GHG emissions and increase carbon sequestration.

3.4.3. Canada

In 2007, Canada's GHG emissions excluding LULUCF sector were approximately 747 million tonnes CO_2e with an increase of 26 per cent compared to 1990 levels partly due to an increase of Canada's economy by 60 per cent. Canada's emission reduction target was 17 per cent below 2005 levels by 2020 (Environment Canada, 2010). Table 24 shows policies and measure that the Canadian Government has adopted to address climate change.

Table 24 Canadian Government's main policies and measures on climate change (Environment Canada, 2010)

Area	Policies and Measures
Clean electricity	• Goal: providing 90 per cent of electricity needs from clean and renewable energy sources by 2020 • Measures: - Incentive to renewable energy sources and replacement of coal - Expanding nuclear and renewable power supply
Energy efficiency	• Introducing new standards on products to improve energy efficiency • Implementing energy efficiency programmes
Carbon Capture and Storage (CCS)	• Regulatory measures to promote implementation of carbon capture and storage • Investing in development of commercial –scale carbon capture and storage
Vehicle emissions	• New GHG emission standards for new car and light trucks from the 2011 model year
Renewable fuels	• Introducing national renewable fuel standard (an average renewable fuel content of at least 5 per cent) from 2010 • Supporting commercial-scale facilities for new-generation renewable fuel production

Canada is one of the world's major agricultural countries. Agriculture accounts for approximately 8 per cent of Canada's total GDP. Canada is the fourth greatest exporter and the fifth biggest importer in the world. Canada also has a cold climate and thus, 82 per cent of agricultural lands are located in the southern regions in Canada (Environment Canada, 2006, 2010). The main products of Canadian agriculture are wheat, barley, canola, cattle, pigs and horses, and hay products for livestock feeding. Climate change is likely to have a significant influence on Canadian agriculture. In particular, less water availability will be a serious challenge to Canadian agriculture. For instance, in 2002 severe national droughts hit Canada and resulted in a loss of C$ 5 billion across the country (Environment Canada, 2006, 2010). As climate change is going on, severe droughts are expected to occur more frequently and unexpectedly in Canada. Warmer temperatures are expected to have multi-faceted effects on Canadian agriculture. For example, in the northern regions growing areas and agricultural yields will increase due to warmer temperatures. However, warmer temperature can cause an increase of energy use for cooling livestock building and also lead to wide spread of animal and plant disease. Tables 25 and 26 show policies and measures in agriculture on climate change, which were reported in the Canadian 4th and 5th National Communication on Climate Change (NC) (Environment Canada, 2006, 2010).

Table 25 Policies and measures in agriculture reported in Canada's 4th National Communication on climate change (Environment Canada, 2006)

Name of policy or measure	Objective and/or activities
Agricultural Policy Framework (APF)	• APF: federal-provincial-territorial strategic agriculture initiative • Funding: $ 5.2 billion over 6 years • Objective: to improve environmental performance at the farm level • Programmes: - Including several programmes such as the Environmental Technology Assessment for Agriculture (ETAA) program, the Greencover Canada initiative[3] etc.
Energy Co-Generation from Agricultural and Municipal Waste (EcoAMu)	• Establishing model pilot plants and investing research and development to encourage technology development for the co-generation of energy from agricultural and municipal waste
Environmental Technology Assessment for Agriculture (ETAA)	• Assessing the performance of new technology to improve environmental performance • Encouraging the adoption of new technologies, production systems, bio-processes and bioproducts
Greenhouse Gas Mitigation Program for Canadian Agriculture (GHGMP)	• Preparing GHG Best Management Practices (BMPs) • Encouraging farmer's adoption of new practices to reduce emissions • Assessing the impact of BMPs
Shelterbelt Enhancement Program (SEP)	• Increasing shelterbelt plantings on agricultural lands across the Prairies with technical assistance, seedlings and plastic mulch for weed control
Model Farm Program	• Providing better information on emissions and carbon sequestration for whole farming system • Identifying best practices

Table 26 Policies and measures in agriculture reported in Canada's 5th National Communication on climate change (Environment Canada, 2010)

Name of policy or measure	Objective and/or activities
Biofuels Capital Initiatives	• Funding for the biofuel production facilities • Supporting the use of agricultural feedstock to produce the biofuel
Biofuels Opportunities for Producers Initiative	• Helping farmer and communities hire experts who support developing business proposal and studies in order to improve producer's biofuel production capacity ($ 18.7m, 120 projects)
Agriculture Bioproducts Innovation Program	• Building research capacity in agricultural bioproducts and bioprocesses ($68.3m)
The National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS)	• Providing an increased ability to assess and report on environmental performance on soil carbon and agricultural GHG emissions
Biomass Inventory Mapping and Analysis Tool (BIMAT)	• Providing interactive queries and maps on the kinds and amounts of feedstocks through internet
Offset system	• Offering offset credits for eligible projects, such as methane capture, reforestation and other forestry projects, and agricultural soil management • Offset credits can be sold in the carbon market

[3] A programme that "provides farmers with financial and technical assistance to convert environmentally sensitive land to perennial cover, to manage agricultural land near water , and to plant trees and shrubs as a habitual part of the agricultural landscape"

Policies and measures reported in the 4th National Communication on Climate Change were related to environmental management, such as preparing best management practises, encouraging environmental management at farm level, and improving soil conservation and carbon sequestration. Unusually, the Energy Co-Generation from Agriculture and Municipal Waste (EcoAMu) has been introduced to improve technology development in the area of co-generation (Environment Canada, 2006). Recently, the Canadian Government has introduced several policies and measures, such as the Biofuel Capital Initiatives, the Biofuel Opportunities for Producers Initiative, the Agriculture Bioproducts Innovation Program, and the Biomass Inventory Mapping and Analysis Tool (BIMAT) in order to encourage research, development and investment in the area of bio-fuel, biomass, and bio-products (Environment Canada, 2010).

In summary, the Canadian Government's policies on climate change have focused on the area of environment management, including developing BMPs and soil conservation in order to reduce GHG emissions. More, recently the Government has been encouraging bio-fuel production.

3.4.4. United Kingdom (UK)

The United Kingdom (UK) set a binding GHG emission reduction as 12.5 per cent below 1990 base year levels from 2008 to 2012. The UK has already achieved GHG emission reduction of 14.6 per cent below 1990 levels in 2004 and 18.4 per cent in 2007. From 1990 to 2007, carbon dioxide emissions including the LULUCF sector reduced by 8.3 per cent. Also, methane and nitrous oxide emissions fell by 53.1 per cent and 46.9 per cent respectively in this period (Department of Energy and Climate Change, 2009).

Table 27 illustrates key policies and measures of the UK Government on climate change. Under the CAP, the Department for Environment, Food and Rural Affairs (DEFRA) has introduced various policies and measures to address climate change. What is interesting about the UK is that the Government has worked in partnership with industry through the high-level Rural Climate Change Forum (RCCF). This Forum has played an important role to inform significant impacts of climate change, coordinate the works on climate change between the Government and the industries, and give the Government advice (Department of Energy and Climate Change, 2009).

Table 27 Key policies and measures of the UK Government on climate change (Department of Energy and Climate Change, 2009)

Name of policy or measure	Objective and/or activities
The EC ETS	• A emission trading system entered into force in 2008
Carbon Reduction Commitment (CRC)	• A new mandatory emission trading scheme begun in 2010
Climate Change Act 2008	• The world's first long-term legally binding framework for mitigation of GHG emissions
Environmental Transportation Fund (ETF)	• Financial assistance to encourage new technology development for clean energy and improve energy efficiency, introduced in 2008
Climate Change Levy (CCL)	• A tax on energy in order to enhance energy efficiency started in 2007
Home Energy Saving Programme (HESP)	• Providing support to help families on middle and modest incomes to reduce energy in their house

Table 28 illustrates the UK government's policies and measures in agriculture to meet climate change. The UK government has reduced the Direct Payment (DP) related with intensified production but maintained DP to set-aside for conservation. Otherwise, the government has increased support to research, development, and adoption of Good Agricultural Practices (GAPs) in order to reduce methane and nitrous oxide emissions from livestock and fertiliser application. The government has also introduced several policies to encourage carbon sequestration and improve energy efficiency. In addition, the government has increased investment to research, technology development and transfer in the areas of anaerobic digestion and non-food crops, such as bio-energy crops in order to make new business opportunity (Department of Energy and Climate Change, 2006). Unlike other countries, the UK policies and measures on climate change are likely to keep a balance between mitigation and adaptation. Recently, the UK government has increased support to adaptation measures, such as flood management programme and long-term water management plan (See Table 29). The Government has also provided practical advice on climate change to the farmers. In addition, the Government has increased financial supports for research on adaptation to climate change (Department of Energy and Climate Change, 2009).

Table 28 Policies and measures in agriculture reported in the UK's 4th National Communication on climate change (Department of Energy and Climate Change, 2006).

Area	Policies and Measures
Common Agricultural Policy (CAP)	• Abolishes Direct Payment (DP) to set-aside • But allows DP to set-aside for water protection and habitats (In England, 5 per cent of the arable area should be reserved for bio-diversity or water quality)
Reducing N_2O emissions	• A Code of Good Agricultural Practice for farmers, growers and land managers (the CoGAP) to reduce pollution • Fertiliser Manual • The PLANET decision support software to help farmers plan and record their fertiliser application • The Catchment Sensitive Farming (CSF) Programme to reduce water pollution
Reducing CH_4 emissions	• Funding research for methane emission reduction from livestock
Anaerobic digestion	• The UK Biomass Strategy 2007: promotes development of anaerobic digestion technology and stimulates markets for anaerobic digestion products • Anaerobic Digestion: Shared Goals 2009: set out the goal for the use of anaerobic digestion in England • Funds for developing reprocessing facilities for food waste under the Waste and Resource Action Programme
Rural development regulation and environmental stewardship	• Rural Development Programmes: increases carbon sequestration with reversion to semi-natural lands, wet-habitats etc.
Energy efficiency	• The Climate Change Agreements to reduce GHG emissions from the pig and poultry farming sectors through improving energy efficiency
Non-food crops	• Non-Food Crops Strategy Action Plan: promotes research communication, information transfer, and supply chain development for the sectors of bio-energy, renewable chemicals, renewable construction materials, and plant based pharmaceuticals • The Energy Crops Scheme: provides grants to farmers for planting energy crops • The Bio-energy Infrastructure Scheme: provides financial support to farmers and the industry to help develop the supply chain of bio-energy products

Table 29 Policies and measures in agriculture reported in the UK's 5th National Communication on climate change (Department of Energy and Climate Change, 2009).

Name of policy or measure	Objective and/or activities
Future Water	• A long-term vision for water policy published by Defra
Making Space for water	• Flood management programme
Farming Futures	• Provides financial support to give practical advice on climate change to farmer
Research	• Impacts of climate change • Improvement of the water use efficiency • Breeding crops to address climate change • Mitigation technologies against the impacts of climate change • Improving opportunities for novel crops • Changes in land use and agricultural practices due to adaptation to climate change

In summary, the UK Government has implemented well-balanced polices including mitigation, adaptation, and developing new business opportunity in terms of climate change. In order to reduce GHG emissions, the Government has cut the Direct Payment for intensified production and promoted GAPs, soil carbon storage, and efficient use of energy. The UK Government's adaptation policies have focused on flood protection and water availability. Also, the Government has provided financial support to give practical advice on climate change to farmers. For developing new business opportunity, the Government has supported research and development in the areas of anaerobic digestion and non-food crops.

3.4.5. United States of America (USA)

The USA GHG reduction emission targets were 17 per cent below 2005 levels by 2020 and 83 per cent below 2005 levels by 2050. In 2007, the USA's GHG emissions were 7150.1 Mt CO_2e and rose by 17 per cent between 1990 and 2007 (United States Department of State, 2010). Fossil fuel consumption was the greatest GHG source of USA's GHG emissions and represented approximately 79 per cent of total USA's GHG emissions in 2007. Methane accounting for 8 per cent of total USA's GHG emissions mostly came from livestock. Nitrous oxide that caused 4.4 per cent of total emissions in 2007 originated from agricultural soil management and fuel combustion of car (United States Department of State, 2010). Table 30 illustrates the key USA Government's policies and measures to meet climate change. The USA Government seems to focus on clean energy technology and energy efficiency more than other countries. For example, many of USA's policies and measures on climate change were related to development and implementation of clean energy technology and improvement of energy efficiency (United States Department of State, 2006, 2010). Also, the USA has enthusiastically participated in intergovernmental partnerships to encourage clean energy technology development. The USA Government has used various means, such as regulations, tax and incentives, education and campaign, and voluntary actions in order to implement policies and measures (United States Department of State, 2006, 2010).

Table 30 Recent USA key policies and measure on climate change since 2006 (United States Department of State, 2006, 2010)

Area	Policies and Measures
American Recovery and Reinvestment Act of 2009	• Aim: to promote clean fuel economy and reduce GHG emissions from motor vehicles • Programmes: Modernized Transit, Reliable and Efficient Electricity Grid, Renewables and Smart Grid Energy Loan Guarantees, GSA Federal Buildings, State and Local Governments Energy Efficiency Grants, Energy Efficiency Housing Retrofits, Energy Efficiency and Renewable Energy Research, Advanced Battery Grants, Home Weatherization, Smart Appliances, GSA Federal Fleet, Electric Transportation, Cleaner Fossil Energy, Training for Green Jobs
Energy	• Energy Efficiency and Conservation Block Grants Net-Zero Energy Commercial Building Initiative, Energy-Intensive Industries Program, Biorefinery Assistance, Energy Smart Parks, Indian Education Renewable Energy Challenge, University-National Park Energy Partnership Program, Energy Transmission Infrastructure, Geothermal Energy Deployment Program, Solar Energy Deployment Program, Wind Energy Development Program
Transport	• Alternative Transport Systems and Use of Clean Vehicles, Advanced Technology Vehicles Manufacturing Incentive, Transit Investments for Greenhouse Gas and Energy Reduction
Industry	• Responsible Appliance Disposal Program
Forestry	• Enhancing Ecosystems Services on Forest, Grasslands, Parks, and Wildlife Reserves
Cross-Sectoral	• Carbon Monitoring and Sequestration, Climate Friendly Parks, Climate Showcase Communities Grant Program, National Action Plan for Energy Efficiency, Interagency Partnership for Sustainable Communities

USA policies and measures for mitigation of agricultural GHG emissions are illustrated in Table 31. USA policy and measures in agriculture mostly concentrated on the areas of conservation and environmental management, renewable energy, energy efficiency, environmental management, and mitigation of methane emissions from livestock. In order to achieve their goal, the USDA has provided various financial incentives, technical support, pilot programmes and education. Also, the USDA has been in close partnership with scientists and farmers in order to help farmers and businesses in agriculture adapt to climate change. Table 32 illustrates USDA policies and measures on adaptation to climate change. The USA government policies on adaptation focused on water availability, pest management, and risk management against climate change (United States Department of State, 2010).

Table 31 USA policies and measures in agriculture to reduce agricultural GHG emissions (United States Department of State, 2010)

Name of policy or measure	Objective and/or activities
Renewable Energy Systems and Energy Efficiency Improvements Program [4]	• Providing loan guarantees and grants to agricultural producers and rural small businesses for renewable energy systems and improvement of energy efficiency
AgSTAR	• Supporting voluntary actions to reduce GHG emissions through the use of methane (biogas) technologies at confined animal feeding operations
Conservation Reserve Program	• Supporting farmers' conversion of agricultural land to native grasses, wild life plantings, trees, restored wetlands etc.
Environmental Quality Incentives Program	• Providing financial support for conservation practices on farm and ranch lands, such as residue management, irrigation and water management, nutrient management, crop rotations, cover crops, restoring wetlands, and grazing land management
Conservation Stewardship Program (Conservation Security Program)	• Providing financial and technical support to encourage the conservation and improvement of the environment including soil and water
Wetlands Reserve Program	• Providing technical and financial support for landowners to protect and restore their wetlands
Grassland Reserve Program	• Purchasing easements to restore or maintain grassland and enhance carbon storage
Wildlife Habit Incentives Program	• Providing financial support for private landowners to create habitat for specific wildlife species

[4] Reported in the USA's 4th National Communication on Climate change (United States Department of State, 2006)

Table 32 USDA's adaptation policies and measures in agriculture to meet climate change (EPA, 2012; USDA Office of the Chief Economist, 2012)

Area	Policies and Measures
Restore and conserve forest, farms, ranches and grass lands	• USDA Climate Change Science Plan • Conservation Technical Assistance (Natural Resources Conservation Service (NRCS)) • Providing climate statistics (NRCS)
Enhance water availability	• Providing data and information on soil moisture and temperature, conditions and trends in rainfall and temperature (NRCS) • Research for climate change adaptation (ARS) • Environmental Quality Incentive Program to help farmers improve their yields under less water conditions • Agricultural Water Enhancement Program, Conservation Innovation Grants, Easement programs, the Wetland Restoration Program, the Healthy Forests Restoration Program
Minimize diseases and pests	• Climate Change Response Plan (Animal and Plant Health Inspection Service (APHIS)) • USDA Climate Change Science Plan
Others	• Risk Management Funds: providing financial assistance to develop risk management tools through partnerships with states, universities and organizations • Research to build better model for the resilience of agricultural systems

3.5. New Zealand (NZ)

3.5.1. New Zealand's Greenhouse gas (GHG) inventory

New Zealand's total gross GHG emissions have increased since 1990s. NZ's total gross emissions in 1990 were about 59.8 Mt CO_2-e. However, total gross emissions in 2010 were 74.7 Mt CO_2-e and NZ's GHG emissions have increased 19.8 per cent at the rate of 0.9 per cent per year between 1990 and 2010 (Ministry for the Environment, 2012a). Table 33 shows changes in GHG emissions by gas. Carbon dioxide emissions caused around 46 per cent of total emissions in 2010 and have increased by 32.7 per cent from 1990 levels, as a result of an increase of emissions from the energy and industry sectors. In 2010, methane represented 37 per cent of NZ's total GHG emissions. Between 1990 and 2010, total methane emissions showed a relatively smaller increase (4 per cent) than other gaseous emissions. This is because methane emissions in New Zealand mostly came from the agricultural sector, especially livestock and stock numbers have not increased significantly in that period (Ministry for the Environment, 2012a). Nitrous oxide emissions represented 15 per cent of total emissions in 2010 and have increased by 25.8 per cent from 1990 levels partly due to an increase of nitrogen fertiliser application (Ministry for the Environment, 2012a).

Table 33 New Zealand's gross greenhouse gas emissions by gas in 1990 and 2010 excluding net removals from the Land Use, Land Use Change and Forestry (LULUCF) (Ministry for the Environment, 2012a)

Gas	GHG emissions (Gg CO_2-e)		Change from 1990 (Gg CO_2-e)	Change from 1990 (%)
	1990	2010		
CO_2	25,014.1	33,199.2	+8,185.2	+32.7
CH_4	25,826.5	26,855.1	+1,028.7	+4
N_2O	8,311.6	10,454.7	+2,143.1	+25.8
HFCs	NO	1,087.2	+1,087.2	NA
PFCs	629.9	40.8	-589.1	-93.5
SF_6	15.2	20.2	+5	+32.6
Total	59,797.2	71,657.2	+11,860.0	+19.8

New Zealand accounted for about 0.2 per cent of global GHG emissions and in 2005 NZ's emissions per capita were the 13th highest in the world. New Zealand has a unique emission profile compared to other countries. Figure 14 shows GHG emissions per person and the relative proportion of carbon dioxide emissions (Ministry for the Environment, 2012b). In most developed countries, carbon dioxide emissions from fossil fuel combustion represented more than 80 per cent of total GHG emissions. Even the relative world average proportion of carbon dioxide emissions was 73 per cent in 2005. However, in New Zealand carbon dioxide emissions accounted for about 45 per cent of NZ's total emissions and non-carbon dioxide emissions were more than carbon dioxide emissions due to higher agricultural production.

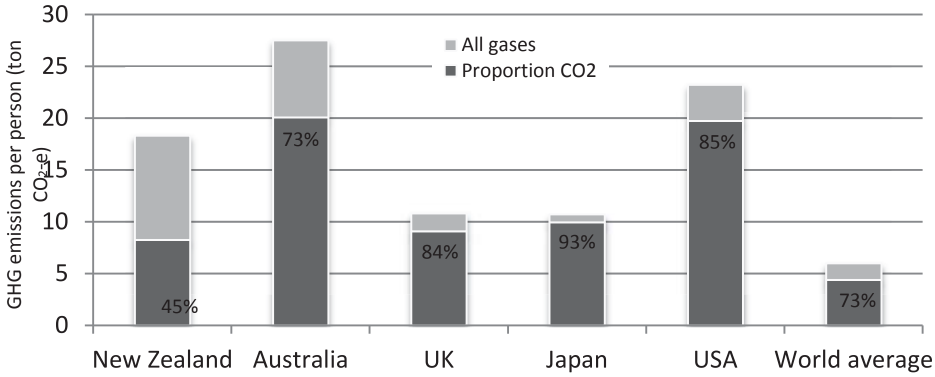

Figure 14 GHG emissions per person in 2005 (Ministry for the Environment, 2012b)

In fact, in New Zealand the primary sectors represented just 7 per cent of GDP. However the agricultural sector accounts for 50 per cent of NZ's total emissions (Table 34). As a result, even though NZ's carbon dioxide emissions were lower relative to the UK and Japan, total emissions of New Zealand were higher than those countries partly due to non-carbon dioxide emissions from the agricultural sectors. Emissions from the energy sector contributed approximately 43 per cent of NZ's total emissions in 2010 and have increased by 32.6 per cent between 1990 and 2010 due to an increase of fossil fuel use for electricity and transport (Ministry for the Environment, 2012a). However, NZ's energy supply from renewable energy sources has significantly increased and in 2009 renewable energy sources, such as hydro-electric, biomass, geothermal and wind comprised about 71 per cent of NZ's electricity supply (Ministry for the Environment, 2009).

Table 34 New Zealand's GHG emissions by sector in 1990 and 2010 (Ministry for the Environment, 2012a)

Sector	GHG emissions (Gg CO_2-e)		Change from 1990 (Gg CO_2-e)	Change from 1990 (%)
	1990	2010		
Energy	23,458.4	31,107.8	+7,649.4	+32.6
Industrial processes	3,388.8	4,778.1	+1,389.3	+41.0
Solvent and other product use	41.5	31.0	-10.5	-25.4
Agriculture	30,855.3	33,748.4	+2,893.2	+9.4
Waste	2,053.2	1,991.8	-61.4	-3.0
Total (excluding LULUCF)	**59,797.2**	**71,657.2**	**+11,860.0**	**+19.8**
LULUCF	-27,388.3	-19,980.5	+7,407.9	+27.0
Net Total (including LULUCF)	**32,408.9**	**51,676.7**	**+19,267.8**	**+59.5**

3.5.2. New Zealand government policies on climate change

Climate change is one of the key priorities of New Zealand Government. New Zealand set the targets as emission reduction of 10 to 20 per cent below 1990 levels by 2020 and 50 per cent below 1990 levels by 2050. In order to meet the goal, the New Zealand Government has introduced and implemented various policies and measures on climate change including the New Zealand Climate Change Programme adopted in 1988. The NZ Government's key strategies for GHG reducing emissions are illustrated in Table 35. The NZ Emission Trading Scheme is a key policy of the NZ Government to address climate change. In 2008, the NZ ETS entered into force from the forestry sector and by 2015 all production sectors will enter the NZ ETS. The NZ Government's adaptation strategies to climate change include legislation, guidance material, and supplementary information and data. The NZ Government revised and accepted several legislation, such as the Resource Management Act 1991, the Civil Defence Emergency Management Act 2002, and the Local Government Act 2002 in order to help local government manage the impacts of climate change. Also, the Government provided the local government sector with guidance material as follows: Climate Change Effects and Impacts Assessments (a guidance manual for local governments) and Coastal Hazards and Climate Change (a technical guidance manual for the coastal areas).

Table 35 New Zealand Government's key strategies to meet climate change (Ministry for the Environment, 2009)

Name of strategy	Objective and/or activities
NZ Emission Trading Scheme (ETS)	• Entered into force in 2008 from the forestry sector to reduce GHG emissions • The NZ ETS will cover all sector and all gases by 2015
NZ Energy Strategy	• Supplying by 90 per cent of NZ's electricity from renewable energy sources by 2025,
NZ Energy Efficiency and Conservation Strategy	• Increasing energy efficiency and conservation
NZ Transport Strategy	• Providing incentives and research to promote development of new fuels and technologies and improve energy efficiency
NZ Waste Strategy	• Minimising and managing waste

The agricultural sector is the greatest emission source in New Zealand and accounts for about 50 per cent of NZ's GHG emissions. The agricultural sector is considered more vulnerable to the impacts of climate change than other sectors because most agricultural production depends on various climate factors, such as temperature, rainfall, wind, and sunshine (Ministry of Agriculture and Forestry, 2007). Thus, adequate policies and measures in agriculture are required to reduce agricultural GHG emissions and meet climate change. The NZ Government's key strategies in agriculture to meet climate change are as follows:

- Sustainable Land Management and Climate Change Plan of Action
- Global Research Alliance on Agricultural Greenhouse Gases
- Primary Growth Partnership (PGP)

The Ministry of Primary Industries (MPI) has seven regional offices in Whangarei, Rotorua, Gisborne, Whanganui, Nelson, Christchurch, and Dunedin. These regional offices are implementing MPI policies at the regional level. They used to have an advisory and consulting function for farmers but those functions were moved to consulting firms and agricultural research institutes, such AgFirst Ltd, National Institute of Water & Atmosphere (NIWA), the Plant and Food Research, and Massey University.

3.5.2.1. Sustainable Land Management and Climate Change Plan of Action

In 2007, the NZ Government proposed Sustainable Land Management and Climate Change Plan of Action (the Plan of Action). The Plan of Action consisted of three key pillars: adaptation, reducing emissions and creating carbon sinks, and business opportunities (Table 36) and has being implemented in partnership with local governments, the primary sectors, and Maori (Ministry of Agriculture and Forestry, 2007).

Table 36 Three pillars of Sustainable Land Management and Climate Change Plan of Action (Ministry of Agriculture and Forestry, 2007)

Pillar	Activities	Subsidiary group
Adaptation	• Partnership between the Government and the sector • Policy development for adaptation to climate change • Community Irrigation Fund • Introduction of adaptation strategies	Adaptation Working Group
Reducing emissions and creating carbon sinks	• NZ ETS • Farm-scale GHG reporting • Forestry complementary measures • Afforestation Grant Scheme	Research, Innovation and Technology Transfer Working Group ETS Design Technical Advisory Group
Business opportunities	• Partnership between the Government and the sector • Policy development • Greenhouse gas footprinting • Biochar and Bioenergy • Sustainable building strategy • Avoided deforestation related to international strategy	Business Opportunities Working Group

The Plan of Action included various programmes and initiatives supported by research and development, communication, and technology transfer in the areas of climate change. Key parts of the SLMACC were researched to understand the impacts of climate change for agriculture and a technology transfer programme. All programmes and initiatives under the Plan of Action were discussed and coordinated by a "Peak Group" which is a high level partnership, and the subsidiary groups. Key programmes and/or initiatives in agriculture implemented under the Plan of Action are described as follows;

Research programme for agricultural and forestry greenhouse gas inventories

The aim of this programme is to improve agricultural and forestry greenhouse gas inventories. The Government is providing more than $2 million of grants in total to support specific research related to agricultural and forestry greenhouse gas inventory (Ministry for the Environment, 2009).

Adapting to a changing climate

In order to promote farmer and industry adaptation responses to climate change, the NZ Government is supporting capacity building for adaptation responses and risk assessment for decision-making on land management. The Government is also providing information on climate change to farmers and agricultural industries. In addition, the Government is providing the Community Irrigation Fund to enhance water availability and implementing researches and technology transfer to facilitate adaptation responses (Ministry for the Environment, 2009; Ministry of Agriculture and Forestry, 2007). Recently, the Community Irrigation Fund has been incorporated into the Irrigation Acceleration Fund (Lill, 2012).

Biochar professorships

Biochar is charcoal-like material and is used to enhance soil carbon storage. The Government is providing financial assistance to establish two professorships in biochar, soil science and pyrolysis processing. The Government is funding about $2.5 million every year for research, laboratory equipment and facilities (Ministry for the Environment, 2009; Ministry of Agriculture and Forestry, 2007). So far, the biochar professorships have been successfully undertaken (Lill, 2012).

Enabling business opportunity

The Government is undertaking strategy analysis to identify business opportunities in the area of climate change, investigating market and trading opportunities, and developing greenhouse gas footprint technologies. In particular, in the area of bio-energy, the Government is implementing the school boiler project to convert fossil fuel boilers to wood fuel boilers in schools, industrial scale co-generation demonstration pilots, and researching collecting wood residues in the forests (Ministry of Agriculture and Forestry, 2007).

Nitrification Inhibitors

The Government is providing financial assistance to enhance research on nitrification inhibitors. The aim of this research is to identify the ability of nitrification inhibitors for reducing GHG emissions, to determine the Best Management Practice for the nitrification inhibitors, and to enhance farmers' understanding of the use of nitrification inhibitors.

Greenhouse gas footprinting strategy

The Government is supporting methodology development of GHG footprint for the primary sector and establishment of an expert group. Also, the Government is improving GHG emission calculation methodologies at the farm level. This programme will be helpful for farmers and agricultural industries to measure and manage greenhouse gas emissions (Ministry for the Environment, 2009; Ministry of Agriculture and Forestry, 2007). Since 2007, sector-specific projects representing over 80 % of NZ's primary sector exports have been successfully implemented (Lill, 2012).

Monitoring and measuring farm emissions and mitigation

In order to promote farm monitoring, the Government is upgrading the Overseer[5] farm nutrient management model, improving the Catchment Land Use for Environmental Sustainability (CLUES) system and the Farm Monitoring Programme. Also, the Government is helping various sectors or farmer's voluntary monitoring activities.

[5] A software package developed by AgResearch in order to enable to predict pastoral greenhouse gas emissions at the farm level.

Technology transfer

The purpose of the technology transfer programme is to promote farmer and industry use of adequate GHG emission mitigation technologies and adaptation measures. The technology transfer programme includes demonstrating new technologies and practices, education and capacity building, and providing farmers with information on new technologies and practices in terms of GHG emissions mitigation and adaptation to climate change.

According to Lill (2012), transfer of knowledge to the sectors is undertaken through a specific technology transfer programme. Under this programme, a number of horticulture specific initiatives have already been undertaken. The overall goal for the technology transfer element of the Sustainable Land Management and Climate Change Plan of Action is:

- To provide technology transfer to enhance the ability of primary industry land managers to adopt land management practices that will:
- Reduce total greenhouse gas emissions, improve the efficiency of resource use and understand and minimise liabilities under an Emissions Trading scheme.
- Adapt to a changing climate.
- Take advantage of new business opportunities relating to climate change.

And currently [2013] the focus is on:

- Collecting and developing resources for sectors, including horticulture;
- Practical demonstration and up-skilling on climate change and greenhouse gas emissions to farmers and growers, and;
- Training rural professionals so that they can better inform their clients about climate change (Ministry of Agriculture and Forestry, 2007; Ministry for the Environment, 2009; Lill, 2012).

Livestock Emissions and Abatement Research Network (LEARN)

LEARN is an international research and collaboration network in order to enhance technology development for measurement, monitoring and mitigation of GHG emissions from livestock. It was established in 2007 and more than 300 researches from 47 countries now participate in LEARN.

Sustainable Farming Fund (SFF)

The purpose of the SFF is to support projects which are undertaken by farmer, grower, and forester and benefit to NZ's primary industries, including agriculture, forestry, aquaculture and fishery in order to solve a problem or to encourage a new opportunity in the primary sectors. Also, the SFF includes projects related to climate change issues, including mitigation, adaptation, and development of new business opportunities. Activities which are appropriate for the SFF include research, demonstration and extension activities and resources, project management, and financial management, etc. (MAF, 2012). The Sustainable Farming Fund has funded projects on horticultural crops, including summer fruits and berry fruit. From 2007 to 2011, 52 SFF projects for climate change were undertaken and 8 projects (15 %) were related to some horticultural crop production while 67 % of them were undertaken for the dairy sector. The list of the SFF projects on climate change is attached as Appendix 1(MPI, 2012b).

Global Research Alliance on Agricultural Greenhouse Gases (the Alliance)

The Global Research Alliance on Agricultural Greenhouse Gases was launched in 2009 in order to promote global cooperation and collaboration for reducing agricultural GHG emissions. Currently, 33 countries have been participating in Global Research Alliance and New Zealand has been playing a leading role to drive research collaboration with member countries since the Alliance was launched. The Alliance is promoting research and development, technology transfer, and practices which help farmers and industry reduce GHG emissions and manage risks from impacts of climate change. To meet the goal, the Alliance focuses on research in the areas of livestock, croplands, and paddy rice. Alliance research is funded voluntarily by member countries (GRAAGG, 2009).

Primary Growth Partnership (PGP)

The Primary Growth Partnership is a partnership initiative between the Government and industry. The aim of PGP is to enhance growth of the NZ's primary industries including pastoral and arable production, horticulture, seafood and aquaculture, forestry, and food processing by providing investment in research and innovation. The PGP is providing about $ 70 million of matching funds with industry annually (Ministry of Agriculture and Forestry, 2007).

New Zealand Agricultural Greenhouse gas Research Centre (NZAGRC)

A key programme of the PGP was the establishment of the NZAGRC. The NZAGRC was established in 2010 to promote and coordinate agricultural researches on greenhouse gas emissions. NZAGRC's mission is "to provide knowledge, technologies and practices which enable agricultural activities to continue to create wealth from agriculture for New Zealand in a carbon constrained world" (NZAGRC, 2010b). To achieve its mission, NZAGRC has developed agricultural greenhouse gas mitigation strategies and funded several research programs to develop new technologies and practices. In addition, the centre has provided the information to the government for decision making on agricultural GHG emissions. NZAGRC's key aims are as follow; "1) Contributing to national agricultural greenhouse gas mitigation, 2) Leading high quality research programmes, 3) Collaboration with national and international partners, 4) Administering funds (NZAGRC, 2010a). The NZ government has funded $45.5 million to NZAGRC's research programs over 10 years from 2009 to 2018. NZAGRC's four main science programs are;

1) Mitigation of methane emissions from livestock
2) Mitigation of nitrous oxide emissions
3) Increasing soil carbon storage
4) Developing integrated systems.

In 2011/2012, NZAGRC's funds were $1,080,000 and 77 per cent was invested in three research areas including methane and nitrous oxide mitigation, and soil carbon storage (NZAGRC, 2010c). The centre works together with nine partners; AgResearch, DairyNZ, Landcare Research, Lincoln University, Massey University, NIWA, Pastoral Greenhouse Gas Research Consortium (PGgRc), Plant & Food Research and Scion. Table 37 defines these nine partners and their research areas (NZAGRC, 2010c).

Table 37 NZAGRC's research partners and research areas (NZAGRC, 2010c)

Partner	Research areas
AgResearch	Mitigation of methane and nitrous oxide emissions, soil carbon sinks
DairyNZ	Application of research results in dairy farming systems
Landcare Research	Measurement of GHG emissions and soil carbon sink
Lincoln University	Nitrous oxide mitigation technologies
Massey University	Biochar and GHG emission mitigation technologies
NIWA	Assessing the effectiveness of mitigation technologies and practices
PGgRc	Application of NZAGRC's research
Plant & Food Research	Soil carbon, nitrous oxide mitigation
SCION	Soil carbon

3.5.2.2. Emission Trading Schemes (ETS)

The forestry sector entered the ETS in 2008 and agriculture is expected to enter the ETS in 2015. However, the start date for the surrender obligation for biological emissions from agriculture is no longer specified in the legislation as the Government has decided that biological emissions from agriculture will have surrender obligations in the ETS only if there is technology available to reduce these emissions and international competitors are taking sufficient action on their emissions in general. However, agricultural processors must report their emissions profiles to the Environmental Protection Authority (EPA) from 2012 (Ministry of Agriculture and Forestry, 2010b; Lill, 2012).

3.5.2.3. Research about the impacts of and adapting to climate change

The Government has funded research on the impacts and adaptation to climate change. From 2008 to 2012, over 100 research projects have been implemented in the areas of the impacts of and adapting to climate change, forestry and carbon markets, addressing greenhouse gases from agriculture, soil carbon and biochar, and economic and social issues in terms of climate change (MPI, 2011b). Appendix 2 identifies the list of research projects funded by the Government with regard to climate change. Most research projects were related to the dairy and forestry sectors. Also, they mainly focused on the impacts of climate change and mitigation of GHG emissions. Just one of them was directly related to the horticultural sector.

3.6. Summary

Government policy is affected by both internal and external factors, including the industry and community's concern, and international issues. This chapter introduced and explored concerns people have and policies some developed countries, including New Zealand, are applying, in order to address climate change.

Recently, international negotiations for mitigating global GHG emissions, the ETS, and carbon labelling have been issued around the world. With the UNFCCC as the centre, international negotiations have been progressing slowly. The Kyoto Protocol which entered into force in 2005 could be an example of international efforts for GHG mitigation. The results of the international negotiations should influence NZ agriculture. For instance, under the Kyoto Protocol, New Zealand should reduce total GHG emissions by 5 % below 1990 levels between 2008 and 2012. Considering the agricultural sector accounts for about half of the total NZ emissions, the impacts of international negotiation would affect NZ's agriculture. Also, major importers of NZ agricultural products, including the UK, the USA, Canada, and Australia, have introduced the ETS and carbon labelling to mitigate GHG emissions. As a result, NZ's agricultural sectors could lose some global competitiveness.

Policies on climate change varied between countries and their different situations. For example, in Canada and the USA which have huge arable land areas, environmental management and conservation could be big issues in terms of mitigation of GHG emissions. On the other hand, in the UK, intensified production, soil carbon storage and efficient use of energy could be applied with regard to GHG mitigation.

The main concern of the industry and farmers in NZ is the ETS. Both industry and farmers thought that the ETS would impose them additional costs and as a result, it would make them less competitive internationally. Water availability was another big concern relative to climate change. Even though water availability has never yet been an issue in New Zealand excepting some dry regions, it is likely that lack of water supply can be a serious issue in the future. Besides the ETS and water availability, there were also concerns about climate events; heavy rainfall and floods, poor drainage, increasing pest, disease and weed problems, and strong winds.

Agriculture is the greatest CO_2 emission source in New Zealand and causes about half of total NZ's GHG emissions. Also, Agriculture represents around 70 % of NZ's commodity exports. Therefore, adequate policies on mitigation and adaptation to climate change are obviously essential for NZ's agriculture. The NZ Government policies on climate change include the three main programmes: the Sustainable Land Management and Climate Change Plan of Action (SLMACC), Global Research Alliance on Agricultural Greenhouse Gases, and Primary Growth Partnership (PGP). The SLMACC programme is the NZ Government's key policy on climate change in the land based sectors, including horticulture and key parts of the SLMACC were research for climate change and technology transfer programme.

CHAPTER FOUR: METHODOLOGY

4.1. Introduction

In the previous chapter, the current situation of climate change, its impacts on agricultural production, and possible adaptive responses were described. The purpose of this chapter is to illustrate the methodology used for designing this study, collecting data and analysing results. For this research, seven case study sites were selected to collect data; a citrus orchard in Gisborne, an apple orchard in Hawke's Bay, four vegetable production farms in Manawatu, and a vineyard in Nelson. A qualitative research method and case study approach to investigate the impacts of climate change and the effectiveness of government policy on climate change was undertaken. This chapter introduces and qualifies the methodologies applied and how the case-sites were determined. In addition, the process used, including preparation of a questionnaire and in-depth interview, audio recording and field notes and non-participant observation, are elaborated on. The methods used for data documentation and analysis are also explained. Ethical considerations are also addressed.

4.2. Research strategy

Qualitative research is a form of systematic empirical scientific research (Shank, 2002) and was developed in social science to study social and cultural phenomena (Myers, 2009). The objectives of qualitative research are to describe people's experiences and variation, and to explain relationships. Qualitative research has a strength in studying how people deal with a particular issue (Mack, Woodsong, MacQueen, Guest, & Namey, 2005). On the other hand, quantitative research was originally developed to study natural phenomena. It usually focuses on quantifying variation and predicting causal relationships (Mack et al., 2005). For this research, a qualitative research method was chosen to gather information and analyse data collected. This is because this research focuses on farmer experiences of climate change and as mentioned, qualitative research methods are more appropriate to describe it rather than quantitative research methods.

A case study is defined as ‘the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances’ (Stake, 1995). Merriam (1988) defined case study as ‘an intensive, holistic description and analysis of a single entity, phenomenon of social unit.’ Yin (2009) indicated that ‘a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident’. In many cases, a case study is regarded as one of qualitative research. Case studies cannot be qualitative research alone and they are generally used with non-qualitative research processes.

This study chose the case study as the primary methodology to investigate the impacts of climate change and the effectiveness of policies and measures at farm production level. This is because the main question of this study is a “how” question, “how” government policy on climate change has been being implemented at farm production level. The research question of this study is how NZ government policies on climate change have been being implemented effectively at farm production level. Therefore, the case study is best suited to identify this research question rather than ‘participatory’ or ‘farmer first’ – methodologies.

There are several strengths of a case study. Firstly, it allows researchers to study particular phenomena. The case study is also useful to understand dynamic changes in phenomena (Simons, 2009). Secondly, it is a suitable way to explain the how and why questions (Simons, 2009; Yin, 2009). Thirdly, the case study is quite flexible; there is no restriction to time and method to conduct case study. Finally, it can give a chance for participants to participate in the research (Simons, 2009). However, the case study has several weaknesses. One of them may be the subjectivity of the researchers. It means that researchers can give a subjective judgement on the case. This is partly because there could be various points of view to explain a particular case and case study is able to let researchers to apply more flexibly. As a result, the subjectivity of researchers is not evitable to undertake case study (Simons, 2009).

Case study can be categorized into various types. Stake (1995) classified case study into three types: intrinsic case study, instrumental case study, and collective case study. In an intrinsic case study, researchers focus on “the intrinsic interest in the case”. In the instrumental case study, researchers choose a case to understanding something else. In collective case study, researchers study several cases to gain "a collective understanding of the issue or question"(Stake, 1995). This study is a collective case study because it chooses several case study sites to collect information on the impacts of climate change and the effectiveness of government policies.

Yin suggested four types of case study designs: single-case (holistic), single-case (embedded), multiple-case (holistic), and multiple-case (embedded) (Yin, 2009). Figure 15 illustrates basic types of case study. According to Yin (2009), multiple-case designs are ones which contain more than a single study and offers the possibility to gain a better understanding of the similarities and difference among the cases, even though it could need more resources and time (Baxter & Jack, 2008). Holistic case studies contain one unit of analysis in a single case. This study used multiple case (holistic) designs in order to compare the impacts of climate change and adaptation response between different crops and areas. This study was implemented in four regions: Gisborne, Hawke's Bay, Nelson, and Manawatu. The unit of analysis used in this research is a farm and an orchard. This is because the unit of analysis could be determined by the research question and purpose which was to define how government policies on climate change are being implemented at a production level (Yin, 2009).

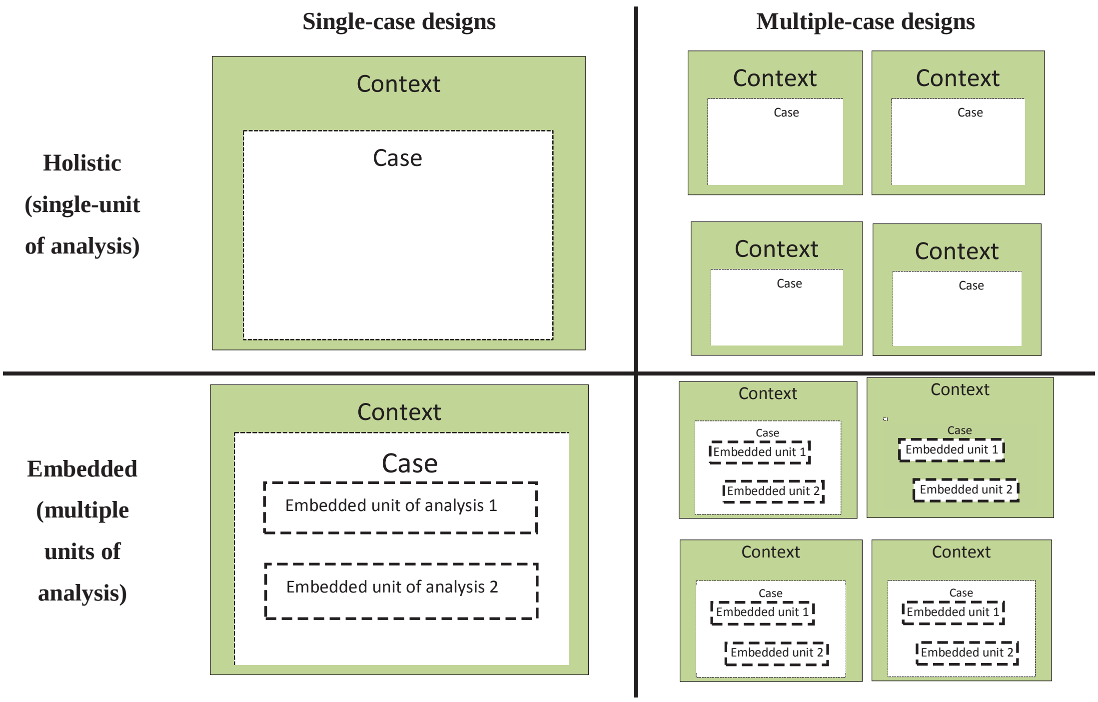

Figure 15 Basic designs for case studies (Yin, 2009)

The purpose of this study is to define how NZ government policies and measures on climate change have been being implemented effectively at farm production level. Government policies can be assessed from various points of view, such as the economic benefit and contribution to public welfare. This study investigated the effectiveness of government policies and measures from the farmers perspective, as it were, how farmers think about government policies and what policies and measures farmers need to meet climate change. This is because most policies and measures are recently introduced and therefore, it is likely to be too early to quantify the effectiveness of government policies and measures. Also, there is uncertainty on the impacts of climate change and the effectiveness of government's actions. However, farmers are really familiar with local climate factors and have good knowledge of adaptation responses at farm production level. Thus, this study focused on farmer experiences and opinion rather than other factors in order to assess government policies and measures. To define the effectiveness of government policies and measures, this study followed three steps. Firstly, this study defined the impacts of climate change and farmer concerns with documents and their experiences. The study then investigated what responses farmers are doing to meet current climate change through in-depth interviews with farmers. Finally, the effectiveness of government policies and measures were identified by investigating how government policies and measures affected farmers' responses to climate change. Partly, this study referred to "farmer participatory approach" or "farmer first methodology" to encourage farmers' participation in the study. The farmer participatory approach is an approach which encourage "the collaboration of farmers and scientists in agricultural research and development" (Bentley, 1994). The farmer participatory approach can allow the researcher to collaborate with farmers and consult about problems in order to find improvement options (Bellon, 2001). During interviews, farmers were informed about the background and the purpose of the study for farmers to gain full knowledge on this study. Then, the farmers were encouraged to express their opinions on government policy freely and those opinions were referred to draw a conclusion and improvement options.

This research selected four case study sites: Gisborne, Hawke's Bay, Nelson, and Manawatu. Before interviewing, question guides and a semi-structured questionnaire were prepared. To investigate the impacts of climate change and the effectiveness of policies, interviews with farmers, local consultants and government officers were undertaken and field observations were combined with the interviews.

4.3. Case designing

4.3.1. Case selection

Defining and selecting any case are important for setting case study parameters. Simons (2009) indicated that various factors were involved in determining the boundaries of the case. For example, the researcher needs to consider which type of case is appropriate, where case is located, and what the output will be driven from case. A case unit also has to be taken into account. For instance, a region can be effective as a unit of case to define the impacts of climate change but to investigate the effect of government policy, a farm or orchard can be more effective that a region. Simons (2009) suggested that the researcher could choose a case where he has “an intrinsic interest” and in a collective case study, cases could be selected from various locations to compare the difference in several cases. The researcher’s interest may be related to the purpose of research and the research question. The research question of this study was “how” agricultural government policies and measures on climate change are being implemented at farm production level. Thus, a farm or orchard was chosen as unit of case and proved adequate to assess the effect of government policies and measures at farm production level and to answer the research question of this study.

Six case study sites (See Figure 16) were chosen; a citrus orchard in Gisborne, an apple orchard in Hawke’s Bay, three vegetable production farms in Manawatu, and a vineyard in Nelson. Gisborne and Hawke’s Bay are located in the east of the North Island while Manawatu is located in the south-west of the North Island. Nelson is located in the upper north of the South Island. The four case study regions have different climate features. For example, the Manawatu climate is dominated by the prevailing westerly winds with wetter winters and springs than the eastern areas, such as Gisborne and Hawke’s Bay. However, Gisborne and Hawke’s Bay are influenced by the easterly winds with less rainfall and more sunshine duration relative to the western regions of the North Island (Ministry for the Environment, 2008a). Nelson is surrounded by high mountains and ranges from the west to the east and faced to the ocean on its northern side. As a result, Nelson has long sunshine duration with less impact of strong winds. Thus, the impacts of climate change and farmers' responses would vary with regions.

In this study, four different crops: citrus (*Citrus reticulata*) (Gisborne), apple (*Malus domestica*) (Hawke's Bay), vegetables (Manawatu), and grape (*Vitis vinifera*) (Nelson) were selected to compare difference in the impacts of climate change and the effectiveness of government policies and measure in each crop production system. This is because each crop has a different phenology and gives different responses to climate change. For example, vegetables, including potatoes, are annual crops and growers can use short-term adaptation measures, such as changing varieties and early planting. However, citrus, apple, and grapes are perennial woody plants and it is difficult to adjust timing of flowering and harvesting. As a result, in many cases, short-term adaptation measures are less available for those crop production systems (Rosenzweig et al., 1996). Also, these crops are major crops represented in each case study region and thus, could be useful to identify the impacts of climate change on each region.

In addition, Yin (2003) recommended researchers should use a case which was close, convenient and easy to access so they could collect the information more easily with a close relationship with interviewees. Manawatu is the one of the main growing areas of vegetables including potatoes and is logistically close to Palmerston North. Therefore, it was convenient for the researcher to visit farms in Manawatu and gather information. Also, Hawke's Bay is near to Palmerston North. Gisborne and Nelson were a longer distance from Palmerston North, however, Gisborne and Nelson are both principal horticultural crop growing areas.

4.3.2. Case study boundary

Researchers have a tendency to try to answer too many questions so that they often lose their own purpose of the research (Baxter & Jack, 2008). In order to avoid this problem, Yin (2003) suggested that it is useful to set a case study boundary. Baxter & Jack (2008) also pointed out that case study boundaries could show what could be studied or not in the scope of the research and include time, place, activity, definition and context. Thus, case study boundaries must be related to the researcher's intrinsic interest, so to speak the purpose of the research and the research question (Simons, 2009). The main purpose of this research was to define how government policies on climate change are being implemented. Therefore, this research focused on the impacts of climate change, farmers' responses, and the effectiveness of government policies. This study investigated government policies which have been introduced during the last 5 years. This is because the NZ Ministry of Agriculture and Forestry (now Ministry for Primary Industries) announced its main climate change action plan in 2007 (Ministry of Agriculture and Forestry, 2007) and introduced related policies. The study further investigated the impacts of climate change in the last a couple of decades because case study farms were mostly established between 10 to 20 years ago. Information on adaptation response mostly relied on farmer's experience. Case studies were undertaken from June 2012 to November 2012 during winter and spring. As a result, field observation couldn't include vivid farming activities. Brief case study criteria, which indicated what should be studied in this research, are as follows: case study location and farm information, local climate data, farm production, impacts of climate change, adaptation responses, and effectiveness of government policies on climate change.

4.4. Primary data collection

Primary data were gathered from case study using in-depth interviews and subsequent field observation. In-depth interviews and an open-ended questionnaire were appropriate to gather data on individuals' perspectives and experience when specific issues are involved (Mack et al., 2005). Also, non-participants observations in the fields were carried out to supplement in-depth interviews.

4.4.1. In-depth interviewing and open-ended questionnaire

In-depth interviews are a common qualitative method designed to obtain the participant's perspective and experience on the research issue. In-depth interviewing has four strengths. Firstly, it can allow the researcher to investigate interviewees' perspective in detail through in-depth interview. Secondly, in-depth interviewing could encourage the close relationship between the researcher and the interviewees. Thirdly, it has flexibility and therefore, the researcher can easily change direction of the interviewing to focus more important and emerging issues. Finally, in interview the researcher can catch interviewees' subtle feeling which can give more information on the topic (Simons, 2009). During in-depth interviews, the researcher sits face to face with the participant and he can easily induce the participant's response and elicit the information from each participant (Mack et al., 2005). Interviews for this study were semi-structured interviews. Semi-structured interviews used open-ended questions and there was no limit to the interviewees' answer. Thus, semi-structured interviews can induce more voluntary discussions and the participant's various opinions. However, semi-structured interviews have a weakness that if the participants are not well guided by the researcher, interviews could wander off and the information obtained might be distorted and useless (Langdridge & Hagger-Johnson, 2009). In order to have effective interviews, a well-organized question guide and questionnaire is necessary for effective semi-structured interviews. In advance, the researcher prepared a fixed, but open-ended guide and questionnaire (detailed in Appendix 3). The questionnaire contained several questions on climate change, including the impacts of climate change on the case study sites, farmers' adaptation responses and perspective on government policies and measures, and potential improvement options to meet climate change.

The interviews with farmers were implemented at case study farms or orchards in order that the researcher could be familiar with the participants and the circumstance of case study areas. The interviews with policy makers and local government officers were implemented at the interviewees' office or using e-mail questionnaire. The researcher recorded when each interview was begun and finished. The interviews were carefully guided not to overrun 2 hours to maintain more concentrated discussion. After each interview, further questions were answered using E-mail or telephone with the participant's consent. The researcher used an audio recorder to record the interview and took notes during the interviews to back up audio recording. Before each interview, oral consent to using the audio recorder was obtained from each participant and the recorder was placed at a distance from the interviewee in order to minimize participant distraction. The participants were informed of background information on the research and benefit or risk so that they could make a decision whether they have interview or not. Also, the research explained the participant that the information gathered from the interview will be treated with confidentiality and oral consent of the participant was obtained.

4.4.2. Field observations

Case studies can use various sources of evidence and direct observations could serve as another method to collect data in case studies (Yin, 2009). Simons (2009) indicated that field observation could allow the researcher to have a comprehensive and holistic picture of the case study site and provide more in-depth and enrich information on the case. Also, information obtained from interviews can easily be distorted or misinterpreted and thus, the researcher could cross-check interviews with field observations. This research included field observations to supplement interviews. After interviews, the researcher visited field sites and gathered information on soil type and topography, crop production, farm facility, irrigation and drainage. During field observations, the researcher recorded all information using field notes. Additionally, photographs at field sites were taken with farmer's consent because photographs could deliver important case characteristics to others (Yin, 2009).

4.5. Secondary data collection

In any case study, documents can provide more enriched information on the case. Even, document analysis can be used as a main method to study the case site (Simons, 2009). In document analysis, documents are not limited to formal documents, such as government documents. They can include industry magazines, newspaper, webpage, rules and regulations, scientific reports and annual reports as well as government documents.

This study used documents as another source of information to supplement interviewing and field observation. Also, information on government policies and measures mostly came from document analysis. Secondary data were collected from various documents, including public literature, electronic materials and government policy documents. Firstly, information on global warming and climate change was obtained from IPCC assessment reports, research articles, books, and electronic materials, such as NZ climate change webpage and NIWA webpage. Secondly, information on intergovernmental activities and foreign government policies on climate change was collected from IPCC and UNFCCC's web documents, National Communication reports, and countries' climate change web page. Thirdly, the researcher referred to MPI and

ME reports and web page, NIWA' climate change reports and web documents, and industry magazines and web pages to collect information on NZ's climate change. Fourthly, information about impacts of climate change on horticulture and adaptation responses were obtained from various sources of literature and electronic materials such as journal articles, reports and web-based documents. Magazines and electronic materials of producer's organizations served as the main source of information about farmers' concerns and response to impacts of climate change. Climatic data and local government policies of the case study sites: Gisborne, Hawke's Bay, Manawatu, and Nelson were gathered from the local authorities' climate change adaptation plans, annual reports and plans, NIWA and ME's documents and web page. Finally, information on the NZ government's policies was obtained from documents and electronic materials of Ministry for Primary Industries and Ministry for the Environment. Additionally, legislation, such as Climate Change Response Act 2002 and Environmental Protection Authority Act 2011, were reviewed to collect further information on government policies.

4.6. Documentation and data analysis

Before analysing data the researcher must transcribe and document the information obtained from interviews and field observations. the researcher made backup copies of audio recordings after each interview and carefully transcribed recordings as soon as possible after they were obtained (Mack et al., 2005). Field notes obtained from interviews and field observations were typed after the interview and observations. Additionally, the researcher's opinions were added to transcripts of field notes.

Qualitative data analysis refers to "a search for general statements about relationships among categories of data" (Marshall & Rossman, 1999). Qualitative data analysis can be laborious and time-consuming, compared to quantitative data analysis because most qualitative data are in the form of written words and therefore the process of data coding and interpreting is necessary (Marshall & Rossman, 1999; Petty, Thomson, & Stew, 2012). Marshall and Rossman (1999) illustrated that typical qualitative data analyses were comprised of six procedures: "(a) organizing the data; (b) generating categories, themes, and patterns; (c) coding the data; (d) testing the emergent understandings; (e) searching for alternative explanations; and (f) writing the report". Dey (1993) stressed that qualitative data analysis included transcribing the data, describing, classifying and connecting. Yin (2009) suggested four general strategies to analyse data obtained from case study as follows. The first strategy is to follow theoretical propositions of the study. This strategy is the most preferred one for analysing data. Usually, theoretical propositions can be found from research purpose and questions. The second strategy is "to develop a descriptive framework" to organize the case. The third strategy is to use both quantitative and qualitative data. The final strategy is to examine rival explanations.

This study followed the first strategy to analyse data of the case because the sample size was too low for a statistical analysis. The research question of this study is "how agricultural government policies and measures on climate change have been being implemented effectively at farm production level". To answer propositions and analysis the case, the following procedures were used in this research. Firstly, the impacts of climate change and farmers' concern were defined using data from interviewing, field observation, and document analysis. Then, farmers' adaptation responses to climate change were identified using data obtained from in-depth interviews with farmers. Next, the relationship between impacts of climate change and farmers' adaptation responses was investigated. Finally, the effectiveness of government policies and measures were identified from the farmer perspective by investigating how much knowledge of government policies farmers have, how government policies and measures affected farmers' responses to climate change, and what additional supports will be required for farmers to meet climate change. Then, improvement options for government policies were recommended.

In this research, data obtained from interviews and observations were documented and classified into four categories: general information about case study site, impacts of climate change, adaptation response, and effectiveness of government policies. The key issues or meaningful message were elicited from each categories and the connection or relationship among them were identified. After all findings were reorganized and alternative explanations for findings sought, the final conclusion was obtained.

4.7. Ethical consideration

To assess the ethical issues of this project, Firstly the Code of Ethical Conduct for Research, Teaching and Evaluations Involving Human Participants was studied carefully. After that the ethical issues of this research were analysed with reference to the codes and the ethical analysis of this project was discussed with supervisor and colleagues. As no harmful ethical issue to the participants was identified for this research, low-risk ethics approval was applied for and granted from the Massey University Human Ethics Committee. The copy of approval is attached in Appendix 4.

Before the interview, the participants were clearly explained the background to this research, such as the purpose of this research, what is expected of the participants and potential risks and benefits. Also, the participants were informed that if they want to they can withdraw the interview at any time (Mack et al., 2005). Privacy and confidentiality of the participants are important and must be protected thoroughly. Thus, the participants were informed that the confidentiality of information collected during interviews and research must be respected (Massey University, 2010). Finally, oral consent was obtained from each participant before interviews.

4.8. Summary

This research used qualitative research methods and a case study approach to collect and analyses data. Multiple (holistic) case studies were designed for this research and case studies were implemented at six case study sites: a citrus orchard in Gisborne, an apple orchard in Hawke's Bay, four vegetable production farms in Manawatu, and a vineyard in Nelson. This study selected four different regions and crop production systems to compare the difference in impacts and adaptation responses to climate change among those regions and crops. Primary data were mainly obtained from in-depth interviews and field observations were followed to supplement to interviewing. Interviewing was semi-structured. A research question guide and an open-ended questionnaire were prepared carefully for semi-structured interviews. All interviews were recorded using audio recorder with the participant's consent and field notes were taken to supplement audio recording. Before each interview, the participants were informed of background information about this research, potential risk and benefit and oral consent was obtained from the participants. Field notes were used to record field observations. After interviews and field observations, audio recordings and field notes were transcribed and documented as soon as possible. Data obtained from interviews and observations were organized and classified into four categories: general information about case study site, impacts of climate change, adaptation response, and effectiveness of government policies. Data obtained from each case study were analysed on a basis of theoretical propositions. The impacts and adaptation responses to climate change in each case were defined and the effectiveness of NZ government activities was identified from each farmer's perspective. Final conclusions and improvement options were drawn from the findings.

CHAPTER FIVE: CASE STUDIES

5.1. Introduction

This chapter presents the findings attained from the case studies, including the impacts of climate change, farmer's concerns and adaptation responses to climate change, the effect of government policy and farmer's perception. In order to collect data, this research selected six case study sites: a citrus orchard in Gisborne, an apple orchard in Hawke's Bay, four vegetable production farms in Manawatu, and a vineyard in Nelson. Figure 16 shows geographical locations of those case study sites.

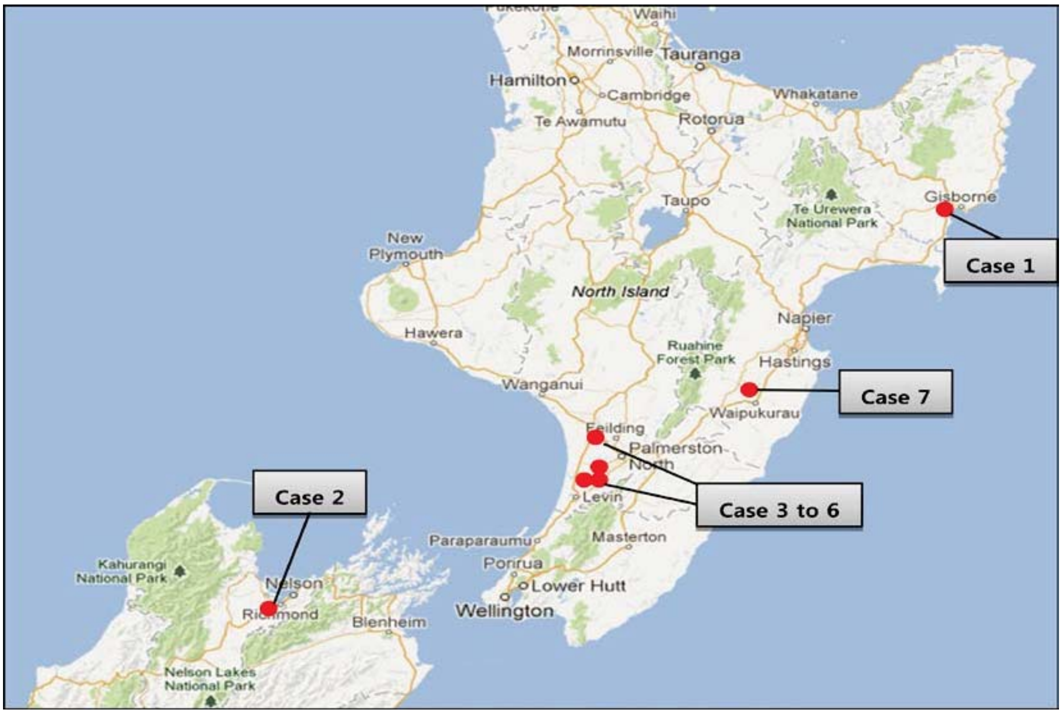

Figure 16 Geographical locations of 7 case study sites in New Zealand

Primary data were mainly obtained from interviews and field observation. To supplement primary data, the researcher referred to various documents, such as local council's annual plans and reports, NIWA reports, and local council's web documents. This chapter presents the results of interviewing, field observation, and document analysis on a case by case basis. Also, information on climate and local government activities for climate change is added to encourage a better understanding of local climate change and adaptation responses.

5.2. Case Study 1: a citrus orchard in Gisborne

5.2.1. Gisborne

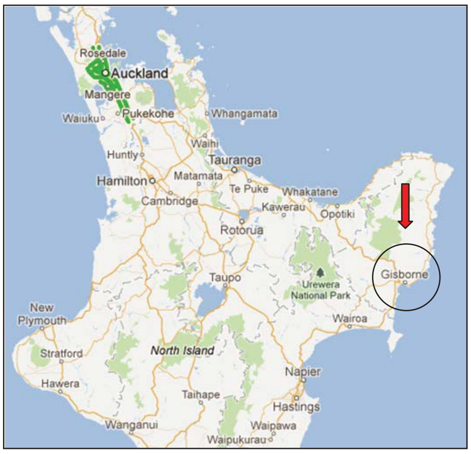

Figure 17 Map of Gisborne district (Google, 2012)

Gisborne District is located in the north-eastern North Island with 8,355 square kilometres of land (see Figure 17). The population of Gisborne was 44,499 in 2006 and 94 per cent of the population lives in Gisborne city (Gisborne District Council, 2010). Gisborne has several rivers; Taruheru River, Waimata River, Turanganui River, Waipaoa River and Te Arai River. Agriculture is the most important industry in Gisborne followed by forestry, horticulture and food processing, and viticulture are attracting growing attention. Gisborne is one of the main grape growing areas in NZ and the wine industry make a great contribution to the Gisborne economy. There are 17 wineries with 1,724 hectares of land (Gisborne District Council, 2010, 2011).

Climate

Gisborne has a dry and sunny climate due to high hills of the west. The duration of sunshine is about 2200 hours annually. Mean air temperatures range from about 10°C to 20°C. The average of the day temperature is around 23°C in summer and 12°C in winter. Summer is warm and Maximum air temperatures in summer vary from 20°C to 28°C but mean temperatures reach above 24°C for over 65 days. Extreme maximum air temperatures have been reached a record high of 38°C in 1979 (Ministry for the Environment, 2008b). Average rainfall ranges between 1000mm and 2500mm and can vary widely from near the coast to high country. In the Manutuke area where the case study orchard is located, monthly mean temperatures range between about 10°C and 20°C. Also, Manutuke’s monthly rainfall varies from about 40mm to 115 mm. Manutuke’s annual rainfall ranges from 600mm to 1400mm. Gisborne’s sunny and mild climate is quite suitable to grow many horticultural crops, such as citrus fruit, kiwifruit and grapes (Gisborne District Council, 2010).

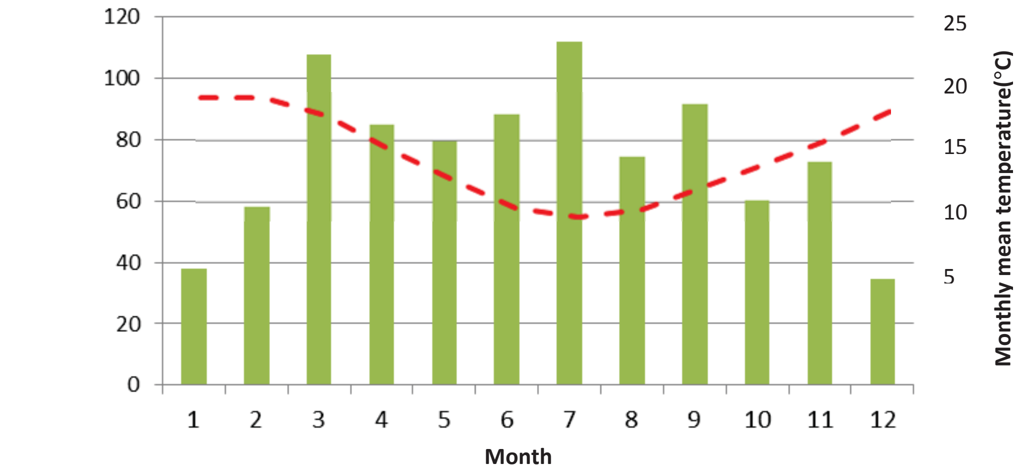

Figure 18 Monthly average rainfalls and mean temperature from observation at the Gisborne Manutuke weather station in the last 30 years (NIWA, 2012b).

Gisborne's recent climate patterns

It is difficult to conclude that Gisborne's climate is changing. Also it is more difficult to accurately predict Gisborne's future climate. This is because many co- and anti-factors are related to climate change and some fluctuation always exist. However, in spite of their limits, some indicators and climate change scenarios show that Gisborne's climate has been changing and will change in the future.

First of all, Gisborne's climate seems to be getting warmer. Annual mean air temperatures have increased slightly during the last 50 years (see Figure 19). In the Manutuke area, annual mean air temperatures has also changed with a slight increase in the last 50 years (Figure 20).

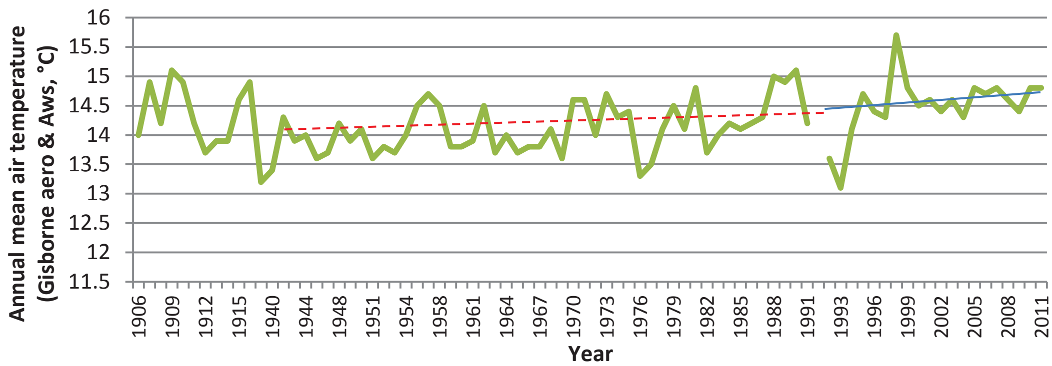

Figure 19 Mean air temperature from observation at the Gisborne Aws from 1937 to 1991 and Gisborne Aws from 1992 to 2011 (The National Institute of Water and Atmospheric Research (NIWA, 2012b).

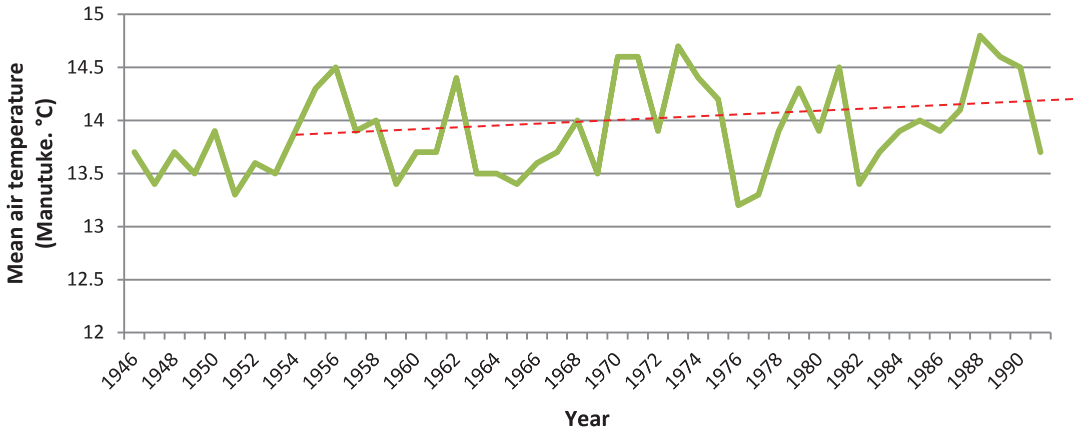

Figure 20 Mean air temperature from observation at the Gisborne Manutuke weather station from 1946 to 1991(NIWA, 2012b)

Climate scenarios by the National Institute of Water and Atmospheric Research (NIWA) also expect that Gisborne's mean air temperatures will increase gradually. Table 38 shows predicted changes in annual mean air temperatures of Gisborne calculated by NIWA's climate scenarios. Annual mean air temperatures are predicted to increase by 2.1℃ between 1990 and 2090 with a greater increase in summer and autumn (Ministry for the Environment, 2008e).

Table 38 Predicted changes (°C) in annual mean air temperature of the Gisborne region by NIWA (The first number is a mid-range estimate) (Ministry for the Environment, 2008b)

	Summer	Autumn	Winter	Spring	Annual
1990-2040	1.0 (+0.2 to +2.6)	1.0 (+0.3 to +2.7)	0.9 (+1.1 to +2.2)	0.8 (+0.0 to +2.1)	0.9 (+0.2 to +2.4)
1990-2090	2.2 (+0.8 to +6.2)	2.2 (+0.6 to +5.6)	2.0 (+0.5 to +5.2)	1.9 (+0.3 to +5.2)	2.1 (+0.6 to +5.5)

The Gisborne regions rainfall shows topographical variations from the coast to the high country. Therefore, it is difficult to predict changes in rainfalls for Gisborne. However, several studies showed that Gisborne is expected to become drier. For example, Manutuke's annual rainfall has decreased slightly between 1945 and 1991 (Figure 21). Annual rainfall from observation at the Gisborne aero weather station showed a similar decreasing trend (Figure 22). NIWA's climate scenarios predicted that Gisborne would be getting drier (Ministry for the Environment, 2008e). Table 39 illustrates changes in rainfalls for Gisborne. In particular, in winter and spring seasons, rainfall is expected to decrease significantly by 13 to 16 % by 2090 due to stronger westerly winds. On the other hand, in summer and autumn seasons westerly winds are predicted to be reduced and as a result, rainfalls are expected to increase.

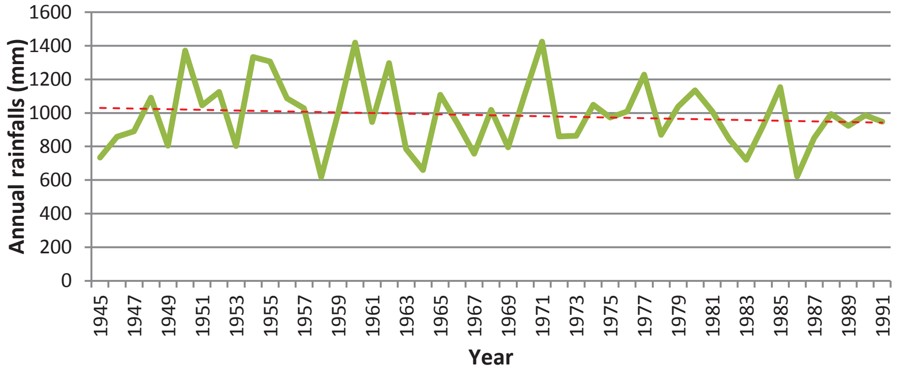

Figure 21 Annual rainfall from observation at the Gisborne Manutuke weather station between 1945 and 1991 (NIWA, 2012b)

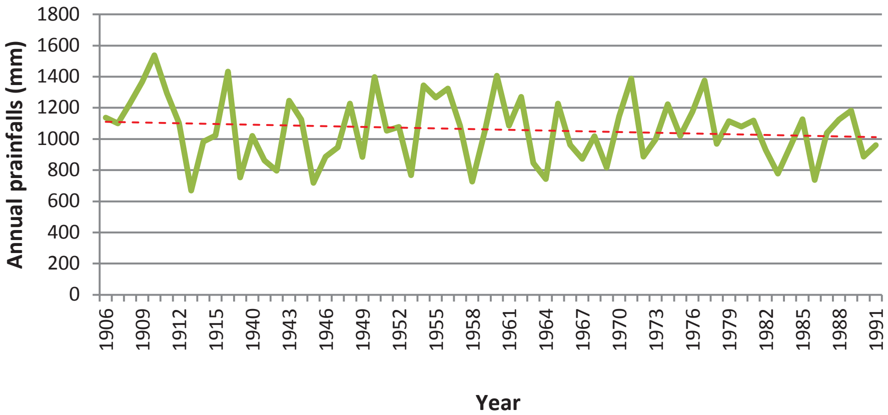

Figure 22 Annual rainfall from observation at the Gisborne Aws between 1906 and 1991 (NIWA, 2012b)

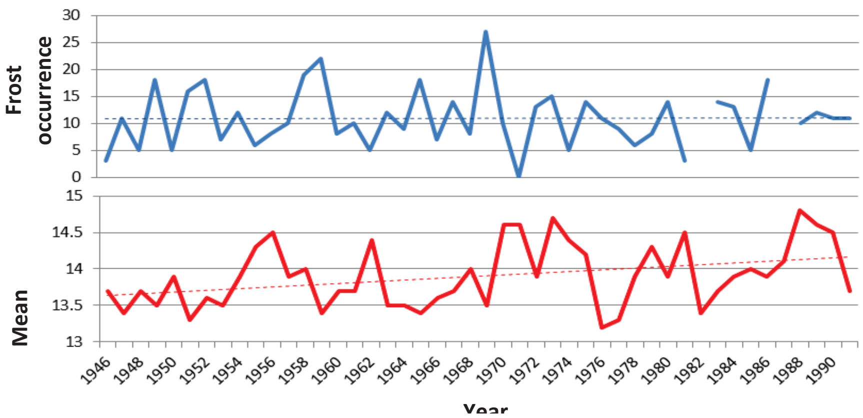

Figure 23 Changes in annual mean air temperatures and frost occurrence from observation at the Gisborne Manutuke weather station from 1946 to 1992 (NIWA, 2012b).

Table 39 Predicted changes (in %) in annual rainfalls for Gisborne calculated by NIWA climate scenarios (The first number is a mid-range estimate) (Ministry for the Environment, 2008b)

	Summer	Autumn	Winter	Spring	Annual
1990-2040	3 (-26 to 33)	4 (-18 to 46)	-11 (-30 to -2)	-9 (-21 to 3)	-4 (-15 to 14)
1990-2090	5 (-38 to 41)	4 (-25 to 27)	-13 (-41 to 1)	-16 (-42 to 7)	-5 (-22 to 8)

Climate extremes may occur more frequently and unexpectedly in the Gisborne District. More severe droughts may happen due to an increase of mean temperature and a decrease of rainfalls. Heavy rainfall events for Gisborne District are predicted to occur more frequently even though rainfall may decrease (Savage, 2009). In addition, variations in micro-climate due to topography may be advantageous but also may add to farmers' difficulties. For example, in 2005 a Gisborne farmer experienced a severe drought without rainfalls for seven months and then a heavy rainfall of 400mm occurred suddenly in a couple of days. However, many other farmers in Gisborne did not experience such climate extremes due to differences of micro-climate. With regard to wind patterns, an increase of westerly winds is expected by 60% in the next 70 years (Ministry for the Environment, 2008e; Savage, 2009). Also, more severe wind events are predicted. Tropical cyclones may affect less frequently but mid-latitude storms are expected to increase (Savage, 2006).

The increase of mean air temperatures is expected to affect crop production in Gisborne. For example, as temperatures are rising, frost days are predicted to decrease (Figure 23). Also, growing seasons are likely to change with warmer winters and earlier springs. However, warmer winters may cause a lack of winter chilling hours and then result in the decrease of the quantity and quality of fruit. Pest, disease and weeds are expected to increase due to warmer conditions and in the future, new types of tropical pest insects may spread across the country (Savage, 2006).

5.2.2. Gisborne District Council's activities for climate change

According to NIWA's climate scenarios, Gisborne is expected to become warmer and slightly drier (Ministry for the Environment, 2008b, 2008e). More climate extremes, such as heavy rainfall events, floods and droughts are likely to increase and the coastal areas will be affected by sea water inundation and storms more frequently and unexpectedly. When Gisborne District Council introduced the 2009-2019 Ten Year Plan, they included climate change in the major issues which the Gisborne district would face in the next 10 years. Now the council is doing various activities related to climate change, including pest management, protection of soils and biodiversity, monitoring of water resources, flood protection, preparing for storm water, and ensuring sufficient high quality water supply (Table 40). In fact, those activities were implemented before climate change was identified as a policy focus and are not new activities to meet climate change. However, most of them can improve the regions capability for addressing climate change. Currently water shortage has been not identified in the Gisborne District. Therefore, most Council activities in terms of water supply focus on monitoring of water resources and ensuring high quality water supply. However, Strongman (2011) indicated that demand may be issued in the future and therefore, adequate measures have to be undertaken to meet growing water demand in Gisborne District.

Table 40 Current activities of Gisborne District Council to meet climate change (Gisborne District Council, 2012)

Area	Main activities
Conservation	• Implementation of Pest Management Strategy, including monitoring. • Encouragement of sustainable land management, soil protection, and biodiversity. • Monitoring of water resources, including ground, surface and coastal waters. • Education and monitoring
Flood control	• Construction of river training works on the Waiapu River and repairing of land drainage and river banks to meet floods under the flood control schemes • Coastal erosion protection
Storm water	• Enhancement of the storm water net-works • Upgrading the storm water system and renewing storm water networks • Education and provision of information
Water supply	• Renewing of water supply network to provide sufficient high quality water

5.2.3. Case Study 1

5.2.3.1. Basic information

a. Size and type

The Farnham orchard was located in the Taruheru valley, Manutuke in Gisborne. The orchard is 89 ha in area with mandarin production (9 ha), forests (25 ha), and beef animals (about 200 cattle). The owner has run the orchard since 1989.

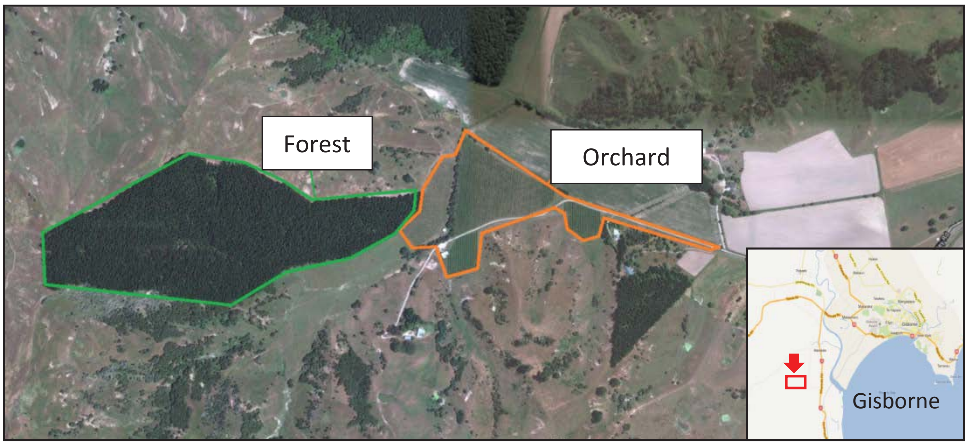

Figure 24 Satellite image of the study area in Gisborne (Google, 2012)

b. Crop production

Two varieties of mandarins, Miho[6] and Kawano[7] are grown on the orchard. First 6000 trees of mandarins were planted in 1997 and the rest of them were planted in 2005. Annually the orchard produces about 200 tonnes of mandarins. Annual production per unit was around 25 tonnes per ha.

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[6] A high sweet tasting and easy peel mandarin which is one of early-maturing and cold-tolerant cultivars of satsuma mandarin came from Japan originally (Stein & Parsons, 2001)

[7] A mid-sized, easy peel, and early to mid-season satsuma mandarin with high flavour

Figure 25 Mandarin trees in the case study orchard

c. Soil type and topology

The orchard is on two different types of soils. The one in lower part of the orchard was an amended silt loam which came from ancient flooding and ancient sea bottom. The other in upper part of the orchard was a heavier clay loam. There is no significant difference in production between two types of soils. There were some management issues like working in the winter time due to mud but they were not insurmountable issues.

d. Water availability

Water has never been an issue in this orchard. The main water source is rainfall. Natural rainfall is not a problem and it is not necessary to irrigate the orchard. Rainfall is enough to grow mandarins. However, historically every five to seven years there have been drought seasons in Gisborne. For example, 1993 and 1999 were very dry years. In the case of dry seasons coming, it would be necessary to build dams and big storages to irrigate land. However, severe droughts have never been experienced in this orchard.

e. Orchard management

A contractor was employed for picking, thinning and pruning operations. He usually brought in ten to twelve people for picking every day. However, the number of day labourers depended on market demand. The orchard has supplied fruit to a company called Kaiaponi which has a packing house. How many labourers were employed for the orchard depended on how much fruit the company wanted to supply the market each day. The orchard had a warehouse and basic facilities such as chemical storage room. Equipment included 3 tractors, 4 loading trucks, sprayers, mowers and tanks. The orchard was surrounded by high hills and therefore wind problem has not been an issue even though there was no windbreak around the orchard.

Figure 26 Orchard facilities and machinery.

The owner managed the orchard and he had a marketing manager who decided the timing and volume of supplying mandarins. The marketing manager worked out how to manage fruits to supply the market demand. There are two big areas where mandarins were grown up in New Zealand. One is in North Auckland and the other is Gisborne. In North Auckland, the growers harvest mandarins from April to mid-Jun. However, in Gisborne, harvest starts at late-June and finishes by August. If North Auckland growers have a big production year, Gisborne growers are careful to avoid the oversupply. If necessary, they have to adjust their harvest so that their supply does not overlap with North Auckland growers' supply otherwise prices could be going down. The orchard uses Gibberellic acid if the fruit needs to slow down maturity. Oil products were also utilized to slow fruits down and to manage pests in the trees. Controlling the rate of fruit maturation is a very important management factor. Thinning was used when specific sized fruits were required. For example, the grower did not thin for smaller fruits but did heavier thinning for bigger fruits.

f. Packing

After being harvested in the orchard, mandarins were transported to a packing house which was located near the orchard. All mandarins from the orchard were automatically washed and graded according to size and then packed. The manager of the packing house decided the quantity of mandarins which were packed daily in the packing house according to the demand of market, in particular Auckland market.

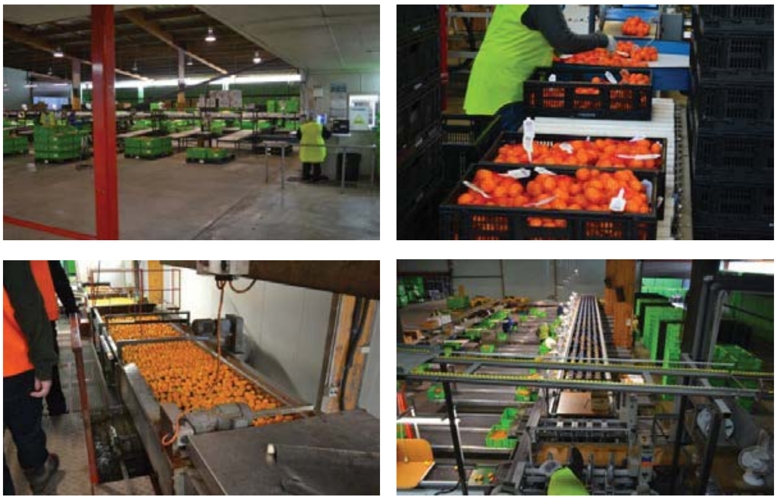

Figure 27 Packing works, such as washing, grading, and packing, which are conducted in the packing house located in Gisborne

5.2.3.2. Impact of Climate change

a. Temperature

The owner was unsure about climate change. The owner thought that if global warming causes more cyclones, Gisborne district might have more cooling effects. He stated:

> *"I don't know climate change. If one thing would be suggested to me, it is the frost. I remember heavy frost as young man 20 years ago, man every morning we got frost first in May. But I have never seen that in the last 15 years. That would be the only thing which convinces me at present that may be a bit of change going on. That's slight longer term. Otherwise, El Nino and La Nina, I don't know"*

The owner thought that global warming could cause cooling effects but not freezing and the climate was expected to be more unstable.

b. Rainfall

The owner noticed that more frequent tropical cyclones have been occurring and cloudy days and rainfall have been increasing. The case study orchard owner stated:

"Last summer [2010]*, a lot of tropical cyclones occurred and cloudy days followed in Gisborne. That caused lack of heat and affected fruit colouring. As a result, many orchards produced light fruits. In this year, the situation is similar but this orchard is one of the exceptions. This is because whole hillsides of the orchard facing north provide shelter from cold. As a result, fruits could get enough heat and colour up."*

"We don't have stable climate anywhere. We have unstable climate in the world. We get a dry winter, this winter is quite good so far even we are working in the orchard there are not so much mud. Sometimes wet season was horrible."

"It is getting wetter with lots of rain. Also, heavy rain events have been occurred more frequently. However, winter seems to be getting drier. In particular, this winter is good with less rainfall so that there were not so much mud and people could work in the orchard. Microclimate seems to be variable. Even within Gisborne district, there was rain in Gisborne city but not in this orchard."

c. Climate extremes

Droughts: There have been drought events in Gisborne every 5-7 years. In 1983 and 1989, there were droughts. Also, in 1993 and 1997, the summer seasons were quite dry.

Floods: There was a heavy rain event in April 2002. At that time, the rainfall during a couple of days was 600mm. In August 2002, a heavy rain event also occurred and rain of 400 mm was recorded over one night. There was no flooding damage to the orchard because the orchard was 2 km away from the river and located on higher hillsides. However, other orchards, which were located near the river had severe flooding damage.

Figure 28 Climate extremes in Gisborne – A flood in the Manutuke area in 2002

Wind: The Wind problem has not been evident because the orchard was surrounded by high hills. As a result, there was no wind break and shelter belts. No shelter belt is better to protect the orchard from disease and pests. However, as climate change is going on, in winter and spring seasons, more gusty north-westerly winds, which would cause drier conditions in Gisborne, are expected.

Hail: There has been no serious hail event in Gisborne district because mountains and ranges prevent storms causing hail to come up to Gisborne.

Frost: The main feature of climate change in Gisborne would be frost. Actually, the owner had no confidence that climate change was real. However, he remembered when he was young, more than 20 years ago he got frost in May or Jun every morning. However, he has not seen that so much now. He used frost protection by helicopter just twice during last 15 years. According to the owner, In Gisborne, heavy frost occurred when a big high met a low which brought cold weather up from the Antarctic. A clash of high and low pressure systems leaves snow on the mountains and then suddenly very cold weather comes with a clear sky and no wind. That condition creates big ground frost. However, recently those big frost events have been reduced significantly. The owner stated:

> *"Climate change tricky one, I don't know. All I can say I can remember when I was a boy younger man, we had big frost in May Jun, but we don't get them so much now. We use frost protection twice last 12-15 years by helicopter, that's all."*

d. Pests, disease and weeds

Citrus Borer (*Citripestis sagittiferella*)**:** After picking and harvesting finish at the beginning of August, pruning has to be started as soon as possible. This is because after August, as temperatures warm up, borers begin to fly. They then attack the trees making a lot of holes on the trees. They are usually attracted by smell of new cuts from pruning. Therefore, pruning must be finished at least two weeks before borers flying. Actually, borers can be found many trees, such as pine trees. Therefore, if pruning is not finished on time, the orchard will gain trouble. However, as mean temperature is rising due to global warming and climate change, the earlier outbreak of borers may become a serious threat to the orchardists.

Australian Citrus Whitefly (ACW): ACW has been a serious issue at the orchard. The orchard was attacked a couple of times by ACW during last two years. In 2000, ACW was first found in New Zealand and now it has been detected in all of the main mandarin growing areas including Gisborne. ACW cause sooty mould problem of fruits and leaves in citrus and make fruits black. As a result, the quality of fruits is decreased (Jamieson, Page-Weir, Chhagan, & Curtis, 2010). The owner was not sure whether climate change leads to the outbreak of ACW or not. He thought that ACW problem could be one of the border control issues. However, considering ACW can overwinter in New Zealand and has already spread all the main mandarin growing areas, it seems likely that ACW is not a border control issue but climate change and warmer condition may influence the outbreak of ACW in New Zealand.

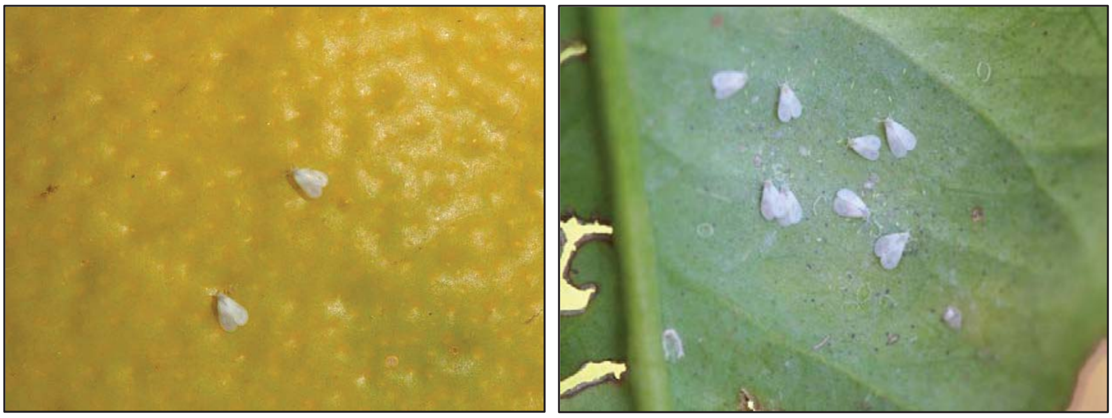

Figure 29 Australian Citrus Whitefly (Ingram, 2012)

5.2.3.3. Adaptation responses

a. High temperature

High temperature has never been an issue in mandarin production in Gisborne.

b. Droughts

If drought events occur, it should be necessary to build dams and big storages to irrigate land. However, recently severe droughts have never been issued in the orchard.

c. Floods

The orchard was located on high hillsides and therefore flooding has never been an issue. However, erosion and landslide on hillsides were a potential threat to the orchard. The geography of hillsides where the orchard is located is so young that landslides can occur easily with heavy rains. In order to prevent erosion and landslide, the owner has planted pine trees since 1989. However, flood can be a serious threat to other orchards which are located near the river. In Gisborne, the Waipaoa River carries considerable mud sediment due to a very young geography of soft hillside. If big floods occur, mud water could spill over orchard lands. After big floods have gone through, all the sediments this river carries would be deposited on orchard land and trees could get buried. In fact, orchards near the river are on high productive land. Therefore, the local government, Gisborne District Council (GDC) is studying and working on the required level of flood protection by stop bank with the growers.

d. Frost

As frequency of frost events was reduced, recently frost has not been a serious problem of the orchard. However, if a weather forecast predicts frost and frost protection is required, frost helicopters can be used for spraying.

e. Pest control

Citrus borer (*Oemona hirta*): In order to prevent an attack of citrus borers, pruning has to be finished as soon as possible. The orchard employed two people for pruning trees and painting chemicals which prevent the attack of borer.

Australian citrus whitefly (*Orchamoplatus citri*): In order to prevent an attack of Australian citrus whitefly (ACW), the mandarin growers use several insecticides, such as pymetrozine, diazinon, spirotetramat, buprofezin, and mineral oil (Jamieson, Page-

Weir, & Pyle, 2011). However, at the case study orchard the grower didn't need to spray too much. This is because the orchard was located in the remote area surrounded by high hillsides. As a result, the outbreaks of pests were lower than other orchards. Also, the owner tried to use not strong chemicals but eco-friendly and soft chemicals, such as mineral oil.

5.2.3.4. Government policy

a. Central government

The owner was not familiar with central government policy on climate change. He had no idea on developing and transferring technologies on climate change by research institutes and therefore has never used them. Also, he was unsure about any government fund or support to help farmers address climate change. The only one that he recognized was the Emission Trading Schemes (ETS). He knew the ETS very well and was concerned about the impacts of the ETS. He has been raising about 200 cattle and therefore, he worried about additional cost due to agricultural emissions by cattle. However, he had 25 ha of pine trees. He thought that he got a balance between emissions of cattle and absorption of pine trees. He had a negative perception of the ETS. He thought that the ETS was not effective to reduce greenhouse gas (GHG) emissions but added additional cost to agricultural sectors. The owner stated:

> *"They are not actually stopping emissions. If policy of trading were effective, it could promote planting more trees in NZ. I still I don't know whether global warming is real which, assuming I thought it's real, if trading emission schemes was generally slowing pollution down then I feel probably more comfortable with it but I don't believe it is."*

> *"You know India, China, and America. They are not starting now they are not even buying into it. A farmer is trying to struggle to make a living. I'm getting taxes for my cattle you know. American farmers tell me before we were farming cows and lambs for last millions years there were a million bison. Nothing was changed. When there were grasses generally grasses in the world that herbivores eat. There has always been herbivore ate that grass. You know what I mean even*

dinosaurs there has been some form of herbivore. When European first came into America farmers could see big bison. That all changed as they shot them and replaced them with beef. Africa was same. Chimney factories, all that production, and burning of the coal are the problem. Agriculture pay all tax but chimney, other guys pay no tax. I think I do seriously believe that's an issue on this level; stop production rather than coming up some sort of scheme. Planting is nothing changed."

He didn't understand why NZ farmers should take a responsibility to reduce GHG emissions even though the chimney industries, the main causes of GHG emissions, didn't take any actions for mitigation of GHG emissions. Also, he thought that Kyoto protocol was wrong because it was manipulated by the big powerful countries, such as USA and China for their sake. Actually, the owner expressed that he had no need of governmental supports to address climate change. He stated:

"Kyoto. My personal belief, Kyoto got it wrong. They established levels of emissions from a certain date. Have a think about it. We were in recession at that time big countries were buoyant for years. They have high production. Agricultural countries in the world were at the low. And then so we have to come from low base. There was recession after that. They had credits to pay. I think that Kyoto was just manipulation of big powerful people just who had no interest in climate change. We just looking after own back pocket. And you get a time and time again you go to Rio just last two weeks same again. Really be serious about human population causing climate change. Huge, millions of people want to have cars. Anybody want to pay the price to fix it. That's the problem."

b. Local government (Gisborne District Council)

The owner used the support of local government, Gisborne District Council (GDC) when he planted 25 ha of pine trees. When planting trees, he received 95% of subsidy from local government. Local government had "3A overlay" scheme to cover trees on steep hill sides in Gisborne for protecting hillsides from erosion and landslides and funded farmers to plant trees on hillsides. In addition, according to "flood control scheme", Gisborne District Council has been doing studies and works on the required level of flood protection for stopbanks. The owner has also participated in consultation groups to discuss the level of flood protection required. Farmers who utilized support or the services of Gisborne District Council have paid taxes to GDC. For example, the owner has made annual payment to GDC for river control and storm water drainage. However, he didn't pay for flood control because his orchard was far from the river and therefore does not need flood control.

5.2.3.5. Local community and industry

a. Local community activity

There were not much local community activities on climate change. The only one that farmers had was a community consultation group with regard to the level of flood protection required. They were going through whole consultation process with all the growers living in flood areas to see what level is comfortable.

b. Industry

The citrus industry has not been doing anything as yet to support the growers' adaptation response to climate change. However, the citrus industry has conducted research on different chemicals, in particular new chemicals approved for application. And this could be associated with the issues of new pressure on plant health. The growers kept watching what new pests could arrive and they tried to have chemicals already when new pests arrive in order to pre-empt their arrival or protect their trees. The owner thought that research on new chemicals could be helpful for the growers to address the attack of new pests even though he was not sure whether new pests came from climate change or border control. He considered there is no need for support from the industry to address climate change.

5.3. Case Study 2: a vineyard in Nelson

5.3.1. Nelson and Tasman

Figure 30 Map of Tasman District (Tasman District Council, 2012b).

Nelson and the Tasman District is located in the northern area of the South Island and covers 9,786 square kilometres of land (Nelson City Council, 2012). From the west to the east, Nelson and the Tasman District is surrounded by the high mountains and ranges, such as the Matiri Ranges, the Tasman Mountains, the Spencer Mountains, the St Arnaud and Richmond Ranges, and the Victoria Ranges. However, its northern areas face the sea. There are several rivers in Nelson and the Tasman District such as the Buller, Takaka and Aorere Rivers. According to the 2007 Census, population of Nelson and the Tasman District was 42,891 and 44,625. Respectively 26 per cent of the population of the Tasman District lives in the urban areas around Richmond. The key industries of the Tasman District are agriculture, horticulture, aquaculture, forestry and tourism (Nelson City Council, 2012; Tasman District Council, 2012c).

Nelson’s climate

The Nelson and the Tasman region are less affected by both the strong westerly and easterly winds because of high ranges and mountains surrounding those regions. As a result, Nelson and the Tasman District have a sunny and mild climate with less winds relative to other regions in New Zealand. Nelson is one of the sunniest cities in New Zealand. In Nelson, the average annual precipitation and sunshine duration are 1,043 mm and 2,449 hours (Nelson City Council, 2012). Mean air temperatures in Nelson around 13.5 °C. Summer is warm and average temperature in summer vary from 12°C to 22°C and in Winter from 14°C to 4°C (Table 41).

Table 41 Average maximum and minimum temperature in Nelson region (Nelson City Council, 2012)

Average Temperature	Spring	Summer	Autumn	Winter
Maximum (°C)	19	22	16	14
Minimum (°C)	9	12	6	4

Climate change in the Nelson and Tasman region

The Nelson-Tasman region is expected to be warmer than compared to 1990 due to global warming and climate change. Figure 31 shows the homogenised annual temperature time series for Appleby using data from a climate station in the Nelson-Tasman region. In spite of year to year variation in annual temperature, there is a long-term upward trend in annual temperature of the Nelson-Tasman region. According to Figure 31, from 1908 to 2006, Tasman's temperature has increase by 0.58°C to 0.88°C (Wratt et al., 2008).

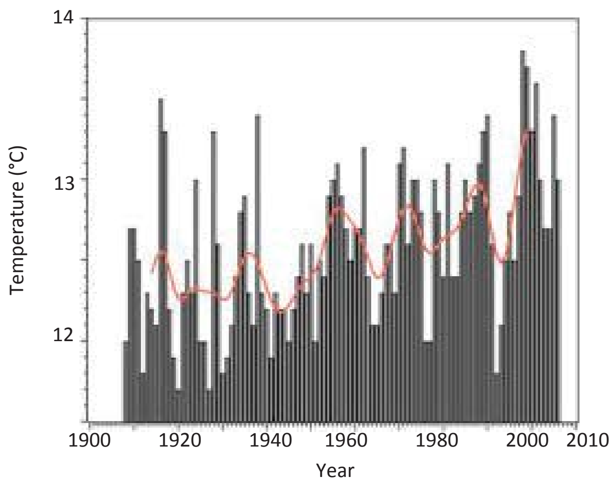

Figure 31 Homogenised annual temperature time series of the Nelson-Tasman region for Appleby (Wratt, Mullan, Ramsay, & Baldi, 2008)

Table 42 shows predicted changes in annual temperature of the Nelson-Tasman region projected by NIWA's climate scenarios. The temperature is predicted to increase by 0.9°C by 2040 and by 2.0°C by 2090 with a greater increase in summer and autumn seasons (Ministry for the Environment, 2008e). As a result, NIWA expects that hot days with temperatures of over 25°C would increase by 20 days per year. On the other hand, frost events are expected to decrease by 10 to 20 frost days annually (Ministry for the Environment, 2008d; Wratt et al., 2008).

Table 42 Predicted changes (°C) in annual mean air temperature of Nelson and Tasman region by NIWA (The first number is a mid-range estimate) (Ministry for the Environment, 2008b)

	Summer	Autumn	Winter	Spring	Annual
1990-2040	1.0 (+0.2 to +2.2)	1.0 (+0.2 to +2.3)	0.9 (+0.2 to +2.0)	0.7 (+0.1 to +1.8)	0.9 (+0.2 to +2.0)
1990-2090	2.2 (+0.9 to +5.6)	2.1 (+0.6 to +5.1)	2.0 (+0.5 to +4.9)	1.7 (+0.3 to +4.6)	2.0 (+0.6 to +5.0)

Rainfall in the Nelson-Tasman region varies with geographical locations from the coast to the high country. However, Figure 32 shows that annual rainfall in Nelson has increased slightly between 1967 and 2010. According to NIWA's projection, average rainfall in the Nelson-Tasman region is expected to increase by 4 per cent by 2090 (Table 43). In particular, in summer, autumn, and winter seasons the Nelson-Tasman region will experience an increase of 5 to 6 per cent in rainfall by 2090 but in spring season rainfall is likely to decrease slightly (Ministry for the Environment, 2008d).

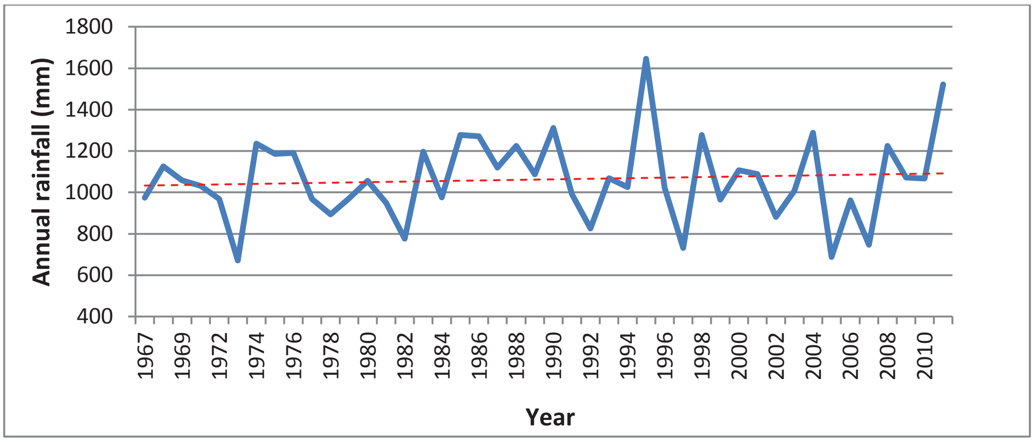

Figure 32 Changes in annual rainfall from observation at Brightwater 2 (Nelson) weather station - 1967 to 2011

Table 43 Predicted changes (in %) in annual rainfalls of Nelson and Tasman region calculated by NIWA climate scenarios (The first number is a mid-range estimate) (Ministry for the Environment, 2008b)

	Summer	Autumn	Winter	Spring	Annual
1990-2040	4 (-14 to 27)	5 (-2 to 19)	1 (-4 to 9)	0 (-8 to 9)	2 (-3 to 9)
1990-2090	6 (-13 to 30)	5 (-4 to 18)	6 (-2 to 19)	-1 (-20 to 19)	4 (-3 to 14)

More climate extremes, such as floods, droughts, and strong winds are expected in the near future. Even though annual rainfall is expected to increase, the Nelson-Tasman region will experience more severe droughts due to warmer temperature. On the other hand, extreme heavy rain and floods are also predicted to increase. As a result, soil erosion will be a significant problem. In addition, lack of water availability will be a constraint to growing horticultural crops in the Nelson-Tasman region due to warmer temperatures and increasing water evaporation. By 2090, the strongest winds are likely to increase slightly.

Climate change in the Nelson-Tasman region will affect the agricultural sector including several horticultural industries, such as wine-grapes and kiwifruit industries. For example, the Nelson-Tasman region will be a more suitable place to grow kiwifruit and grapes with increasing temperatures while kiwifruit production in Bay of Plenty is expected to decrease due to warmer winters and lack of chilling hours. However, an increase of the growing areas for kiwifruit and grapes will be determined by water availability and water supply will become a more serious issue of horticultural production. On the other hand, there is concern that warmer temperatures will cause an increase of pests and disease. For instance, outbreaks of *botrytis*, which is a wine grape disease is expected to increase under warmer conditions. Also, the summer-fruit industry will be affected by fungal disease more frequently under warmer and humid conditions in spring seasons (Ministry for the Environment, 2008d; Ministry of Agriculture and Forestry, 2010d).

5.3.2. Tasman District Council's activities for climate change

Climate change is expected to influence the Nelson and Tasman region with a predicted increase of about 2.0°C in average temperature by 2090. Therefore, appropriate responses are required to meet climate change. Table 44 shows responses the Tasman District Council is already doing to address climate change. The main impacts of climate change are water shortage, sea water inundation, floods, and bio-security. To meet growing water demand of rural and urban communities, Council has been expanding water storage, including dams, such as the Wai iti dam. Also, Council has encouraged efficient water use in order to decrease water use per householder or farms. To deal with sea water inundation, Council has been doing various measures, such as reviewing engineering standards and providing information on low-lying areas. In addition, Council is trying to enhance infrastructure to meet storm-water and sea water intrusion. Furthermore, as the Nelson and Tasman region is one of the major horticultural areas in New Zealand, bio-security would be a significant issue in this region. Council has periodically reviewed the bio-security strategy to deal with bio-security issues (Jackson, 2007). More additional responses should be required to address climate change in the Nelson and Tasman region. For example, current water allocation should be reviewed to prepare future increasing demand of water. Also, Council should consider more options to increase water supply, including the dams. In addition, to address storm water, a need for pumping facilities for storm water has been identified (Jackson, 2007).

Table 44 Current Tasman District Council's activities for climate change (Jackson, 2007)

Area	Tasman District Council responses
Water security	• Wai iti dam has been constructed in 2006 in order to increase water supply during dry seasons. • Council is investigating the feasibility of other new dams, including the Lee dam to meet growing demand of water due to warmer weather. • Water rationing scheme
Coastal development	• Engineering standards, such as minimum ground levels and floor levels, were reviewed. • Sea water inundation was taken into account in development of the coastal areas. • Coastal protection works were undertaken to meet sea level rise. • Information on low-lying areas has been provided
Infrastructure	• Council encourages low impact design for storm water management • Replacement of bores to deal with sea water intrusion
Biosecurity	• Biosecurity strategy has been reviewed periodically to check whether addition pest control is required

5.3.3. Case Study 2:

5.3.3.1. Basic information

Size and type

A winery and vineyard studied were located in the Nelson-Tasman region. The winery and vineyards were 26 ha in total. The winery owns three vineyards: River Terrace, Winery block, and Livingston Road. The initial vineyard was owned from 1994 and has expanded.

Figure 33 Satellite image of the study area in Nelson (Google, 2012)

Crop production

The River Terrace vine yard which is 6 hectare was planted from 1997 to 1998 and has produced Sauvignon Blanc, Mendoza Chardonnay, Pinot Gris, and Pinot Noir. The Winery Block vineyard is 10 ha in area and was planted in 1995.

Figure 34 Case study vineyard in Nelson planted Sauvignon Blanc, Pinot Gris, and Muscas

This vineyard has produced Sauvignon Blanc, Chardonnay, Pinot Gris, Pinot Blanc, Muscat and Syrah. The Livingston Road vineyard with 10.5 ha in area was planted in 2007 and has produced Sauvignon Blanc, Pinot Gris, Riesling, Viognier, Pinot Noir, Merlot, Petit Verdot and Syrah. These vineyards collectively produce about 180 tonne of grapes annually and the winery produces around 12,000 cases (Kaimira Ventures Ltd, 2012).

Soil type and topology

The vineyards are located in the flat areas alongside the Wairoa River. The soils in the River Terrace vineyard, which are river alluvium with stones originated from the nearby hills, are free-draining and have low natural fertility. The soils in the Winery block and the Livingston Road vineyards are clay based silt with river stone and gravels, and also free-draining (Kaimira Ventures Ltd, 2012).

Water availability

Water availability for the vineyards is quite good. The vineyards use on average 2 per cent of their allowable allocation. They usually utilize natural rainfall and don't irrigate. This is because vine roots can go down to 3 - 4 metres into the ground. However, in these areas the soils below 3m in depth are always damp and roots can get enough water. As a result, it is not necessary to irrigate the vineyards except in severe drought events.

Orchard management

There were four permanent staff who work for the vineyards and the winery. There is a marketing manager who helps the owners decide on when and how they should sell wines. The winery had an office, a wine factory, 2 storage sheds and a workshop. Also, there were tractors and dedicated equipment, such as mowers and sprayers. The owner determined all plans for the winery management with the manager's advice. The vineyard has been applying an organic programme since 2009.

Figure 35 Winery facilities and machinery.

5.3.3.2. Impact of Climate change

The owner was not sure about climate change. He thought that Nelson's climate might be very slight warming. However, he acknowledged that there was no empirical evidence to support that. With regard to rainfall, he indicated that there was no significant change in rainfall. He explained that variation in rainfall along the years had always existed and he was not sure that variation came from man-made greenhouse gases emissions.

Also, he thought that there was no significant change in occurrence of climate extremes. In 2003, he experienced heavy rainfall and also there was a severe drought event in 2005 and he lost a thousand vines. However, he commented that looking back over last 100 years, the climate extreme events in the last decade appeared about normal. He thought that there was no significant issue in terms of climate change in his vineyards.

5.3.3.3. Adaptation responses

The owner was not undertaking anything for adaptation responses to climate change. This is because he thought that there was no significant climate change in the Nelson-Tasman region. He acknowledged that water availability can be an issue in this region but not a big issue. He commented that:

> *"If all land were made for prudent use of water, I probably wouldn't have a problem for a long way into the future."*

As a business, the vineyard and the winery have been carbon-zero certified since 2006. This means that the vineyard and the winery can manage greenhouse gas emission factors. The carbon-zero certification covered everything from grapes, bottles of wines, and distribution in the overseas market. Recently four wineries in New Zealand have achieved carbon-zero certification. However, there is no significant market advantage of carbon-zero certification. The owner indicated that economically his vineyards and winery could save money with a decrease of production cost. Furthermore, the vineyards were conducting sustainable wine growing programme with no synthetic fertilizers and chemicals. Natural lime and fish-based fertilizers, such as fish oil and fish meat have been used to provide nutrients and suppress the outbreak of pests and disease. In 2009, the vineyards began to conduct the organic transition programme and all vineyards will be organically certified in 2013. In the vineyards, mussel shells were being put on the fields for prohibiting weeds, providing minerals and reflecting sunshine. Also, mussel shells could be beneficial for vines to get more heat.

5.3.3.4. Government policy

The owner felt that he was well informed on government policies and initiatives. However, he indicated that they were largely "all talk" and no substance in terms of climate change. He believed that those government policies and initiatives were only to provide employment for bureaucrats. He knew the Emission Trading Schemes (ETS) very well but had objection to it. He thought that the ETS had a negative impact on his business. With regard to government funds and technology transferring, he has never utilized them and also didn't need them.

With regard to the role of local government, the owner thought that local government supports and policies on climate change were weak and politically driven by lobby groups.

5.3.3.5. Local community and industry

The owner was not sure about local community activities and not involved. He thought that the industry should promote sustainable production including organic farming and the industry's continuing refinement of sustainable wine growing programme could be very helpful.

5.4. Case Studies 3-6: vegetable production in Manawatu

5.4.1. Manawatu-Whanganui region

Figure 36 Map of Manawatu-Whanganui region (Horizons Regional Council, 2012a)

The Manawatu-Whanganui region is located in the south-west North Island. It covers 22,215 square kilometres of land and represents about 8 per cent of NZ's land. The Horizons Region Council consists of seven district and city councils; Horowhenua, Manawatu, Palmerston North, Rangitikei, Ruapehu, Tararua, Whanganui. Also, small parts of Stratford, Taupo, and Waitomo are included in the Horizons region (Horizons Regional Council, 2012a). The west side of the region faces the Tasman Sea while its east side is surrounded by the high mountains and ranges. About 61 per cent of land in the region is located in the hill country and much of it exposed to growing risk of soil erosion. The Horizons region has three big rivers: the Whanganui, Rangitikei, and the Manawatu. Population of the region was about 232,150 and more than half of them live in the cities of Palmerston North and Whanganui (Horizons Regional Council, 2012b). Agriculture is a major industry in the Horizons region (Table 45). The Manawatu-Whanganui region represented about 18 per cent of NZ sheep and 15 per cent of NZ beef cattle in 2011. Also, this region is one of the biggest areas where maize and potatoes are grown. The region accounted for around 15 per cent of total NZ growing area in maize and 11 per cent of total growing area in potatoes (Statistics New Zealand, 2012a).

Table 45 Major agricultural production in the Manawatu-Wanganui region in 2011 (Statistics New Zealand, 2012a)

	Total New Zealand (A)	Horizons (B)	% (B/A)
Sheep (number)	31,132,000	5,731,000	18%
Dairy cattle (number)	6,175,000	473,000	8%
Beef cattle (number)	3,846,000	594,000	15%
Wheat (hectares)	52,600	900	2%
Barley (hectares)	64,900	5,100	8%
Maize (hectares)	18,500	2,700	15%
Onions (hectares)	5,140	280	5%
Potatoes (hectares)	10,720	1,210	11%

Climate of the Manawatu-Whanganui region

New Zealand's climate is typically dominated by the strong westerly and south-westerly winds and also considerable variation in climate between the eastern and the western areas can be found due to the high mountains and ranges in the middle of the country. The Manawatu-Whanganui region is located in the south-west of the North Island. This region can be exposed to the impacts of strong westerly winds from the Tasman Sea. As a result, the region's climate is quite windy with wetter winters and springs as the westerly winds affect New Zealand significantly. Summers are warm and mean temperatures in summer seasons vary from 19°C to 24°C. Maximum temperatures in winter are between 10 to 14 °C with a relatively milder climate in Whanganui and cooler in Palmerston North (Horizons Regional Council, 2012a; Palmerston North City Council, 2000). Sunshine duration of the Horizons region is around 2000 hours. In particularly, inland areas, such as Palmerston North, have much cloudier climate due to the westerly winds and the high mountains and ranges in the east of the region. Table 46 shows Palmerston North's average temperatures in summer and winter. Average temperatures in summer seasons vary from 13°C to 22°C and in winter seasons vary from 4°C to 12°C. Annual average precipitation in Palmerston North is about 982 mm (Palmerston North City Council, 2000).

Table 46 Average air temperature in summers and winters in Palmerston North (Palmerston North City Council, 2000)

	Average air temperature	
	Daytime High	**Over-night Low**
Summer	22°C	13°C
Winter	12°C	4°C

Manawatu-Whanganui's recent climate pattern

Manawatu-Wanganui region is likely to be getting warmer. Figures 37 to 39, the current trends in annual mean air temperatures observed at three stations were upwards. Of course, it is not relevant to determine that climate is changing and global warming is going on in this region, just with relying on observation of mean air temperatures. This is because climate can vary with many factors. However, current observation of temperature shows us that this region seems to be getting warmer.

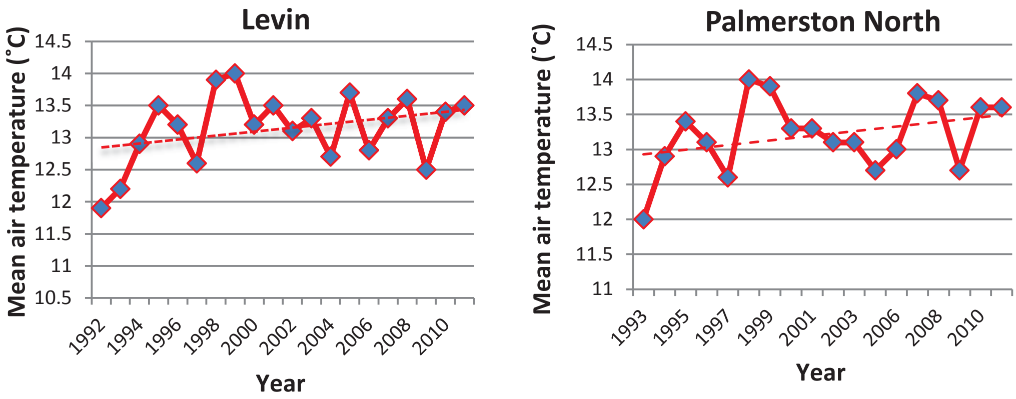

Figure 37 Annual mean air temperatures observed at the Levin Aws and Palmerston North Aws from 1992 to 2011 (NIWA, 2012b)

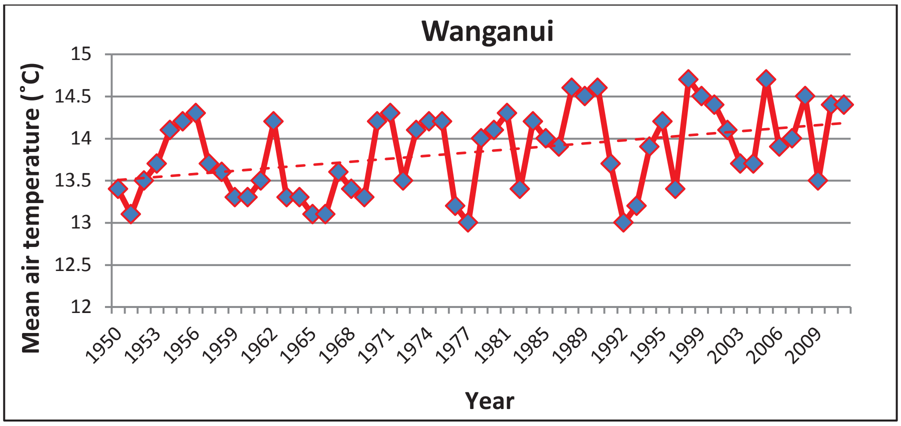

Figure 38 Annual mean air temperature observed at the Whanganui Spriggens Park Aws from 1950 to 2011 (NIWA, 2012b)

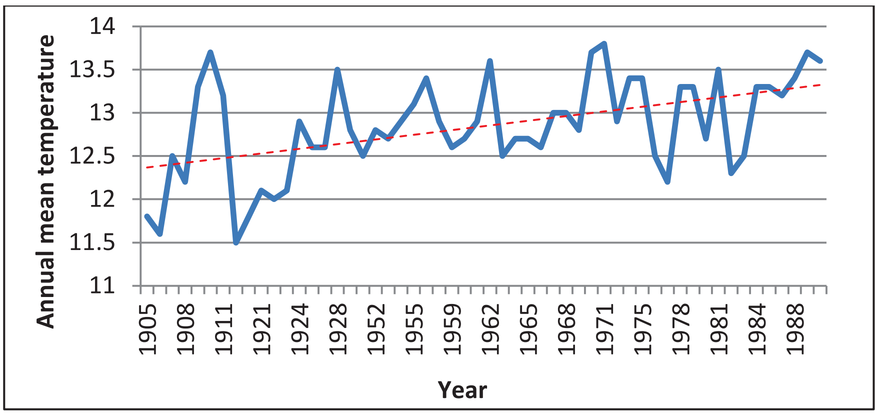

Figure 39 Changes in annual mean air temperature from observation at the Levin M.A.F weather station from 1905 to 1990 (NIWA, 2012b)

Rainfall in Manawatu varies with geographical locations (Figure 41 to 42). In Palmerston North and Levin, average annual rainfall has slightly increased. However, from observation at the Levin Aws weather station, rainfall has decreased while at the same period, rainfall at the Palmerston North Aws weather station has increased (NIWA, 2012b).

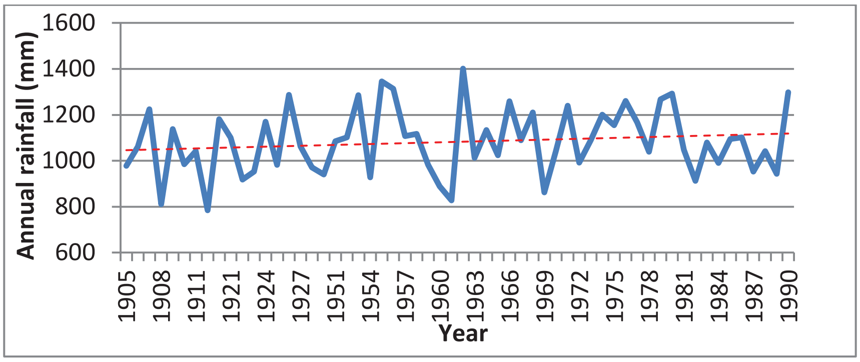

Figure 40 Changes in annual rainfall from observation at Levin M.A.F weather station from 1905 to 1990 (NIWA, 2012b)

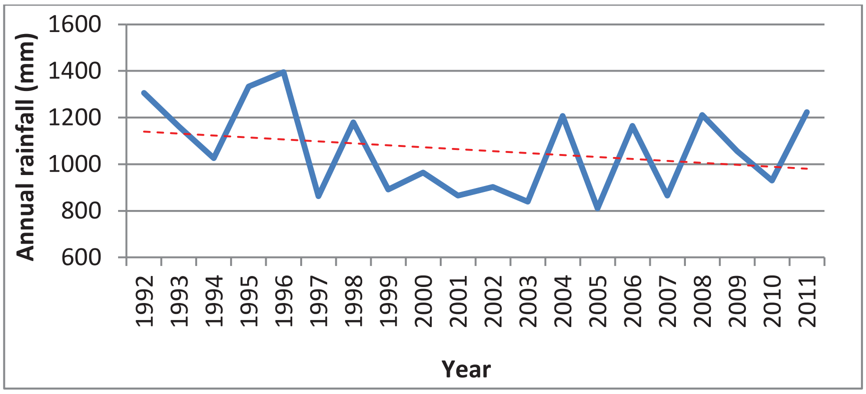

Figure 41 Changes in annual rainfall from observation at the Levin Aws from 1992 to 2011 (NIWA, 2012b)

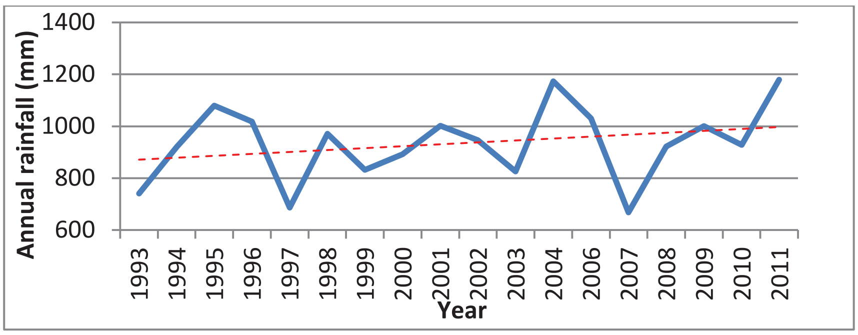

Figure 42 Changes in annual rainfall from observation at the Palmerston North Aws weather station from 1993 to 2011 (NIWA, 2012b)

NIWA's climate scenarios also projected similar climate trends. According to their scenarios, the Manawatu-Whanganui region is predicted to become warmer and wetter at the end of this century. Table 47 shows projected changes in average temperatures of the Horizons region by 2090. Average temperatures are expected to increase by 0.9°C by 2040 and by 2.1°C by 2090 with greater increases in summers and autumns (Ministry for the Environment, 2008e). As temperatures rise, hot days exceeding 25°C will increase by 10 to 45 days per year and particularly the east of the region will experience more hot days than the west. However, frost events are expected to decrease by about 10 to 20 per cent due to warmer temperatures (Ministry for the Environment, 2008c).

Average precipitation in the Manawatu-Whanganui region is expected to increase but there are region to region variations in projected changes in rainfall between the coastal and inland areas. For example, while rainfall in Taumarunui is expected to increase by 3 per cent at the end of this century (Table 48), average rainfall in Whanganui is likely to change relatively little. Changes in rainfall will be greater in winters with up to 13 per cent of changes. Otherwise, there will be little decrease in rainfall during summer and autumn seasons (Ministry for the Environment, 2008e).

Table 47 Predicted changes (°C) in annual mean air temperature of the Manawatu-Whanganui region by NIWA (The first number is a mid-range estimate) (Ministry for the Environment, 2008e)

	Summer	Autumn	Winter	Spring	Annual
1990-2040	1.1 (+0.2 to +2.3)	1.0 (+0.2 to +2.6)	0.9 (+0.2 to +2.2)	0.8 (+0.0 to +1.9)	0.9 (+0.2 to +2.2)
1990-2090	2.3 (+0.9 to +6.0)	2.2 (+0.6 to +5.3)	2.1 (+0.5 to +5.0)	1.8 (+0.3 to +4.9)	2.1 (+0.6 to +5.3)

Table 48 Predicted changes (in %) in annual rainfalls of the Manawatu-Whanganui region calculated by NIWA climate scenarios (The first number is a mid-range estimate) (Ministry for the Environment, 2008e)

		Summer	Autumn	Winter	Spring	Annual
Whanganui	**1990-2040**	-1 (-21 to 13)	3 (-8 to 10)	5 (-3 to 15)	1 (-10 to 15)	2 (-3 to 10)
	1990-2090	-3 (-42 to 12)	-1 (-20 to 12)	8 (-5 to 25)	0 (-16 to 23)	1 (-11 to 11)
Taumarunui	**1990-2040**	0 (-19 to 19)	2 (-10 to 13)	7 (0 to 17)	2 (-12 to 19)	3 (0 to 13)
	1990-2090	-1 (-36 to 18)	-2 (-25 to 12)	13 (1 to 36)	1 (-16 to 26)	3 (-7 to 15)

The Manawatu-Whanganui region is expected to experience more climate extremes. For instance, heavy rainfall events will occur more frequently in the region. Also, the prevailing westerly winds will increase. As a result, soil erosion will be a serious issue in the region's hill country. The number and the intensity of storms from the Tasman Sea are likely to increase in summer seasons. Also sea levels are expected to rise by 0.8m by 2090. Therefore, sea water inundation will be issued in the low-coastal areas (Horizons Regional Council, 2012b).

5.4.2. Horizon Regional Council's activities for climate change

According to NIWA's prediction, the region will experience the strengthened westerly wind and heavy rainfall events more frequently in the next 50 years due to global warming and climate change. Usually, winds and heavy rainfall can exacerbate soil erosion and floods. The impacts of an increase in winds and rainfall may be greater in the Horizons region than in others because more than 60 per cent of the Manawatu-Whanganui region is hill country. Horizons Regional Council is now undertaking various activities to protect land from soil erosion and floods. Table 49 illustrates Horizons Regional Council's activities related to climate change. In terms of land management, Council is implementing three land management programmes: the Sustainable Land Use Initiative (SLUI), the Whanganui Catchment Strategy (WCS), and the Regional and Coastal Land Programme, in order to protect land and coastal areas which is prone to erosion (Horizons Regional Council, 2011).

Also, Council is undertaking the River and Drainage Activities, including investigation of floods, implementation of mitigation options, river management, erosion control, and improvement of drainage systems in order to deal with floods and erosion.

In the Manawatu-Whanganui region, the demand for water has increased in the last two decades and much of the demand for water comes from the dairy sector. Therefore, securing adequate water quality and quantity may be another issue for the region. The Manawatu River Accord was established in order to protect water quality of the region. Also, to address water quality and quantity issues, Council has been implementing various activities, including water quality and quantity monitoring, improving of waterways, spreading of information and supporting of water quality research as shown in Table 49.

Agriculture is the important industry in the region and therefore, the spread of new pests can cause significant economic losses of the agricultural industry. Council has introduced the Regional Pest Plant Management Strategy (RPPMS) and the Regional Animal Pest Management Strategy (RAPMS) under the Biosecurity Act (1993) to protect the region from the spread of new pest animals and plants, such as possums. Also, Council has undertaken biological control programmes, including monitoring of biosecurity, rook and possum control, and pest plant control.

Table 49 Current Horizons Regional Council's activities related to climate change (Horizons Regional Council, 2011)

Area	Horizons Regional Council's activities
Land management	• **The Sustainable Land Use Initiative (SLUI**): SLUI focuses on land which is susceptible to erosion and encourages farmers to undertake sustainable land programmes using various grants, incentives, partnerships and advice. • **The Whanganui Catchment Strategy (WCS)**: WCS is done to meet erosion challenges in a catchment • **Regional and Coastal Land Programme**: RCLP focuses on coastal habitats • Research and monitoring
Water quality and quantity	• **The Manawatu River Accord**, which is an initiative to protect water quality in the region, was formed and supported by the Council • Protecting and enhancing waterways to improve water quality and quantity with supports, grants and partnership • Water quality monitoring and science programme • Monitoring water abstraction • Dissemination of information on water quality and quantity from monitoring and science programme • Support of water quality research
River and drainage	• **The River and Drainage General (Non-Scheme) Activity** is implemented to protect life, property and infrastructure from floods and erosion in the region. This activities include investigation of floods and erosion risks, development and implementation of mitigation options • **The River and Drainage – Scheme Activity**: Council is undertaking 22 river management and erosion control schemes to protect lands and urban areas from floods, riverbank erosion and channel movement. Also, Council is doing 11 drainage schemes to increase drainage efficiency in the lower areas.
Biosecurity	• **Regional Pest Plant Management Strategy** was introduced to deal with the biosecurity issues • Biological control programme is implemented to eradicate pest plants, including monitoring.
Environmental reporting and education	• Environmental monitoring and reporting • Environmental education including the Regional Information on the Go (RIG)

5.4.3. Case Studies 3 to 5: Vegetable production in Opiki

5.4.3.1. Basic information

Size and type

The case 3 farm was located near Levin with over 100 ha in the area. The case 4 and 5 farms were located in Opiki with smaller cultivated areas than the case 3 farm. The main crops of those case study farms were vegetables, including lettuce, onions, and potatoes.

Figure 43 Images of the case 3 farm

Figure 44 Images of the case 4 and 5 farms

Crop production

The case 3 farm has produced various vegetables, including lettuce, celery, beet, spinach, pumpkin, onions and cabbage. Figure 45 illustrates a planning plan of the case 3 farm in 2012. The case 4 farm was cultivating lettuce and cabbage. The major crops of the case 5 farm were onions and potatoes.

Figure 45 Planting plan of the case study 3 farm in 2012

5.4.3.2. Impact of Climate change

All farmers of the case study 3 to 5 had little knowledge about climate change and didn't think that climate has been changing. Even the case 3 farmer indicated that from historical records of his farm, average temperatures at the case 3 farm have decreased in the last decades. He stated:

> *"Temperature is dropping even though climate change is going on. Winter is getting colder and chilling unit is increasing for last ten years."*

Also, climate varied with geographical locations. A local consultant (Clarke, 2012) indicated:

> *"In the world, global temperature has increased by 2 or 3 degree in the world scale things. But localized climate change could be different. For example, even*

when Palmerston North has rain or hail, nothing has happened in Levin because of the hills. Palmerston North has a different climate from Foxton.”

The case 4 farmer had 40 years farming experience but also didn’t believe climate change. He commented:

“There is no climate extreme in this area in the last 40 years. Just a little warmer. Yesterday we had hail and frost in October. I don’t reckon that it was attributed by climate change things. Some introduction of pests is undergoing. Climate change is tough one. -- I’m not believing climate change. 3000 years ago, records started to know what climate change we have? “

The case 5 farmer thought that there was no significant change in climate. He indicated that planting time was still not changing. He commented:

“We experience more extreme weather at time. But hard to say, when I was in 15 and 16 years, there were traditional floods in October. More runoffs, but extremes are the same as before. Realistically no change. Snow last year, we had snow forty years ago. There was no snow after that but it happens first time our generation happen. Give me example, we plant maize on 15 to 16 Oct and we are still doing that. We found still 15 to 16 Oct is right time to plant maize. A main reason is late frost. We can’t go too early because of late frost. Those things have not changed. We getting no more hail important to onions. Still get a deal odd time. No more or no less than other years. Nothing changing about cropping seasons which we rely on not a lot of change. We are still running the same programme. Nothing has changed as far as planting time or maturity time.”

5.4.3.3. Government policies and activities

The case 3 farmer had little understanding on government policies. He knew the ETS but he thought that the ETS is only about tax. He thought there were financial drivers for the ETS. He agreed that the principle of the ETS was very good but system was totally fraught and the ETS became a type of stock exchange. Also he added that the ETS would increase his production cost. He stated:

> *"I think that there is no outcome from the ETS. Only thing is more cost for people. It's not going to change. I've got no economic alternative."*

The case 3 farmer had no experience to use any government grants or funds. He indicated that in the horticultural industry and glasshouse industry they often used SFF.

The case 4 farmer also didn't utilize any government supports, grants and technology transfer programme. The only thing that he knew was the horticulture levy. According to him the levy was used (by HortNZ) for research and development. In particular, currently the levy has been being utilized for enhancing water use efficiency.

5.4.3.4. Local community and industry

The farmers had no recognition about local community activities relating to climate change.

5.4.4. Case Study 6: a vegetable farm in Ohakea (Paiwhenua Trust)

5.4.4.1. Basic information

The case 6 farm, which was called as Paiwhenua Trust, was located in Ohakea, Manawatu. The farm was owned by Whanau Trust and so, the cultivated areas of the farm varied seasonally. The farm was cultivating potatoes, kumara, and corn producing 10 to 12 tonne of potatoes from around 0.4 ha of the area planted in potatoes. The areas planted in kumara and corn varied each year. The soil type was Ohakea Silt Loam. The main water source was natural rainfall. There was a milking shed nearby the farm that can be used as a water source but the farm had never used it. There was a permanent and a part-time worker.

5.4.4.2. Impact of Climate change

Ohakea's summers are dry with 26 to 28 ˚C of maximum temperatures. Winters were cool with regular frost events. Rainfall was about 1000mm per year.

The case 6 farmer thought that climate change was happening in his area. He stated:

> *"Seasons seem to be later. We have weather events now with more regularity. E.g. wind storms that damage the trees,"*

In terms of climate extremes, he has experienced dry summers in the last few years and a severe wind storm in 2011. The main concerns on crop production at his farm were long summers and earlier planting dates due to climate change. In particular, he worried that very dry and hot periods would cause an increase of Tomato-Potato Psyllid (*Bactericera cockerelli*). He indicated earlier springs and an increase of pest and disease would be the most significant issues in the near future. He stated:

> *"The main problem for us will be how early in spring we can work the soil and plant. Secondly, the impacts of pest and disease levels seem to be getting worse."*

5.4.4.3. Adaptation responses

The case 6 farmer indicated that it is necessary to plant earlier to avoid psyllid infestation. Also, adjusting planting dates can be useful to deal with droughts. He was using spray programmes and rotation practices to reduce pest and disease levels. The main concern of the farm was psyllid. He considered a change in crop production system due to psyllid. He commented:

> *"We have had to change our production system because of psyllid. Aim is to have crop set before mid-summer hot period and therefore less effect of the psyllid. The weather has also been making us rethink our harvest – especially because of wet autumn"*

5.4.4.4. Government policy, local council and industry's activities

With regard to government policy on climate change, the case 6 farmer was aware of the ETS but didn't use and involve government policies, supports or grants except for local government policy on water. He had no experience to directly use government funds or grants. However, he has been a party to a SFF project on crop rotation (still current) through a grower collective. He was not familiar with technology transferring programmes. In terms of the effectiveness of government policies on climate change at farm production level, he stated:

> *"It is a complicated matter and policies should not be looked at in isolation. For our small operation, we have not looked for anything yet. It is necessary to connect government and industry e.g. HortNZ for a common approach."*

He thought that bio-security would become a major issue and it would be necessary to invest research & development for new varieties and characteristics in horticultural crops.

With regard to local council's activities on climate change, he has been involved in Rangitikei River management as a member of the reference group with Horizons. He was not sure about local government activities on climate change. He commented:

> *"The implementation of local government activities is not too obvious for us but larger properties may be more involved – especially with the ETS"*

He indicated that the science budget should be more responsive to specific issues. He was not involved in any local community activities for climate change. In terms of the role of the industry, he stress that linked responses and collaboration between industry and growers should be developed. He stated:

> *"Probably better linked to growers, e.g. HortNZ and the SFF projects are an example of linked responses. We need to be more collaborative."*

In addition, he recommended that there was a need to contribute more to teaching people about climate change and related things like the ETS. He stated:

> *"The public don't understand the situation well and therefore, some clear information is necessary to work with"*

5.5. Case Study 7: an apple orchard in Hawke's Bay

5.5.1. Hawke's Bay

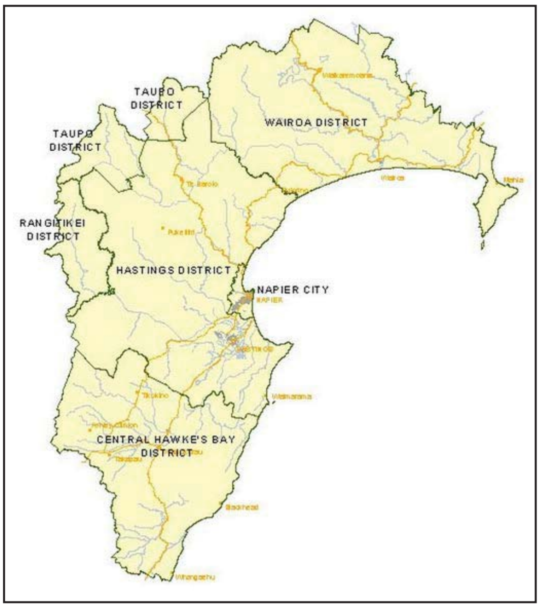

Figure 46 Map of Hawke's Bay Region (Hawke's Bay Regional Council, 2012c)

The Hawke's Bay region (Figure 46) is located in the east of the North Island. It covers about 14,200 square kilometres of land with 350 km of coastline. The region consists of five districts and a city: Central Hawke's Bay District, Hastings District, Rangitikei District, Taupo District, Wairoa District, and Napier City. In the region there are 7 major rivers: Esk, Mohaka, Ngaruroro, Tukituki, Tutaekuri, Wairoa, and Waipawa. The west side of the region is surrounded by high mountain ranges, such as the Ruataniwha and Kaweka mountains (Hawke's Bay Regional Council, 2012c). The population of the region was approximately 154,800 people in 2010 and represented about 3.5 per cent of NZ's total population (Hawke's Bay Regional Council, 2012a). Hawke's Bay is one of the major horticultural crop growing areas (Table 50). In particular, over half of NZ apple production is in the Hawke's Bay region and vegetable crops, such as kabocha squash, peas, and sweetcorn, are grown widely (Statistics New Zealand, 2012a).

Table 50 Major agricultural production in the Hawke's Bay region in 2011 (Statistics New Zealand, 2012a)

	Total New Zealand (A)	Hawke's Bay (B)	% (B/A)
Sheep (number)	31,132,000	3267,000	10 %
Dairy cattle (number)	6,175,000	91,000	1 %
Beef cattle (number)	3,846,000	488,000	13 %
Wheat (hectares)	52,600	400	1 %
Barley (hectares)	64,900	2300	4 %
Maize (hectares)	18,500	2,700	15 %
Apples (hectares)	9000	5140	57 %
Avocados (hectares)	3980	30	1 %
Kiwifruit (hectares)	13070	210	2 %
Wine grapes (hectares)	34060	4810	14 %
Cherries (hectares)	580	20	3 %
Onions (hectares)	5,140	810	16 %
Potatoes (hectares)	10,720	420	4 %
Kabocha squash (hectares)	6470	3150	49 %
Peas (hectares)	6230	2070	33 %
Sweetcorn (hectares)	3560	830	23 %

Climate of Hawke’s Bay

Hawke’s Bay is located on the east of the North Island and surrounded by high mountain ranges on its west side giving shelter from the strong westerly. Hawke’s Bay has a sunny, dry and warm climate with 2,100 to 2,200 sunshine hours annually. Summers are hotter than other regions with less rainfall and droughts and the maximum temperatures in summer vary from 19 to 24 °C. Winters are mild and the maximum temperatures are usually 10 to 15 °C even though sometimes frost and snow events occur. Rainfall in Hawke’s Bay is quite variable with geographical location. Rainfall in the hill country varies 1,200 to 2,400 mm per year. However, the central plains receive less rainfall than other areas with 800 to 1200 mm of annual rainfall. Droughts are common in the central plains from October and March. However, floods also occur frequently due to the moist north-easterly winds (Figure 47) (Pollock, 2010; Hawke's Bay Regional Council, 2012a).

Figure 47 Heavy rainfall and flood in Central Hawke's Bay and the Waipawa River in 2012

Climate change in Hawke’s Bay

According to historical climate records, Hawke’s Bay is likely to become warmer and drier. Figure 48 shows changes in average temperature in Napier. Between 1906 and 2010, average temperatures have increased by around 0.9˚C and this increase in average temperature does coincide with the change in NZ’s average temperature at the same period. Figures 49 and 50 illustrate changes in annual rainfall from observations at Napier and Central Hawke’s Bay. Even though there are some variations between geographical locations, rainfall has trended to decrease slightly in both areas.

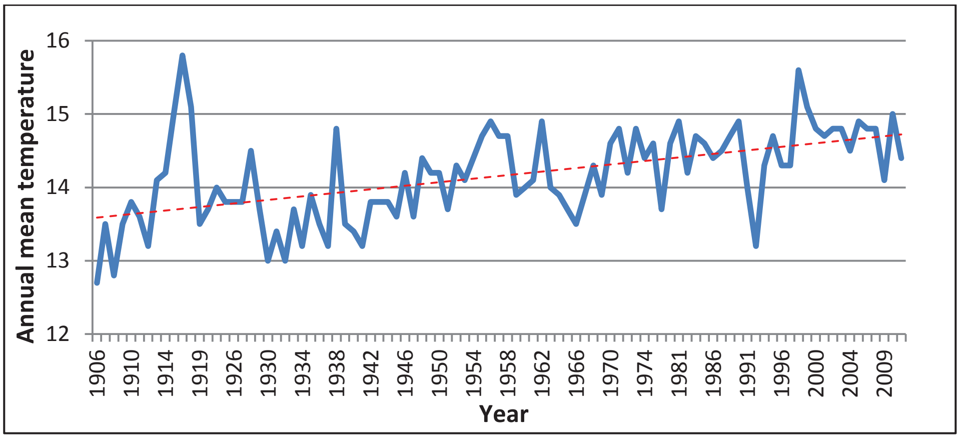

Figure 48 Changes in annual mean air temperatures from observation at NIWA's Napier Nelson Pk weather station between 1906 and 2011 (NIWA, 2012b).

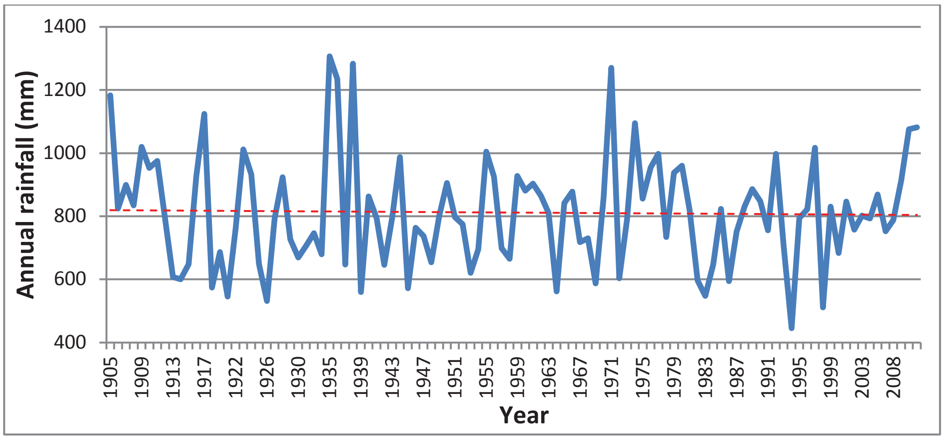

Figure 49 Changes in annual rainfall from observation at NIWA's Napier Nelson Pk weather station between 1906 and 2011 (NIWA, 2012b)

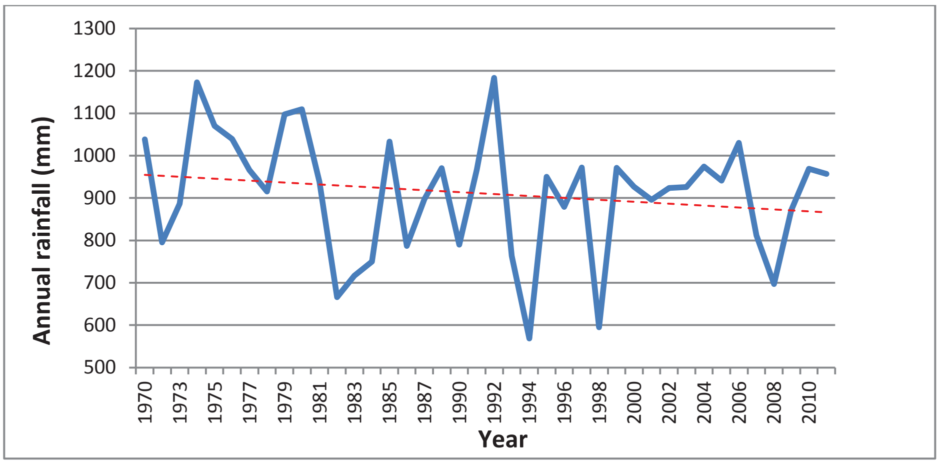

Figure 50 Changes in annual rainfall from observation at the Ongaonga weather station between 1906 and 2011 (NIWA, 2012b)

According to NIWA's projection, Hawke's Bay is expected to become warmer and drier due to global warming and climate change. Table 51 shows projected changes in average temperatures of the Hawke's Bay region by 2040 and by 2090. Average air temperatures are projected to increase by 0.9°C by 2040 and by 2.1°C by 2090 with greater increases in summers and autumns. However, annual rainfall is expected to decrease by 3 per cent by 2040 and 4 per cent by 2090 with a greater decrease in winters, although rainfall in summers and spring is expected to increase by 5 to 9 per cent by 2090 (Ministry for the Environment, 2008e). As average temperatures rise, drought events are expected to increase, especially in the central plains, and water supply will be an issue in the near future. However, extreme rainfall events are expected to also increase at a rate of 8 per cent increase with every 1°C increase in average temperature. In addition, the strong winds will increase in winter seasons. As a result, soil erosion will be a challenge in the hill country (Hawke's Bay Regional Council, 2012b).

Table 51 Predicted changes (°C) in annual mean air temperature and rainfall of the Hawke's Bay regionby NIWA (The first number is a mid-range estimate) (Ministry for the Environment, 2008e)

	Summer	**Autumn**	**Winter**	**Spring**	**Annual**
Temperature (°C) **1990-2040** **1990-2090**	1.0 (+0.2 to +2.5) 2.1 (+0.8 to +6.0)	1.0 (+0.3 to +2.6) 2.1 (+0.6 to +5.3)	0.9 (+0.1 to +2.2) 2.1 (+0.5 to +5.1)	0.8 (+0.0 to +2.0) 1.9 (+0.3 to +5.1)	0.9 (+0.2 to +2.3) 2.1 (+0.6 to +5.4)
Rainfall (%) (Napier) **1990-2040** **1990-2090**	4 (-33 to 38) 9 (-46 to 52)	5 (-14 to +42) 5 (-14 to +25)	-13 (-34 to -1) -16 (-45 to -1)	-7 (-17 to 3) -13 (-38 to 9)	-3 (-14 to 14) -4 (-20 to 11)

5.5.2. Hawke's Bay Regional Council's activities for climate change

Hawke's Bay Regional Council carries out various measures to meet climate change, including land drainage and river control, resource management, biosecurity, and emergency management. Table 52 shows a summary of Hawke's Bay Regional Council's activities related to climate change. Firstly, in terms of land drainage and river control, the Council is undertaking 12 Flood Control Schemes to protect communities from flooding, monitoring flood events and waterways, and upgrading stop-banks to reduce flood damage. Secondly, as extreme heavy rainfall events and strong winds are expected to increase in Hawke's Bay, soil erosion and adequate water quality and quantity will be serious challenges to farmers. Thus, the Council implements land and water management activities, such as Hill Country Erosion project supported by Sustainable Farming Fund and monitoring focal catchments to prevent soil erosion and secure adequate water quality and supply (Hawke's Bay Regional Council, 2012a). Thirdly, with regard to bio-security, the Council has concern about the impacts of warmer temperature on pests and disease control due to climate change and therefore undertakes Animal and Plant Pest Control Programmes, including Animal Health Board (AHB) vector control, Possum Control Area programmes, plant pest control, monitoring and education to address the impacts of climate change. Finally, the Council carries out emergency management, such as hazard identification and flood warning system (Hawke's Bay Regional Council, 2012a).

Table 52 Current Hawke's Bay Regional Council activities related to climate change (Hawke's Bay Regional Council, 2012a).

Area	Activities
Land drainage and river control	• **Flood protection and drainage schemes,** including Flood Control Schemes, monitoring of flood events, annual asset audit, ongoing sawfly damage monitoring and alternative species planting, upgrade stopbanks and river edge, and protecting and enhancing riparian land and waterway. • **Investigation and enquiries,** including advice, consultancy service, and capacity building • **Sundry works,** checking the extent of erosion at Westshore and inspecting river mouths and lagoon to prevent flood due to sea level rise
Land, water, and gravel management	• **Land management,** including managing focal catchments/area, monitoring, and Hill Country Erosion Sustainable Farming Fund project • **Water management,** including catchment sensitivity analysis, establishing and facilitating Water User Groups. • **Gravel management,** including undertaking survey of rivers every 3-6 years, and gravel allocation process and management activities.
Biosecurity	• **Animal Pest Control Programmes,** including Animal Health Board (AHB) vector control, Possum Control Area programmes • **Plant Pest Control Programmes**, including undertaking control on all plant pests to prevent their seeding, monitoring, recording and educating
Emergency management	• Hazard identification • Flood Warning System • Emergency Response Management

5.5.3. Case Study 7:

5.5.3.1. Basic information

Size and type

The apple orchard studied is located at Waipawa, Central Hawke's Bay. The orchard is 105 ha in area. Mr Apple, which is the biggest apple producing company, has 12 orchards over the country and each one is about same size to this orchard around 100ha. The case study orchard is a Mr Apple orchard located on State Highway 50.

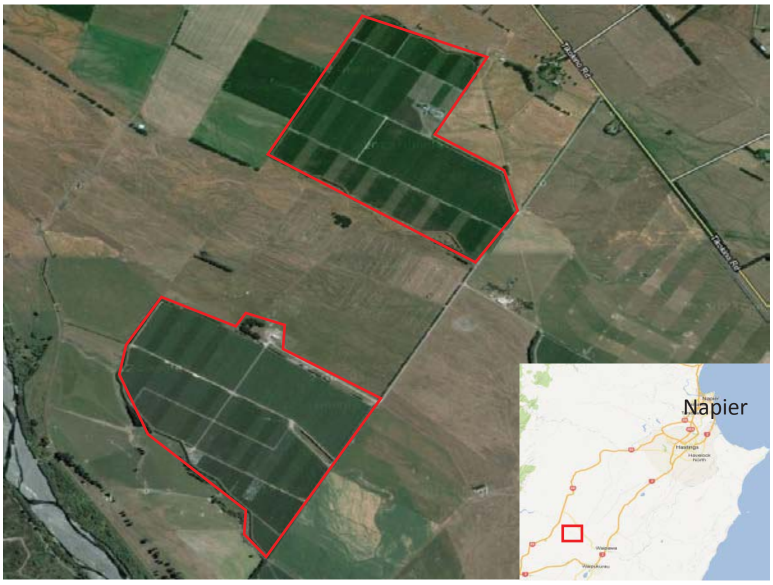

Figure 51 Satellite image of the study area in Hawke's Bay (Google, 2012)

Crop production

The orchard was planted in 1987 and the majority of apple trees are around 27 years old. There are 13 apple varieties planted in the orchard, including Braeburn, Royal Gala, Fuji, Granny Smith, Red Delicious, Pacific Queen, Pacific Rose, Pink Lady and Jazz. The major variety is Braeburn with 28 ha of the planted area. The second one is Pacific Queen at 26 ha. Pacific Rose and Royal Gala have occupied 10 ha and 17 ha in area. Recently the orchard has changed the apple variety mix from Fuji to Pacific series using grafting. Fuji developed in Japan is one of the favourite varieties in the Asian Market. However, China has now planted large areas of Fuji. As a result, the Asian market for Fuji is expected to become very difficult due to Chinese supply. The orchard has been replacing Fuji with Pacific series, as a result such as Pacific Queen and Pacific Rose which are expected to become popular in the Asian market. With regard to production per area, Braeburn in the case study orchard produced 10 tonnes per ha.

Figure 52 Images of the case 7 orchard

Water availability

Annual rainfall at the case study orchard was around 900 mm per year (NIWA, 2012b). The Central Hawke's Bay region is one of the dry regions in New Zealand and therefore, particularly in hot and dry summer seasons, irrigation is essential to secure sufficient water supply for trees. The case study orchard utilized aquifer water to irrigate. There were a couple of bores to draw out water from the aquifer.

Orchard management

There was an orchard manager and around ten permanent staff for the case study orchard. They were managing the apple orchard including marketing. In harvesting seasons, the orchard employs a large number of temporary seasonal workers to pick the fruits.

5.5.3.2. Impact of Climate change

Waipawa (Central Hawke's Bay) where the case study orchard is located has a different climate from Hastings and Napier. In winter, Waipawa is usually colder than Hastings and Napier but in summer it is warmer. Also, Waipawa has a huge daily temperature range. Thus, those conditions allow apple orchards in the Waipawa area to produce good quality apple fruit. On the other hand, frost can be a serious challenge of the orchards in the Waipawa area, especially during blossoming and fruit-set periods.

The manager believed that climate change is real and going on. In particular, he experienced abnormal wet and cool summers in the last two years and he thought climate change is happening. Also, fungus and disease problems have become a serious challenge to orchard management. With regard to the impacts of climate change, droughts could be a challenge to the Hawke's Bay region. However, droughts were not a big issue of this orchard. This is because the orchard had a sufficient water supply via aquifer water. However, the present drought in Feb/Mar 2013 is quite serious and many regions in North Island including Hawke's Bay are suffering from severe drought (TVNZ, 2013). He stated:

> *"There were two wetter years in the last two years. I have been working for 20 years but never experienced any year like the last two years. The east of the North Island normally has hot dry summers. However, in the last 2 years there were completely wet and cold summers. In this year, the climate goes back to normal. Something is happening. It's difficult to quantify but it is certainly different from what worked 20 years ago. These springs were probably cooler, more clouds and wetter than normal conditions. As a result, fungus and disease control is becoming issued. This is because under the cooler and wetter conditions, it is more difficult to control black spot fungus and other tree diseases which can have serious influence on apple production and wetter condition deteriorates disease problems. 2011 and 2010 were crazy years. This year is so far completely normal.*

> *"Drought has biggest possibility here because we are on the east coast and usually dry and extreme conditions can be very dry. But for us, we have irrigation, reliable irrigation. So, drought is not so much problem.*

Usually, the climate of Hawke's Bay in summer seasons is hot and dry. However, in the last two years, the case study orchard experienced a wetter and cooler climate. Thus, the manager thought that last two years were not normal and climate change was happening. Fungus and disease control was a big challenge to apple production due to wetter and cooler conditions. Also, frost was a problem for apple production of the case study orchard. As mentioned, frost has been an issue in the Waipawa area partly because of its huge daily or diurnal temperature range. With regard to frost, the manager stated:

"Our biggest problem is really the impacts of spring conditions and frost. We have possibility of if it's dry you have more chance of frost. And conditions in spring, some flowering and Christmas time is time when cell division is happening in the fruit. And we need this time to be warm and dry. They have no problem with fungal diseases. And warmer conditions for cell division allow fruits to get maximum cell division and make big apple."

"Frost protection is the main issue in the orchard. If trees get frost damage in flowering seasons, we can get nothing. This method is useful to prevent frost damage. We do a lot of efforts for frost protection."

The manager showed increasing concerns about frost. According to NIWA's scenarios, late spring frost will have serious influence on NZ's horticultural production more unexpectedly due to climate change and therefore, climate change can make the frost problem worse.

5.5.3.3. Adaptation responses

The case study orchard used frost protection fans to prevent frost damage. The manager stated:

"We have tried helicopters and watering systems and other possibilities but this is very effective and most cost effective. 30- 40 metres temperature there will be maybe 4-5 degree but temperature of ground will be -1 or -2 degree. This machine is pulling down the air into the orchard and goes rotation in 3 min around the tower."

Figure 53 Frost protection fan which was used in the case 7 orchard

5.5.3.4. Government policy

The case 7 orchard manager knew climate change well. He thought that climate change was likely to cause recent cooler and wetter summers and was worried about impact on crop management such as an increase of fungal diseases because of cooler and wetter conditions. However, he had little knowledge about government policies on climate change and didn't get involved in them.

5.6. Summary

Case studies were implemented at seven farms or orchards in four different regions: Gisborne, Nelson, Manawatu, and Hawke's Bay. Information on regional climate change and local council's activities on climate change was gathered from various sources including a literature review. Field interviews and observations were undertaken to identify the impacts of climate change and the effectiveness of government policies or activities on climate change. From observation at NIWA's weather stations, four regions studied were getting warmer. In the regions, average temperatures have increased by about 0.5˚C to 1˚C even though there were some variations in regions. A trend in annual rainfall varied with regions. In the eastern regions, such as Gisborne and Hawke's Bay, annual rainfall has decreased slightly. On the contrary, in Nelson and Manawatu, rainfall showed an upward trend. According to NIWA's projections, the average air temperature will increase by about 2˚C by 2090 in all regions. However, the trend in rainfall will be different between regions. In the eastern regions, rainfall is expected to decrease while in the western regions rainfall will increase due to climate change.

Field interviews with farmers revealed that many farmers were unsure about climate change. Some farmers agreed that there were some changes in weather pattern but they were not sure that those changes came from climate change. Many of them thought that some fluctuations in climate have existed at all times and there was no significant change in climate until now except for the case 7 farmer who was concerned about recent cooler and wetter summers due to climate change. No particular adaptation response relating to climate change was undertaken at any of the case study farms. This is because there was no apparent impact of climate change on crop production at the case study farms. The main concerns on climate change appear to be water availability, flood protection, and pest and disease control.

Most of farmers interviewed had little knowledge about government policies and activities on climate change. They didn't get involved in any government support, grants, or technology transferring programmes to cope with climate change but they knew about the ETS and generally expressed negative opinions on the ETS.

CHAPTER SIX: DISCUSSION

6.1. Introduction

This chapter seeks to find an answer to the research questions given in the first chapter through a comparison between the findings from the case studies and information obtained from the literature review. The main purpose of this research is to define the effectiveness of government policies and measures on climate change at farm production level. This study investigated the effectiveness of government of policies and measures from farmer's perspective. The four questions which were cast to achieve the purpose of the research were as follows:

1. What changes in climate are occurring and how is climate change affecting horticultural production?
2. What concerns about climate change do farmers and industries have?
3. How are farmers responding to climate change? What adaptation response are farmers doing to meet climate change?
4. How have NZ government policies on climate change been being implemented effectively at farm production level?

In the previous chapter, data attained from the case studies were illustrated and those data included the impacts of climate change, farmer's concerns and adaptation response, and farmer's perception of government policies and measures on climate change. In the literature review, general pictures on climate change and its impacts were attained. However, the general view can be quite different from farmer's perspective and farmers can have a different perception and experience of climate change. This chapter will interpret data from farmer's perspective and compare information from literature review with the findings from the case studies and interviews in order to show a comprehensive picture on the relationship between climate change, horticultural production and government policies in order to answer the research questions.

This chapter will identify the impacts of climate change, adaptation response, and the effectiveness of government policy. Then, the main findings and conclusion will follow. Finally, any recommendation relative to policy and future research undertaking will be suggested.

6.2. Impacts of climate change

What changes to climate are occurring in the case study sites? How is climate change affecting horticultural production?

There is high confidence that New Zealand’s climate is changing. NZ’s Climate is becoming warmer and weather patterns, such as rainfall and winds have been changing. From NIWA’s observation, NZ’s annual average air temperatures have increased by 0.9ºC in the last 100 years. Sea surface temperatures also show a similar upward trend to average air temperatures (Mullan et al., 2010; Renwick et al., 2010; NIWA, 2012b). There is a tendency that the northerly winds have dwindled since the 1960s. In contrast, the westerly and southwesterly wind have increased (Mullan et al., 2010). As wind patterns have been changing, NZ’s rainfall has been changing. For example, rainfall in the western regions has increased by 5% to 15% in the last 50 years because of the strengthened westerly winds. On the other hand, rainfall has decreased by 5% to 20% at the same period in the eastern regions, such as Gisborne, Hawke’s Bay, and Canterbury (Warrick et al., 2001; Renwick et al., 2010) .

It is likely that changes in NZ’s climate are highly related with global climate change. This is because NZ’s climate is dominated by the influence of global climate systmes, such as the El Niño-Southern Oscillation (ENSO), the Interdecadal Pacific Oscillation (IPO), and the Southern Annular Mode (SAM). For example, during El Niño events, there is a tendency that westerly winds are increased. Recently, El Niño events have occurred more frequently due to global warming and as a result, the more westerly winds have affected New Zealand (NIWA, 2012a).

There is a similar upward trend in annual average air temperatures among case study sites. In the Gisborne District, annual average temperatures have increase by around 0.5 ºC in the last 50 years and this upward trend is partly coincident with NIWA’s projection. In Nelson and Tasman region, annual mean air temperatures has increased by 0.58 °C to 0.88 °C over the last 100 years (Wratt et al., 2008). In Manawatu and Hawke’s Bay regions, annual average temperatures have increased by around 0.5 °C to 1 °C gradually even though there were year to year variations (NIWA, 2012b).

On the other hand, rainfall trends varied with case study areas even though trends in rainfall among regions were partly similar to NZ's general rainfall trend projected by NIWA. From observation at Manutuke and Gisborne airport weather station in Gisborne, there was a negative trend in rainfall over the last 50 years (NIWA, 2012b).

In Hawke's Bay, a similar downward trend in rainfall was observed. These downward trends in rainfall at the case study sites located in the east of the North Island were partly coincident with NIWA's scenarios and projections. There was an upward trend in rainfall in the Nelson region. NIWA projected that rainfall in Nelson will increase by 2 % between 1990 and 2040 due to climate change (Ministry for the Environment, 2008e). Thus, the real trend in rainfall show a similar tendency to NIWA's projection and therefore, it can be assumed that global climate change will affect NZ's rainfall.

However, in Manawatu, trends in rainfall were varied with geographical location. For example, an upward trend in rainfall between 1992 and 2011 was observed at the Palmerston North Aws weather station (NIWA, 2012b). However, at the same period there was a downward trend in rainfall at the Levin Aws weather station. According to NIWA's projection, rainfall in Manawatu is expected to increase from 1990 to 2090. However, observation data show region to region variations in rainfall (Ministry for the Environment, 2008e).

Farmers' experience and perception are somewhat different from the findings in the literature review. The findings showed that case study areas became warmer and the eastern regions of the North Island are getting drier while the western regions are getting wetter. However, field interviews revealed that most of farmers who were interviewed thought that climate change was not happening at all or it is too early to comment.

All farmers interviewed had more than 15 years of farming experience. They also had basic knowledge about climate change. However, most of them thought that there was no significant change in climate over the last 20 years. The farmer, who has 40 years of farming experience in the Manawatu region, mentioned that "there was no climate extreme during the last 40 years and I don't believe climate change". The other two farmers in Manawatu indicated that they experienced neither climate change nor climate extremes. The farmers in Gisborne and Nelson agreed that there was no significant change in climate in their respective regions.

Most farmers mentioned that there was no change in their farming practises. For example, they planted maize at the same time every year. One farmer admitted that there was a minor rise in the outbreak of pest and disease. However, he was not sure that that change came from climate change or border control. On the other hand, the manager of the apple orchard in Hawke’s Bay believed climate change. He indicated that the last 2 years’ climate was not normal. He thought that something was happening if not quantified.

Field interviews and observation indicated that there was no significant impact of climate change on horticultural production in the case study sites yet.

For instance, in Gisborne warmer temperatures had no significant harmful influence on citrus production. In fact, citrus is a subtropical crop and therefore, an increase of mean temperatures could be beneficial for citrus production in Gisborne. Also, the case 1 farmer noted that occurrence of frost events was likely to decrease over the last 12-15 years. From observation at the Gisborne, Manutuke weather station, there was no particular trend in frost occurrences from 1946 to 1992 (NIWA, 2012b). However, there was a tendency that a change in temperature is contrary to occurrence of frost events. For example, when the annual mean temperature is high, frosts occurred less frequently. Thus, as climate is getting warmer, frost events are expected to decrease. As a result, less frost occurrence will be useful for citrus production.

In Nelson, it is likely that there was also no significant impact of climate change on grape production of the case 2 vineyard. Change in climate, including increased temperature and reduced rainfall, will probably affect vineyard management activities, such as irrigation and pest, disease and weed control. However, the case 2 farmer in Nelson commented that there was no significant change in vineyard management activities yet. He had owned vineyards since in 1994 and so he had about 18 years of farming experience. However, he has felt no significant change in weather pattern. He thought that there might be slight warming but he was not sure about that because there was no empirical evidence available to him to support that.

Field interviews and observation revealed that there was also no significant impact of climate change on vegetable crop production in Manawatu. The case 5 farmer indicated that over the last 20 years, there was no change in farm management activities, such as planting schedule, irrigation, and pest, disease and weed control. For example, he has planted maize on 15 to 16 October every year and he was still planting at the same time. Also, he didn't observe any significant change in occurrence of pest, disease and weed.

However, in Hawke's Bay, climate change was likely to affect apple production at the case study orchard. The manager of the apple orchard experienced wet and cool summers in the last two years and he thought that those wetter and cooler conditions affected occurrence of fungus and tree diseases. A regional consultant indicated that quite a lot of farmers didn't really believe in climate change but they accepted climate would become more variable (Clarke, 2012).

Data from literature review showed that NZ's climate has been changing. However, most of the farmers who were interviewed thought that climate change was not real and nothing was happening. Farmers' perception was different from data in the literature review and there is a clear gap between scientific data and farmers' experience? Why do the farmers not believe climate change? Several reasons can be suggested.

Firstly, there has been no dramatic change in NZ's climate as of 2012. On the other hand, year to year variations were bigger than climate change so that farmers couldn't realize climate change. For instance, mean annual air temperatures have increased by 0.9 ºC over the last 100 years. However, there were year to year variations in mean temperatures between 0.5 ºC and 1 ºC. This means that an annual increase of temperatures is much lower than year to year variation in mean temperatures. In fact, New Zealand is surrounded by the ocean and therefore has moderate climate compared with the countries influenced by the continental climate. As a result, there was a relatively small change in mean air temperature in New Zealand. Thus, it is likely that farmers couldn't recognize a change in climate easily.

Secondly, even though climate change affects crop production, every crop has some range of adaptability to climate change and a crop's adaptability can partly offset the impacts of climate change excepting extreme weather condition, such as extreme heat and cold events severe droughts and floods, without significant loss of crop yields.

Finally, the New Zealand agricultural sector generally has sufficient infrastructure, such as dams, irrigation and drainage systems. Thus, farmers can usually cope with droughts and floods efficiently with little significant damage to their properties and crop production. Therefore, that could be the one of the reasons why most farmers have little concerns about climate change and think climate change is not happening. However, the 2012/13 summer was quite different and New Zealand has experienced a severe drought, especially in the several regions of the North Island, including Hawke's Bay. In the 2012/13 summer, weak La Niña has affected New Zealand and therefore, mild droughts relative to ENSO neutral conditions could be somewhat predicted (NOAA, 2013). But a recent severe drought appears to be abnormal and cannot be explained not only by the impact of weak La Niña but also by global warming and climate change. After the 2012/13 summer NZ farmers appear to be concerned about climate change more seriously than ever (TVNZ, 2013).

To sum up, the findings from literature review showed that NZ's climate has been changing over the last 100 years with warmer temperatures, wetter conditions in the west and drier conditions in the east of the country, although there were some regional variations in climate change. However, field interviews and observation revealed that farmers' perception was different from the findings from literature review. Most of farmers who were interviewed thought that climate change has not been happening around their farms. Even though someone indicated there were little changes in temperature and disease occurrence but they were not sure about whether those changes originated from climate change or not. In addition, in the case study farms there was no significant impact of climate change in crop production. Case study farmers grew various horticultural crops, including citrus, grapes, apple, potatoes, onions, and other vegetable crops. However, most of them found no significant impact of climate change on their farming activities, including planting and harvesting. This study assumed several reasons which can explain a gap between the findings from literature review and farmers' perception. Firstly, NZ's climate change is not severe and even year-to-year variations are bigger than annual climate change so that farmers could not perceive climate change. Secondly, crop's adaptability to climate change can overcome mild impacts of climate change. Finally, sufficient agricultural infrastructure allows farmers to cope with climate extremes efficiently. However, there is no significant impact of climate change on horticultural production in New Zealand so far, the accumulating impacts of climate change can have significant influence on NZ horticultural production in the future, as many researches indicated. It is worth noting that some farmers partly admitted that their climate would be getting more variable.

6.3. Farmers' concerns about climate change

What concerns do farmers or industries have with regard to climate change?

The literature review indicates that NZ horticultural industry and farmers are concerned about the Emission Trading Scheme (ETS), water supply and floods, soil erosion and increased pest, disease, and weed problem with regard to climate change.

The main concern of the industry and farmers is the ETS. The industry and farmers thought that the ETS would make the horticultural industry less competitive due to an increase of production costs. It is highly likely that the ETS put additional costs onto horticultural production. From a government estimation, the price of petrol, electricity, and natural gas are expected to increase by 3.5 % to 13 % because of the ETS (Ward, 2010; Ministry for the Environment, 2011). NZ fuel suppliers, including BP, Shell, Mobil and Caltex increase prices for petrol by 3 cents per litre or more after the ETS entered into force (Fairtax NZ News, 2010). These increases will probably lead to an increase of horticultural production costs. HortNZ estimates that the horticultural sector would need to pay additional costs of $ 11 million per year due to climate change. Even the ETS would be fatal to some greenhouse crops, such as capsicum and greenhouse tomatoes. For example, farmers who grow greenhouse tomatoes with coal need to pay $ 44,121 per hectare of additional ETS costs of and capsicums growers need to pay $ 31,330 per hectare of additional ETS costs.

The industry and farmers' other concern was water availability. In New Zealand water availability has not yet been an issue excepting some dry regions such as Canterbury and Central Otago. This is because New Zealand is surrounded by the ocean and generally provides sufficient water from natural rainfall. However, as global warming occurs, concerns about water supply have increased. From NIWA's climate change projection, the average temperature in New Zealand will increase by 2.1 °C by 2090 and the eastern regions are expected to be getting hotter and drier. Therefore, adequate measures are necessary to secure sufficient water supply.

Besides the ETS and water availability, the industry and farmers had a growing concern about heavy rainfall and floods, poor drainage, and increasing pest, disease and weed problems. So they unwillingly recognise some changes occurring. In addition, in some regions farmers were slightly concerned about rain during harvesting seasons and strong winds with regard to climate change.

However, from field interviews, case study farmers had little concern about climate change and its impacts on their farming. This is because most of them thought that there was no significant change in climate in their regions and therefore, didn’t take climate change into account seriously. However, most of them were concerned about the ETS and believed that the ETS gave farmers not an advantage but additional costs.

For instance, the case 1 farmer in Gisborne admitted that frost events had been reduced for last a couple of decades and more tropical cyclones seemed to be happening. However, he was not sure about climate change and had little concerns about that. This is partly because the case 1 orchard was located in the hill country and surrounded by hillsides. As a result, strong winds and floods had never been an issue in the orchard. However, the case 1 farmer had a slight concern about pest and disease problems. He indicated that recently Australian Citrus Whitefly (ACW) had increased in the North Island and could be a threat to citrus corps. However, he was not sure whether ACW had increased due to climate change or border control. Also, he was concerned about the impacts of the ETS. He thought that the ETS would be not effective for GHG mitigation but give additional costs to farmers. In addition, floods could be an issue in lower areas near the big river, including the Waipaoa River. The case 1 farmer was participating in the flood protection advisory group in the region and the Council was doing flood protection works in cooperation with the group.

The case 2 farmer in Nelson also had little concern about climate change. He had no confidence about climate change. He thought there was no significant climate change in Nelson. Only, he had little concern about water supply but this was not big challenge to him because most water needed in his vineyard was provided from natural rainfall and he used just 2 % of allocated water. In addition his vineyard was doing carbon-zero certification and sustainable farming programme as a business. Carbon-zero certification is related to carbon labelling and GHG emissions. Therefore, his concern about carbon-zero certification is likely probably to be associated with climate change issues.

The case 3 farmer in Manawatu had a big concern about the ETS. He agreed on the principle of the ETS. However, he thought that there would be no outcome from the ETS and nothing would be changing excepting additional costs to people. The case 4 and 5 farmers were also concerned about the ETS even though they had no concern about other impacts of climate change, such as warmer temperature and climate extremes.

However, the case 7 farmer had much more concern about recent variable changes in climate. He agreed that climate was changing really. For instance, he indicated that in last two years there were unusual wetter and cooler summers which he had never experienced during last 20 years. Then, he was concerned about fungal disease problems. This is because under the wetter and cooler conditions, it is more difficult to control increasing fungal diseases. With regard to drought, although droughts could be a big problem in Hawke's Bay, he thought that drought was not so much problem due to his irrigation system. On the other hand, late spring frost was a big concern to production and the orchard used frost protection fan to prevent frost damage.

To sum up, in terms of climate change, the horticultural industry has concerned about ETS issue, water availability and poor drainage, heavy rainfall and floods. The industry and farmers thought that the ETS would impose additional costs on farmers without significant effects on GHG mitigation. The industry and farmers were worried that they would lose their competitiveness in the international markets due to additional costs of the ETS. Field interviews also revealed that farmers had strong objection to the ETS. They believed that there would be no outcome from the ETS and nothing would be changing excepting additional costs to people. Water availability has also been a growing concern of farmers, particularly in some dry regions, such as Central Otago and Canterbury. In Nelson, the Council launched a new plan for building a dam in order to increase water supply for the Waimea Plains. The industry admitted that there was increasing tension around freshwater management, including water allocation. Also a dam is being planned for central Hawke's Bay. The NZ government has introduced a water metering system in some areas in order to monitor water use. As global warming becomes more evident, water availability and supply is expected to be an issue in many regions even though New Zealand has sufficient rainfall and water supply so far. Thus, the NZ government must take water availability problem into account when they introduce policy on climate change.

Field interviews showed that farmers had minor (or growing) concerns about water supply. As of 2012, this is because lack of water would be a problem of some dry regions and water availability has not been an issue in most regions where the case studies were implemented. Besides water availability, there was a little concern about floods and poor drainage, and pest, disease and weed problems. In field interviews, some farmers expressed that increasing diseases problem could be an issue due to climate change.

6.4. Adaptation responses

How are farmers responding to climate change? What adaptation response are farmers doing to meet climate change?

Adaptation is the primary focus of this study. This is because agricultural and horticultural crops should be susceptible to the impacts of climate change, such as warmer temperature, droughts and floods, unexpected climate extremes. If relevant adaptation measures were not undertaken to meet the impacts of climate change, it is evident that farmers should experience severe loss of their crop production.

From the literature review, potential adaptation measures can be illustrated. For example, as short-term adaptation measures, farmers can change planting and/or harvesting dates, varieties, tillage and rotation practices, and pest and disease management. Long term measures for adaptation to climate change include breeding of new cultivars, enhancing water availability using dams and other water storage, technology development and transfer, and relocation of farming areas. Pipfruit New Zealand have considered relocation of the growing areas in pipfruit from Hawke's Bay to Canterbury or Otago, as one of the long-term adaptation options. However, relocation should be the last option for adaptation to climate change because relocation requires huge resource investment. The result of the "Adapting to climate change in eastern New Zealand" project showed that as adaptation responses, farmers considered increasing of water supply and efficient allocation, breeding new varieties with pest and disease resistance, using of soil organic matter (SOM) and soil protection management, reforestation, sustainable farming management, relocation, and enhanced pest and disease control, etc. In terms of kiwifruit, the impacts of climate change on kiwifruit were more severe than other horticultural crops and Kenny (2001 & 2008) suggested developing new chemicals for breaking winter dormancy of kiwifruit as a short-term measure. And also as a mid-term measure, he indicated that it is necessary to develop new varieties which have less winter dormancy requirement. Finally he recommended relocation as a long-term measure. On the other hand, apples are relatively less sensitive to climate change than kiwifruit. This is because apples have a lower chilling requirement than kiwifruit. However, general impacts of climate change, such as severe droughts and floods, late spring frost, and an increase of pests and disease will impact on apple production. In particular, most apple orchards in NZ are located in Hawke's Bay and Tasman where water availability can be an issue. Therefore, efficient use of water and development of new water sources will be necessary to meet climate change.

However, field interviews and observation revealed that farmers interviewed had little current concern about the impacts of climate change and as a result, they were not undertaking much adaptation responses to meet climate change. The case 1 farmer in Gisborne planted pinetrees on the hillside in order to balance carbon emissions and mitigation in his orchard. Nevertheless, planting trees can also be a potential adaptation response so as to prevent landslides on the hillside. He used natural rainfall to grow citrus and there was no need to irrigate. However, if severe droughts happen, he would consider building a small dam to increase water supply but water supply has never been an issue in his orchard. In addition, he participated in the consultant group meeting to adjust stop bank level to enhance flood protection in the Manutuke area. The case 2 farmer in Nelson didn't undertake any particular adaptation measures. This is because there was no apparent issue with regard to climate change. He was undertaking carbon-zero certification and a sustainable farming programme as a business. Those activities can be beneficial for mitigation of greenhouse gases emissions but not much related to adaptation response to climate change. However, from the long-term point of view, the sustainable farming programme will be helpful to enhance adaptability to climate change. This is because an increase of soil organic matter allows the soils to get more moisture and as a result, the orchard can cope with droughts more efficiently. The case 2 vineyard had a water tank under the ground of the winery to collect and use natural rainfall efficiently. Also, they used drip irrigation to reduce water use for grape cultivation. The case 3 to 5 farmers in Manawatu were not undertaking any particular adaptation responses. This is partly because there was no significant change in temperature, rainfall and climate extremes even though the farms relied on natural rainfall as a main water source. In Hawke's Bay, frost and diseases were a challenge to the case 6 orchard with regard to climate change. Especially, late spring frost can severely damage apple production and therefore, the orchard uses a frost protection fan to prevent frost damage to the flowers and fruit. Also, in the last two years, wetter and cooler summers were an issue in the orchard. Under the wet and cool condition, fungal diseases can increase. Therefore, the orchard undertook more disease control practices to address those problems. The case 7 orchard used aquifer water to irrigate in hot and dry summer seasons. However, water supply has never been an issue in the orchard. Pipfruit NZ have indicated no serious concern about climate change. The manager who worked in the Pipfruit NZ climate change commented that the Pipfruit NZ was not doing any particular activities in terms of climate change. He added that relocation can be one of the options to address climate change.

In summary, the literature review showed potential adaptation measures to meet climate change in the horticultural sector. However, field interview and observation revealed that farmers were not doing much in the way of adaptation responses to climate change. This is because there has been no serious impact of climate change on their crop production yet and therefore, they had little concerns about climate change. Also, what they have been doing currently was not mid or long-term responses but short-term responses. So their approach is tactical rather than strategic.

6.5. The effectiveness of government policies and measures on climate change

How have NZ government policies on climate change been being implemented effectively at farm production level?

Government policy on climate change may be affected by both internal and external factors, including the industry and farmers' concerns and international issues. Therefore, to define the effectiveness of NZ government policy on climate change, first of all it is necessary to understand what factors have affected NZ government policy actually and what response NZ government has been doing.

Mitigation of GHG emissions has been an issue around the world and recent international negotiations for GHG mitigation have a significant influence on NZ government policy on climate change. Also, the Emission Trading Schemes and carbon labelling which many countries introduced in order to reduce their GHG emissions affect NZ government policy.

Since the IPCC published the first assessment report on global climate change in 1990, most countries in the world have recognized the significance of climate change. All countries of the world have tried to find a solution for mitigating GHG emissions which were known as the primary cause of global warming with UNFCCC as the centre. In fact, the UNFCCC has played an important role in global negotiation on climate change and GHG mitigation. For example, the Kyoto Protocol, which entered into force in 2005, was adopted by the UNFCCC in 1997. Also, many group meeting and discussion have been undertaken with the subsidiary bodies of the UNFCCC.

Then, what impacts do the international negotiations have on NZ government policy on climate change and NZ agricultural sectors? According to the Kyoto Protocol, 37 developed countries, including New Zealand, should reduce GHG emissions by 5 % below 1990 level between 2008 and 2012. It means that New Zealand must find a way to reduce total GHG emissions. Many developed countries introduced the Emission Trading Schemes (ETS) as a primary tool for mitigating their total GHG emissions. New Zealand government also introduced the ETS in 2008 from the forestry sector in order to reduce GHG emissions. Actually, NZ agricultural sectors account for half of

NZ total GHG emissions. As subsequent negotiations of the Kyoto Protocol are progressing in the UNFCCC, the pressure for GHG mitigation is expected to continue to mount. Thus, the NZ agricultural sectors’ burden is also expected to increase with an increase of developed countries’ emission targets.

Carbon labelling is likely to be another international issue which affects NZ agriculture. Since Carbon Trust in the UK launched the first carbon labelling in 2007, many countries, including France, Germany, Switzerland, Sweden, Holland, the USA, Canada, Korea, and Japan, have introduced similar carbon labelling. Actually, carbon labelling can be disadvantageous for the NZ horticultural industry. This is because many NZ horticultural products export to those overseas markets. Shipping from New Zealand to the overseas markets can increase carbon emissions of NZ horticultural products and as a result, carbon labelling can make NZ products footprint be less competitive in the overseas markets.

The horticultural industry and farmers both have great concerns about the ETS and water availability with regard to climate change. Also, they have lesser concern about flood and poor drainage, and increasing pest, disease and weed problem.

Policies on climate change vary with countries and their current situations. Table 53 summarizes key areas of some countries’ policies on climate change. The UK Government policies on climate change were well-balanced between mitigation, adaptation and developing of new business opportunity. The UK has a relatively smaller land area than other countries, such as Australia, Canada, and the USA. Thus, the UK Government’s mitigation policies focused on GAPs, reducing of intensified production, increasing of energy efficiency and soil carbon storage. Also, to develop new business opportunity, the UK Government provided supports in the areas of anaerobic digestion and non-food crops, including bio-mass. On the other hand, in Australia, Canada, and the USA, environmental management and soil conservation became greater issues on climate change due to their big land areas. In addition, in Canada and the USA, bio-energy crop productions should be a promising business using their sufficient arable land areas.

Table 53 Key international policy drivers on climate change

	Mitigation	Adaptation	New business opportunity
EU	• Reduced the DP for intensified production • Improving of soil carbon storage • Efficient use of energy, manure management and adequate use of fertilizers	• Water management • Technology transfer	
UK	• Reduced DP for intensified production • Research for GAPs • Increasing of soil carbon storage • Efficient use of energy	• Improving of flood protection and water availability • Practical advice on climate change to farmers	• Research and development in the areas of anaerobic digestion and non-food crops
Australia	• Mitigation of emissions from livestock and soils • Increasing of soil carbon storage and bio-sequestration	• Research and development on climate change • Partnership • On-farm demonstration projects	
Canada	• Environmental management, including BMPs, soil conservation		• Financial supports for bio-fuel production
USA	• Environmental management and conservation • Improving energy efficiency • Mitigation of methane emissions from livestock	• Improving water availability • Enhancing of pest management • Improving of risk management	• Encouraging of renewable energy production

New Zealand does not have a large land area compared to Canada and the USA. New Zealand's natural conditions are similar to the UK with relatively small land area and a maritime climate. Therefore, the UK Government's policies on climate change can be a reference to NZ's policies. However, there are some differences between New Zealand and the UK. For example, NZ's economy is mainly based on agriculture while the UK has been more industrialized than New Zealand. Thus, the environmental management and conservation would be more important to New Zealand than the UK.

New Zealand set the goals as CO_2 emission reduction of 10 to 20 % below 1990 levels by 2020 and 50 % below 1990 levels by 2050. The main NZ government policy should be the ETS. To achieve emission reduction goals, the NZ government introduced the ETS in 2008 from the forestry sector and all sectors except agriculture will enter the ETS in 2015. But it is influenced by offshore values on C and is currently [2012] very low.

The Sustainable Land Management and Climate Change Plan of Action (SLMACC) is the government's key response to climate change in the land based sectors, including horticulture. Under the SLMACC, NZ government policies and measures on climate change for agriculture are classified into 3 categories: mitigation, adaptation, and development of business opportunities. Key parts of the SLMACC programme relevant to growers are research to understand the impacts for the sector, as well as the technology transfer programme (Lill, 2012).

The aim of the technology transfer programme is to enhance the ability of the primary land manager, reduce GHG emissions, adapt to climate change and develop new business opportunities relating to climate change. The technology transfer programme has focused on collecting and developing resources, practical demonstration and up-skilling on climate change and greenhouse gas emissions, and training rural professionals who assist farmers and growers. In particular, as one of technology transfer programme, the training project entitled “Managing farm businesses in a changing climate – the opportunities for rural professionals” was implemented between April and June 2012 in order to train rural professionals relating to climate change. Under the project, 13 workshops were held throughout the country and 230 participants attended the workshops. The attendance was lower than expected, however the subsequent survey revealed that their knowledge on climate change has increased due to workshops (MPI, 2012a).

The Government has provided financial support for research on mitigation of GHG emissions and adaptation to climate change. Between 2008 and 2011, the Government has funded more than 100 research projects in the area of the impacts of and adapting to climate change, forestry and carbon markets, addressing greenhouse gases from agriculture, soil carbon and biochar, and economic and social issues relating to climate change (MPI, 2011b). In terms of climate change, the Sustainable Farming Fund (SFF) has also funded around 52 projects including summer fruits and berry fruit. However, most research projects focused on understanding the impacts of climate change and reducing GHG emissions in the dairy and forestry sectors. The research projects for horticulture were relatively fewer than those for the dairy sector. The projects for horticulture funded under the SFF were not focussed on climate change but many did look at water efficiency (Lill, 2012).

In terms of adaptation to climate change, the role of the local councils is likely to be more important than the central government. This is because they have been implementing essential activities for adaptation to climate change in each region, such as enhancing water availability and flood protection, and securing bio-security. Most local councils have included activities on climate change into their annual and long-term plans required under the RMA and undertaken them.

As mentioned in the chapter four, the effectiveness of government policies and activities are identified from farmer perspectives by investigating how much knowledge about government policies farmers have and how often farmers have utilized government policies and activities to deal with climate change.

Field interviews showed that most farmers had little knowledge about government policies. They knew the ETS but thought that the ETS would have a negative impact on their business with an increase of production cost. The case 3 famers commented that:

> *"I think that there is no outcome from the ETS. Only thing is more cost for people. It's not going to change. I've got no economic alternative."*

Also, most of the farmers interviewed had little knowledge about government support, funding, and the technology transferring programmes and didn't involve in government funding projects or technology transferring programmes. The case 3 farmer commented:

> *"I didn't use any government grants or funds. In the horticultural industries, glasshouse industry may use the SFF. For me nothing."*

The case 4 farmer also didn't utilize any government supports, grants and technology transfer programme. The only thing that he knew was the levy. Some farmers (cases 6 and 7) were worried about fungal or virus diseases levels. They indicated that such diseases in apple and potato production could increase due to climate change. However, they didn't get any support from the government.

Field interviews revealed that the farmers interviewed didn't know local council activities on climate change well. From the literature review, local councils have been undertaking several activities on climate change, such as enhancing of water availability and flood protection, improve pest and disease control. However, many farmers had little awareness about those activities. The case 1 farmer only involved in consultation group for the level of flood protection required. The case 2 farmer indicated:

> *"Local council's supports and activities on climate change were weak and politically driven by lobby groups nor focused on construction."*

The case 6 farmer were a member of the reference group for Rangitikei River management but he was not sure about local government activities on climate change.

Field interviews and observations revealed that government policies on climate change seem not to be working well at horticultural farm production level. Most of the farmers interviewed were not sure about government policies and had little experience to involve in them. Why are government policies not being implemented at horticultural crop production level? Several reasons can be suggested as follows;

Firstly, farmers have little attention to government policies on climate change and that could be one of the reasons why government policies have not been working well. Many interviewees didn't consider climate change as a serious issue. This is partly because the impacts of climate change have affected horticultural crop production not suddenly but slowly and gradually, and current climate change has little influence on their horticultural crop production. Also, they usually have a short-term view and seem to ignore long-term impacts or threats, like climate change partly due to their limited resources, money, and information. Also, they generally rely on lobby groups such as HortNZ. Therefore, they tend to pay little attention to government policies on climate change and even do nothing to adapt to climate change.

Secondly, it is likely that government policies have mostly focused on the dairy industry and mitigation of GHG emissions from livestock and pastures. The SLMACC programme is the NZ Government's key policy on climate change for the agricultural sectors, including horticulture and key parts of the SLMACC are research for climate change and technology transfer programme. However, most research projects and technology transferring programmes funded from government are related to the dairy industry and mitigation measures. This is because the agricultural sector is a major source of GHG emissions in New Zealand and agricultural GHG emissions mostly come from livestock and pasture. Therefore, NZ's government policies on climate change may concentrate on mitigation of GHG emissions in the dairy industry. However, considering that the horticultural industries, including wine and kiwifruit industries, play an important role in NZ's commodity exports and those industries are susceptible to climate change, government policies on adaptation should be provided for enhancing the horticultural industries' adaptability to the impacts of climate change.

Thirdly, local councils have insufficient resources and budget to deal with regional issues on climate change. The major adaptation responses to climate change include securing of water availability, improving of flood protection, and enhancing pest and disease control. Those adaptation responses are mainly implemented by local councils with central government's assistance. However, local councils have insufficient budgets to undertake those things. For example, in 2010 the Tasman District experienced severe heavy rainfall and flood caused around $ 6 million of damage. The Council funding to repair Council infrastructure and flood protection structures came from disaster funds which the Council accumulated for such major events. However, those disaster funds were depleted due to earlier disaster and subsequent damage. Thus, the Tasman Council experienced a shortage of funding to repair or replace infrastructure (Tasman District Council, 2011). In addition, the Tasman District Council plans to build the Lee Valley Dam to meet an increasing demand of water. The cost of the dam is estimated at about $ 41.6 million. The Council considers many options for paying the cost of the dam, including funding from the Central Government and the Nelson Council, all landowners, and irrigators (Tasman District Council, 2012a). However, still raising enough funds will be a key constraint for building the dam.

Fourthly, one of the limits of government policy on climate change is a lack of the policy for enhancing business opportunity. In fact, climate change can create new business opportunities in the area of the agricultural sectors, including bio-energy crop production. In order to develop new business opportunity, the UK, the USA and Canada Governments provided financial supports in the areas of anaerobic digestion, non-food crops including bio-mass, and bio-fuel crop production. NZ Government is also providing financial assistance to establish two professorships relating to biochar but this support is insufficient to boost business opportunity in the area of climate change.

Fifthly, government policies on climate change are mostly undertaken on an industry basis and comprehensive approach which encompasses various horticultural industries and regions is not enough. For instance, Bay of Plenty is one of the major growing areas in kiwifruit. However, from NIWA's high and mid-end climate change scenarios, a significant decrease in suitable area for growing kiwifruit is expected in the Bay of Plenty by 2090 due to warmer winter and insufficient winter chilling (Kenny, 2001). On the other hand, Hawke's Bay and Nelson are expected to be more suitable areas to grow kiwifruit. Thus, under NIWA's climate change scenarios, relocation of the growing areas in kiwifruit from Bay of Plenty to Hawke's Bay or Nelson may be the best option for kiwifruit growers can choose. However, in Hawke's Bay and Nelson, water is already tightly allocated and there is little room to share. As a result, water availability for irrigation will be a significant limiting factor to expand areas planted in kiwifruit in Hawke's Bay and Nelson (Kenny, 2001). Also, relocation of kiwifruit will affect other horticultural crop production with competition for securing suitable growing areas between crops. Support industries and infrastructure will also be affected, generally in a negative way. Therefore, in order to maintain the kiwifruit industry, the comprehensive adjustment plans which encompass relocation and securing of water supply will be necessary. Each industry or region cannot deal with those complicated problems. Thus, the government should prepare the comprehensive plans and subsequent policies to meet those problems and enhance NZ horticulture's adaptability to climate change.

Finally, most government policies, including research, development, and technology transfer are the long-term strategies and implemented gradually. As a result, the effects of them have not been seen for some time. Thus, farmers may not recognize government policies are currently being undertaken and how they affect the horticultural sector.

In summary, the NZ Government has introduced several policies on climate change, including the ETS. The ETS is one of the main policies on climate change and entered into force in 2008 with the forestry sector. The horticultural industry and many farmers were concerned that the ETS would have negative impacts on horticultural sectors with an increase of production cost. The SLMACC was the key policy on climate change for agriculture. The key parts of the SLMACC were research and the technology transfer programmes. However, field interviews revealed that many farmers had little knowledge on government policies on climate change and did not get involved in those government policies and activities. Also, many of farmers interviewed did not know about local government activities on climate change. This is because current climate change has so far had little influence on horticultural crop production and the horticulture sector relies heavily on lobby groups. Secondly, most government policies have focused on the dairy industry and mitigation of GHG emissions from livestock and pastures rather than horticultural crops. Thirdly, local councils have insufficient resources and budget to effectively deal with climate change. Fourthly, there is a lack of policy for enhancing business opportunity in current NZ government policies on climate change. Fifthly, it appears that a comprehensive approach and strategic long-term plans are insufficient as they currently stand in order to deal with some growing issues including relocation and water supply. Finally, it takes time, sometimes years, to see the effects of most government policies.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

Many scientific studies show climate change is occurring. From the IPCC reports, global average temperatures have increased by 0.74˚C in the last 150 years and sea level has risen by 3.1 mm per year in the last 10 year. It is evident that global warming and climate change have significant influence on agricultural sectors, including horticulture.

The NZ Government has introduced several policies on climate change, including the ETS and the SLMACC. The main objective of this study is to identify how government policies on climate change are been being implemented at farm production level. In order to achieve the goal, this study suggested four research questions: how is climate change affecting horticultural production? What concerns do farmers have in terms of climate change? What adaptation responses to climate change are farmers doing? How are government policies on climate change effective at farm production level?

The impacts of climate change

In terms of the impacts of climate change on horticultural production, there is considerable evidence to confirm climate change is occurring in New Zealand. Annual average temperatures have increased by 0.58˚C to 0.88 ˚C in Nelson over the last 100 years. Annual rainfall is changing with an increase in the western regions and a decrease in the eastern regions. However, field interviews and observations revealed that most farmers thought that climate was not changing even though someone agreed there were minor changes in temperatures. Thus, they didn't change their farming activities, such as planting and harvesting. From the case studies this study found that that there was no current significant impact of climate change on some horticultural crops, including citrus, wine grapes, apples, and vegetables. This is partly because NZ's climate change is not severe due to maritime climate system. Also, plants can adapt to mild climate change. In addition, adequate agricultural infrastructure in New Zealand helps mitigate the impacts of climate change on horticultural production.

The industry and farmer's concerns

Both the industry and farmers' had concerns about the ETS, water availability, flood protection, and disease control in terms of climate change. However, field interview showed that farmers had minor concerns about climate change issues except for the ETS. Water availability has never been an issue in cast study sites due to sufficient rainfall and aquifer. But the 2012/13 drought may make farmers reconsider their position. A farmer in Hawke's Bay expressed some concern about disease levels due to recent cooler and wetter summers.

Adaptation responses

From field interviews and observation, most farmers were doing little adaptation responses to climate change. This is because they didn't think of climate change as an issue in their regions. Thus, they were not concerned about climate change. Just an apple orchard in Hawke's Bay was running frost protection fans to prevent the damage from the late frost events.

The effectiveness of government policies on climate change

From the case studies, government (central and local) policies and activities seem to currently have little effect at the farm production level. Field interviews revealed that many farmers had little knowledge on government policies on climate change and didn't involve themselves in those government policies and activities. Also, many of farmers interviewed were not aware about local government activities on climate change. This is because firstly, farmers who have a short-term view tend not to pay attention to long-term threats, such as climate change and they leave it to their industry representatives such as HortNZ. Secondly, many NZ government policies on climate change are focusing on the dairy industry and mitigation of GHG emissions from livestock and pasture. Thirdly, local council resources and finance are not sufficient to deal with many issues on climate change. Fourthly, a lack of policies for enhancing business opportunities is one of the limits of NZ government policies on climate change.

Fifthly, NZ policies on climate change are on the industry basis and have little comprehensive approach. Finally, most government policies, including research, development, and technology transfer are long-term strategies. However, it is hard to conclude that government policies and activities on climate change are not effective at horticultural farm production level even though the farmers had little knowledge about government policies and activities on climate change and didn't involve in them until now. This is because as mentioned, the effects of government policies may be somewhat passive and can be realized later or longer term.

7.2. Recommendations

7.2.1 Recommendations for policy makers

Firstly, the Government needs to develop more policies for enhancing horticultural sector adaptability to climate change. Currently, most government policies on climate change are focusing on mitigation of GHG emissions from livestock and pasture. However, the horticultural industries are playing important role in NZ's commodity exports. Also, horticultural crops are susceptible to the impacts of climate change, such as rising temperatures, droughts and floods. Thus, adequate policies are necessary to promote famers' adaptation responses to climate change.

Secondly, government policy on adaptation to climate change needs to focus on enhancing of horticultural industries' resilience on climate extremes. Climate has always fluctuated and year-to-year variations in climate are bigger than climate change. Also, as climate change is going on, climate extremes are expected to influence horticultural production more frequently and unexpectedly. Therefore, farmers need to raise their resilience on climate extremes to reduce the damage. In order to raise resilience, the Government needs to increase their investment for agricultural infrastructures, including dams, aquifer, and stop-bank.

Thirdly, the central Government needs to provide more financial support to local councils in order to improve their capability of undertaking adaptation activities to climate change, such as building dams and improving stopbanks. Local councils are doing the first and tactical adaptation responses including, securing water availability, enhancing flood protection, and improving pest and disease control. However, local councils have insufficient resources and the budgets to deal with lots of issues on climate change. Thus the central Government's supports are required to improve local councils' adaptation response.

Fourthly, the Government needs to develop comprehensive and long-term strategies for relocation and increasing water supply. According to NIWA's projection, NZ's average temperatures will increase by about 2˚C by 2090. If NIWA's projection comes true, the most realistic option for some sectors or horticultural industries would be relocation or re-establishing in regions with a better alignment to crop needs. However, competition for land and water will be seriously issued if relocation happens. Therefore, the Government should prepare long-term strategies for relocation and replacement, and securing water availability including construction of new dams.

Fifthly, the Government needs to provide famers with more educational opportunity in order to improve their knowledge about climate change. Most farmers cannot recognize the significance of climate change on their farming before serious damages from climate change have occurred. Therefore, the Government needs to give farmers a warning using education in order to promote farmers' adaptation responses. For example, between April and June 2012, 13 workshops for lead farmers and rural professionals were held over the country in order to improve their knowledge on managing farm businesses in a changing climate. The Government needs to provide those educational opportunities for more farmers.

Finally, the Government needs to provide support to develop new business opportunities in terms of climate change. The USA and Canadian Governments provide financial support for improved research, development and on-farm projects in the area of bio-fuel to expand new business opportunities. The UK Government also supports research and development in the areas of anaerobic digestion and non-food crops. The NZ government supports two professorships for bio-char research. The support for new business opportunities in terms of climate change needs to expand into broader sectors. New Zealand agriculture has global competitiveness in the areas of agricultural research and development. Thus, NZ agricultural industries need to utilize their ability to enlarge new business chance.

7.2.2 Recommendations for further research

The objective of this study was to identify how government policies on climate change have been being implemented at farm production level. This study used case study and field interviews to achieve the objective. However, the case study was implemented at only seven farms due to the limit time of the study and therefore, it is hard to conclude that those farms represented all horticultural farms. Thus, it is highly recommended that further research should have more, and diverse, case studies and examples to fully explore the effectiveness of government policies on climate change.

Most interviews of this case study took around 1-2 hours. However, that was insufficient time to get enough thorough information from the farmers. When interviewing, interviewees couldn't always concentrate on the research questions. They often told their individual things. Of course, it is useful to let interviewees to talk about their individual affairs in order to make friendly environment for interviewing. Thus, sufficient time will be required to get more detailed information on research questions and the broader use of interviews and questionnaires for data collection.

This study used qualitative research methods to identify the effectiveness of government policies. However, using both qualitative and quantitative research methods are better to achieve the objective of the study. A survey with enough cases for quantitative analysis would be effective to giving evidence on how the farmers feel about government policies on climate change and provide further options for improving those policies. Closed questions will be more useful for quantitative research.

Random sampling methods can be useful to select the cases. This study had just 7 cases and the researcher selected the cases considering his intrinsic interest and convenience for research. However, if many cases were selected and investigated, random sampling methods would be more effective.

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APPENDICES

Appendix 1: Project list funded by SFF with regard to climate change

Year	Applicant Group	Project Title
2007	Foundation for Arable Research	Using maize to manage dairy shed effluent
2007	Ngati Whakaue Tribal Lands Incorporated (NWTL)	On-farm mitigation options to control nutrient losses
2007	West Coast Dairy Farmers on Modified Soils	Best management practices to optimise nutrient use efficiency on modified soils of the South Island West Coast
2007	Foundation for Arable Research	Developing a climate change strategy for the NZ Arable Industry
2007	Irrigated Dairy Farmers Group	Adapting to a drier environment by improving irrigation practices
2007	New Zealand Winegrowers through Sustainable Winegrowing New Zealand	Sustainable Water Use Indicators for Grape and Wine Production 1: Irrigation
2007	Canterbury/North Otago irrigated pastoral farmers	Spatial mapping of soil water holding capacity to improve irrigation efficiency for pastoral farms
2007	Stand-off Facility User Group	Grazing strategies and standoff use to minimise nitrogen derived emissions from dairy farms
2007	National Climate Impact Group	Monitoring Climate Change on Pasture Production: Phase 1
2008	STIMBR (Stakeholders in Methyl Bromide Reduction)	Alternatives to methyl bromide fumigation for forest exports
2008	The protein extractors	Protein extraction from pasture
2008	Fonterra and AgResearch in conjunction with farmers from the Lake Rotorua Catchment	Greenhouse gas mitigation opportunities on dairy farms using Overseer and Udder modelling tools
2008	Stratford Demonstration Farm Society	Taranaki farm system environmental evaluation
2008	Sheep & Beef Farmers Climate change Group	Understanding Climate change and GHG emissions on sheep & beef farms
2008	New Zealand, Boysenberry Council, Wellington	Greenhouse gas footprinting and adapting berry production to Climate change
2008	Dairy Carbon Footprint - Conventional and Organic Production	Dairy Carbon Footprint - Conventional and Organic Production
2008	Onions New Zealand Inc.: An Integrated Industry	Onion's Carbon Footprint and Industry Strategy
2008	NZ Landcare Trust	Towards Resilient Farmers in Northland
2008	Hawke's Bay climate change adaptation group	Adapting to Climate change in hill country Hawke's Bay
2008	Pastoral meat farming community group	New priorities for meat producers adapting to impacts of Climate change and changing land use
2008	Hawke's Bay Focus Vineyard Group	Hawke's Bay Winegrowers' Climate change Project
2008	Risk - Averse Sheep Farmers of Canterbury, Southland and Otago	Lamb Alive: a long term approach to an annual risk
2008	Ruakura FE Group	Managing increasing facial eczema challenges in dairying
2008	Foundation for Arable Research (FAR)	Improving water use efficiency to adapt arable farms to Climate change
2008	TANES TREE TRUST	National survey of indigenous plantations for carbon accounting
2008	Montfort Trimble Foundation	Enhancing pastoral farming sustainability through carbon sequestration
2008	Farmers, Farm Foresters & Forest Managers. The NZ Landcare Trust and NZ Farm Forestry Association	Carbon Farming: Opportunities & Issues for Rural NZ, Information transfer for Landowners and Managers
2008	Blackcurrant New Zealand	Adapting Berry Production to Climate Change

2008	LandWISE and FAR as leaders of consortium	Using Advanced Technology to Create Sustainable Cropping Systems
2008	Central Regions, NZDFA Deer Industry Focus Farm Community Group	Determining net Greenhouse Gas (GHG) emissions and Environmental Footprints of a Deer Focus Farm
2008	Te Arawa Lakes Trusts/Scion Partnership	Vermicomposting of lake weeds and pulp & paper solids for carbon resource recovery for primary sectors
2008	Earthwise Consulting Ltd	Adaptation of lowland/coastal dairy farming in the Bay of Plenty
2008	Summerfruit NZ	Scoping the implications of Climate change for the Summerfruit Industry
2008	The New Zealand Farm Forestry Association	Adding to the Farm Forestry Model
2008	New Zealand Biochar Network	New Zealand Biochar Network
2008	Te Tumu Kaituna 7B2 Trust	Field measurement of existing Chinese tallow trees and their potential for bio-diesel production in NZ
2009	Huatokitoki Landcare Community Project	Creating a Climate for Success - Huatokitoki Community Catchment Management Project
2009	North Canterbury Farmers' Group	Dryland pasture persistence
2009	Foundation for Arable Research	Preparing For a Drier Future by Discovering Crop Cultivars with Better Water Use Efficiency
2009	Carbon in Orchard Soils Team (COST)	Carbon storage in kiwifruit orchards to mitigate and adapt to climate change
2009	High Country Land Managers	High Country Carbon Project
2009	Poukawa Research Foundation	Reducing urinary nitrogen in farm systems to minimise nitrous oxide emissions
2009	Forest industry Footprint Collaborative	Greenhouse Gas Footprint Program for New Zealand's Forest and Solid Wood Industries
2009	Adapting productive coastal landuses to Climate Change	Dune Restoration Trust of New Zealand (Dunes Trust)
2009	Avocado Growers' Association	Preparing the NZ avocado industry for climate change
2009	New Zealand Farmers via the arable sector levy group the Foundation for Arable Research	Quantifying Soil Carbon Pools in New Zealand Soils
2009	New Zealand Land Treatment Collective	Review of hardwoods in effluent schemes
2009	Foundation for Arable Research	Reducing N20 Emissions from the Arable industry through best practice
2010	House wintering system interest group	Greenhouse gas (GHG) footprints from dairy farm systems associated with housed wintering systems
2010	Marlborough Research Centre Trust (MRCT) on behalf of the New Zealand Dryland Forest Initiative (NZDFI)	Establishing forests of genetically improved durable eucalypts in NZ drylands
2011	New Zealand Farm Forestry Association	Trees on farms workshops
2011	Visionary East Coast Group	Future Farming Systems for East Coast Dryland

Appendix 2: Research projects funded by the Government with regard to climate change

1. Impacts of and Adapting to climate change

Organisation	Finish Date	Subject Area	Report Title
EcoClimate Consortium	30-Apr-08	Climate change and agricultural production	Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand Agriculture: What Do We Know so Far?
AgResearch	30-Jun-08	Improved field facilities to study climate change impacts and adaptations in pasture	Improved Field Facilities to Study Climate Change Impacts and Adaptations in Pasture
AgResearch	30-Jun-08	Enhanced modelling capability to conduct impact assessments	Enhanced modelling capability to conduct climate change impact assessments
Aqualinc Research Ltd	30-Jun-08	Adaptation vulnerability and impacts of climate change on NZ's pastoral systems	Projected Effects of Climate Change on Water Supply Reliability in Mid-Canterbury
Auckland UniServices Ltd	30-Jun-08	Vulnerability of NZ pastoral farming to the impacts of future climate change and the soil water regime	Vulnerability of New Zealand pastoral farming to the impacts of future climate change on the soil water regime
Crop & Food Research	30-Jun-08	Forage crop opportunities as a result of climate change	Forage crop opportunities as a result of climate change
Earthwise Consulting Limited	30-Jun-08	Adaptation - developing case studies in the Kiwifruit Industry	Adapting to climate change in the kiwifruit industry
NIWA	30-Jun-08	Impact of climate change on drought and agricultural production	Drought, Agricultural Production & Climate Change – A Way Forward to a Better Understanding
Landcare Research	30-Jun-08	Climate change risks to pastoral production systems	Climate change risks to pastoral production systems
Scion	30-Jun-08	The effect of climate change on New Zealand's planted forests	The effect of climate change on New Zealand's planted forests. Impacts, risks and opportunities
Scion	31-Dec-09	Climate change and fire danger	Improved estimates of the effect of climate change on NZ fire danger
NIWA	Mar-09	Frost	Recent frost trends for New Zealand
NIWA	Mar-09	Frost	Recent trends in frost in New Zealand
NIWA	31-Dec-09	Impacts of climate change on soil conditions, river flow and floods	Flood risk under climate change
NIWA	31-Dec-09	Climate change and extreme winds	
NIWA	31-Dec-09	Climate change and drought risk	
AgResearch	31-Dec-09	Climate change and pasture performance	Improving Sustainable Life-time Performance of Pastures: Learning from Extreme Climatic Events
AgResearch	31-Dec-09	Subtropical boundaries under climate change	Tomorrow's pastures: subtropical grass growth under climate change
Scion	31-Dec-09	Future proofing plantation forests from pests	Factsheet: The threat to New Zealand's plantation forests from four pests under a changing climate

MWH	30-Jun-10	Climate change on rural water infrastructure	Impacts of Climate Change on Rural Water Infrastructure
MWH	30-Jun-10	Climate change on rural water infrastructure	Climate Change Impacts on Rural Water Infrastructure
AgResearch	30-Jun-10	Climate change and biocontrol	Possible impacts of climate change on biocontrol systems in New Zealand
AgResearch	30-Jun-10	Climate change and biocontrol	Climate change and biocontrol systems
GNS	30-Jun-10	Climate impacts on hydrological systems	Framework for assessment of climate impacts on New Zealand's hydrological systems
Landcare Research	30-Jun-10	Planet to paddocks land-use trends: Impacts of climate change	
AgResearch	30-Jun-11	Elevated CO2 and productivity due to climate change	
Landcare Research	30-Jun-11	Farm adaptive capacity and finance	
Landcare Research	30-Jun-12	Catchment analysis of climate change	
NIWA	30-Jun-12	Climate change impacts and adaptation analysis for New Zealand's primary sector	

2. Forestry and Carbon Markets

Organisation	Finish Date	Subject Area	Report Title
URS New Zealand Ltd	30-Jun-07	Voluntary greenhouse gas reporting feasibility study	Voluntary Greenhouse Gas Reporting Feasibility Study
NZ Institute for the Study of Competition and Regulation	30-Jun-08	Forest and forest land valuation	Forest and Forest land valuation: How to value forests and forest land to include carbon costs and benefits
Scion	30-Jun-08	The effect of climate change on New Zealand's planted forests	The effect of climate change on New Zealand's planted forests. Impacts, risks and opportunities
Scion	30-Jun-08	Life Cycle Assessment (LCA): adopting and/or adapting overseas LCA data and methodologies for building materials in New Zealand	Life Cycle Assessment Adopting and adapting overseas LCA data and methodologies for building materials in New Zealand
Scion	30-Jun-08	Forest management for carbon and carbon price risk	Managing New Zealand planted forests for carbon a review of selected management scenarios and identification of knowledge gaps
University of Canterbury	30-Jun-08	Carbon trading and forestry decision-making, carbon accounting and forest growth rates	Impact of the ETS on Forest Management
University of Canterbury	30-Jun-08	Carbon trading and forestry decision-making, carbon accounting and forest growth rates	Forestry Accounting Options
University of Canterbury	30-Jun-08	Carbon trading and forestry decision-making, carbon accounting and forest growth rates	Carbon Accounting: Forest Growth Rates and Changing Climates
URS New	30-Jun-08	Forest risk management strategies - how can forest owners manage	Carbon Risk Management Strategies for Forest Owners in New Zealand

Zealand Ltd		risk and uncertainty associated with carbon prices?	
University of Otago	30-Jun-08	Voluntary carbon markets - analysis of risks and opportunities: Investigating the social dynamics of emissions trading scenarios in NZ's pastoral sector	New Zealand Pastoral Farmers and the Mitigation of Greenhouse Gases in the Agricultural Sector
The Karo Group Ltd	30-Jun-08	Identification and analysis of voluntary carbon market opportunities for the NZ agriculture and forestry sectors	Final Report on the Study on Global Voluntary Carbon Market Opportunities for New Zealand Agriculture and Forestry
University of Canterbury	31-Dec-09	Managing risks in carbon forestry	Quantification and Management of the Risk of Wind Damage to New Zealand's Planted Forests
Scion	31-Dec-09	Future proofing plantation forests from pests	Future proofing plantation forests from pests
Scion	31-Dec-09	Future proofing plantation forests from pests	The threat to New Zealand's plantation forests from four pests under a changing climate
Scion	31-Dec-09	Improving the Eucalyptus fastigata growth model	Eucalyptus fastigata carbon sequestration web tool
Scion	31-Dec-09	Improving the Eucalyptus fastigata growth model	Development of a carbon sequestration web tool for Eucalyptus fastigata
Scion	31-Dec-09	Improving the Eucalyptus fastigata growth model	Above- and below-ground carbon in Eucalyptus fastigata in the Central North Island of New Zealand
Scion	31-Dec-09	Reducing harvesting costs	
Landcare Research	30-Jun-10	Development of forest productivity surfaces	Productivity surfaces for Pinus radiata and a range of indigenous forest species under current climatic conditions, and exploration of the effect of future climatic changes on Pinus radiata productivity
Scion	30-Jun-11	Land use tools	
Scion	30-Jun-11	Douglas-fir model enhancement for carbon	
University of Canterbury	30-Jun-12	Forestry systems for difficult sites	
Scion	30-Jun-12	Future forest systems	
Scion	30-Jun-13	Resilient new indigenous forests	

3. Addressing Greenhouse Gases from Agriculture

Organisation	Finish Date	Subject Area	Report Title
Bruce D White Consulting Limited	30-Jun-06	Climate change policy measures to address agriculture sector GHG emissions	Climate Change Policy Measures to address Agriculture Sector GHG Emissions
AgResearch /PGGRC	30-Jun-08	Fermentation systems for rapid and accurate modelling of rumen function	A fermentation system for rapid and accurate modelling of rumen function
AgResearch	30-Jun-08	Manipulating rumen fermentation for lower methane emissions	Developing better methods for culturing rumen bacteria: A Summary Report.
AgResearch/ PGGRC	30-Jun-08	Ruminant methane-extension of the animal calorimetry facility at AgResearch Grasslands	Ruminant methane – Extension of the animal calorimetry facility at AgResearch Grasslands
AgResearch	30-Jun-08	Rapid assessment of nitrous oxide	Rapid Assessment of Nitrous Oxide
AgResearch/ PGGRC	30-Jun-08	Assessing the role of dietary carbohydrate to protein ratios on greenhouse gas emissions from pastoral agriculture	Assessing the role of dietary carbohydrate to protein ratios on GHG emissions from pastoral agriculture

AgResearch	30-Jun-08	Development of a urine sensor to measure urinary nitrogen concentrations in situ	Urine sensor development project for MAFpol
AgResearch	30-Jun-08	Quantifying the variability of the effectiveness of nitrification inhibitors on nitrous oxide emissions	Quantifying the Variability of the Effectiveness of Nitrification Inhibitors on N2O emissions (P21 lysimeter trial)
Diffuse Sources Ltd	30-Jun-08	Significance of wetlands in the agricultural landscape as sources of nitrous oxide emissions	Significance of wetlands in the agricultural landscape as sources of nitrous oxide emissions. A review and synthesis of hypotheses
Landcare Research	30-Jun-08	Soil Methanotrophy-A Novel methane mitigation Technology	Soil Methanotrophy-A Novel methane mitigation Technology?
Lincoln University	28-Aug-08	Nitrous oxide-novel mitigation methodologies	Nitrous Oxide-Novel Mitigation Methodologies: Objective 1 - Hippuric Acid effects on N2O emissions.
Lincoln University	28-Aug-08	Nitrous oxide-novel mitigation methodologies	Nitrous Oxide-Novel Mitigation Methodologies: Objective 2 - Biochar effects on urinary-N N2O emissions.
Lincoln University	30-Jun-08	Alternative methods of direct rumen methane assessment	Novel methane assessment in ruminants
Lincoln University	30-Jun-08	Diagnostic tests for greenhouse gas production	Diagnostic Tests For Greenhouse Gas Production
MWH New Zealand Ltd	30-Jun-08	Methane from animal waste management systems	Methane from Animal Waste Management Systems
NIWA	30-Jun-08	Agricultural mitigation rapid assessment of methane and nitrous oxide	Agricultural greenhouse mitigation - methods for rapid assessment of methane and nitrous Oxide
On-Farm Research Ltd	30-Jun-08	Improving the sheep component of the methane model and provide management strategies for farmers to reduce methane production	Modelling management change on production efficiency and methane output within a sheep flock
AgResearch	31-Dec-09	Plant canopy nitrous oxide emissions	Plant canopy nitrous oxide emissions
AgResearch	31-Dec-09	Forage/fungal associations for reducing methanogenesis	Forage-fungal associations and effects on methanogenesis
Massey University	30-Jun-10	Can cattle do it?: Agriculture: mitigation potential of new or alternative technologies	Assessment of the influence of biochar on rumen fermentation: A laboratory-scale experiment
Landcare Research	30-Jun-11	Ammonia from animal excreta	
Landcare Research	30-Jun-11	Mitigation technologies for methane	
Dairy NZ	30-Jun-11	GHG mitigation using efficient cows	
NIWA	30-Jun-11	Paddock to regional GHG management and mitigation of N2O emission	
PGGRC	30-Jun-11	Enteric methane mitigation	
PGGRC	30-Jun-11	Accelerated ruminant methane mitigation	
Lincoln University	30-Jun-11	Negative N2O fluxes - importance to New Zealand	
AgResearch	30-Jun-12	Identifying non-agricultural and agricultural plant species with anti-methanogenic properties	
AgResearch	30-Jun-12	Farm management and GHG for pastoral sector	
PFR	30-Jun-12	Closed-loop N-supply biofuel crops	
PGGRC	30-Jun-12	Sheep, cattle, and methane predictors: Agriculture: identifying and exploiting genetic variation of GHG emissions	

4. Soil Carbon and Biochar

Organisation	Finish Date	Subject Area	Report Title
Landcare Research	30-Jun-08	Carbon stocks and change in NZ's soils and forests, and the implications of post-2012 accounting options for land based emissions offsets and mitigation opportunities	Carbon Stocks and Changes in New Zealand's Soils and Forests, and Implications of Post-2012 Accounting Options for Land-Based Emissions Offsets and Mitigation Opportunities
Landcare Research	31-Dec-09	Review of soil carbon methodologies	Review of soil carbon measurement methodologies and technologies, including nature and intensity of sampling, their uncertainties and costs
AgResearch	31-Dec-09	Modelling pastoral soil carbon	Modelling pastoral soil carbon
Lincoln University	30-Jun-10	Biochar in grazed pasture systems	
Landcare Research	30-Jun-13	Soil carbon stocks and changes	
Massey University	30-Jun-13	Soil carbon sink enhancement	

5. Living with Climate Change (Economic and Social Issues)

Organisation	Finish Date	Subject Area	Report Title
Auckland UniServices Ltd	30-Jun-08	Information, decision and action: the factors that determine farmers' environmental behaviour	Information, Decision and Action The Factors that Determine Farmers Environmental Decision-making
AgResearch	30-Jun-08	Learning from past adaptation to extreme climatic events: a case study of drought	Learning from past adaptations to extreme climatic events: A case study of drought. Part A: Summary Report
AgResearch	30-Jun-08	Learning from past adaptation to extreme climatic events: a case study of drought	Learning from past adaptations to extreme climatic events: Part B: Literature Review
AgResearch	30-Jun-08	Learning from past adaptation to extreme climatic events: a case study of drought	Learning from past adaptations to extreme climatic events: A case study of drought Part C: Main Report
AgResearch	30-Jun-08	Learning from past adaptation to extreme climatic events: a case study of drought	adapting to a changing climate: Case Study 2: Drought Learning from the past
Nimmo-Bell & Company Ltd	30-Jun-08	Bridging the gap between environmental knowledge and Research, and desired outcomes to achieve sustainable land management - Phase 3	Bridging the gap between environmental knowledge and research, and desired environmental outcomes to achieve sustainable land management. Phase three.
Lincoln University	31-Dec-09	Climate change and international trade	
Landcare Research	30-Jun-10	Climate change and Maori land: business opportunities as it affects Maori owned land.	Climate change business opportunities for Maori land and Maori organisations
Viclink - Victoria University	30-Jun-11	Implications of alternative GHG metrics - global warming potential & global temperature potential	
MOTU	30-Jun-12	Coordination and cooperation: Economic and systems analysis of climate change impacts and adaptation measures	
Landcare Research	30-Jun-13	Integrated global environment and economic trade assessment modelling	

Appendix 3: Questionnaire

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Information on the Research

Research Title:	The Impacts of Climate Change and the Effectiveness of Government Policies on Climate Change at Farm Production Level: A Case Study
Researcher:	Choul Kim, MA Thesis, Massey University

BACKGROUND

There is a general consensus that over the last five years the seasons have changed towards warmer winters, unpredictable spring condition with increased late spring frost, warmer autumns, and increased frequency of hail and strong winds. According to Ministry for the Environment, mean temperature is expected to increase up to 2.2 ℃ within 2090 and at the same period, rainfall is predicted to decrease in the east regions, such as Hawke's Bay, Canterbury and Otago.

Climate change can have significant influence on horticultural production. For example, warmer winters can affect breaking dormancy of many perennial crops, such as pip-fruit and result in a delayed bud burst, a lower bud break rate, subsequent slower and weaker growth, and the decrease of fruit yields and quality. Also, rising temperature can cause the increase of pest, weeds and diseases. The change in rainfall can result in lack of water supply. Therefore, appropriate adaptation responses at farm production level are required to address current climate change. Also, support or steps from regional and central government are essential to facilitate farmer's adaptation responses.

NZ government introduced several policies on climate change, such as Emission Trading Schemes (ETS), Fund and technology developing and transfer in order to mitigate greenhouse gas emissions and support adaptation responses. However, many of support and policies are related to dairy production not horticultural production and it is not certain whether those policies are being implemented effectively at farm production level or not.

WHAT IS THE PURPOSE OF THIS RESEARCH?

The purpose of this research is
- To identify the impacts of current climate change on horticultural crop production
- To identify farmer's adaptation responses to address climate change

- To identify whether NZ government support or policies on climate change are being implemented effectively at farm production level

WHAT WILL HAPPEN DURING INTERVIEWS AND HOW LONG WILL IT TAKE?

A participant, interviewee will be asked several questions on the impacts of climate change and the effectiveness of government support or policies. The interviewee can answer his knowledge or opinion on the questions freely. It will take 1 to 2 hours to do an interview.

THE RISKS AND THE BENEFITS OF THIS RESEARCH

There are no foreseeable risks to participating. A participant will not benefit directly from this research. However, in the future, the horticultural industry including the citrus and potato industries will benefit from this research because the findings from this research can be utilized to develop and introduce more efficient government support and/or policies on climate change.

CONFIDENTIALITY

Privacy and confidentiality of the participants are important and must be protected thoroughly. Thus, the confidentiality of information collected during interviews will be respected to the extent permitted by law. If the results of this research are published, participants' identity will not be made public, nor will the information be reported in a way that individuals or firms could be identified with responses.

DO A PARTICIPANT HAVE A CHOICE TO BE IN THE RESEARCH?

You will not lose any benefits or rights you would normally have if you choose not to take part in this research. You can stop at any time during the interview and the research. You still keep the benefits and rights you had before taking part in this research and will not be treated differently if you decide to stop taking part in this research. The participant can skip any questions that he prefers not to answer. If the participant chooses to withdraw from this research before it ends, the researcher may keep information collected and this information may be included in the thesis.

WHAT IF I HAVE QUESTIONS?

If you have any question on this research, please contact: Choul Kim, telephone (021) 069 4999, email hopelasa@gmail.com

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.

If you have concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor John O'Neill, Director (Research Ethics), telephone (06) 350 5249, email humanethicspn@massey.ac.nz

Thank you for your time and contribution to this questionnaire.

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Interview Questionnaire

I have read the information sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time. I agree to participate in this research under the conditions set out in the information sheet.

Signature: ……………………………………….. **Date: ………….……………………….**

Full Name Printed: …………………………………………..

QUESTIONS:

Owner name: ……………………………………………………………………………

Farm name: ……………………………………………………………………………

Address: ………………………………………………………………………………

Ph: ……………………………………….. Mobile: ………………………………………

Email: …………………………………………………………………………………

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1. BASIC INFORMATION

<Farm size>

Q1. Could you let me know how large your farm size is and how long you have been running your farm? Could you outline your farm history briefly?

Total farm area (ha): ……………………………………………………………………

History: …………………………………………………………………………………

<Production focus>

Q2. What sorts of crops and varieties are grown in your farm? How large is the size of the cultivated area of each crop? How much does your farm yield annually?

Plants or animals	Variety	Cultivated area (ha)	Annual yields
e.g. potatoes			

<Soil type>

Q3. Could you explain soil type and topography of your farm?

Soil type and topography: ……………………………………………………………………………

………………………………………………………………………………..

………………………………………………………………………………..

<Water source and availability>

Q4. Where are the main water sources of your farm and how do you utilize them? And how is the availability of these water sources?

Irrigated/not irrigated: ……………………………………………………………………………

Water source: ………………………………………………………………………………………

Water availability: …………………………………………………………………………………

<Social: farm management, workers>

Q5. How many people work on your farm? How do you manage your farm?

Workers: ……………………………………………..

Facilities: ……………………………………………………………………………………………

Machinery: …………………………………………………………………………………………

Farm management: …………………………………………………………………………………

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2. MAIN CLIMATE FEATURES AND CHALLENGE

<Current climate change>

Q6. Could you give me basic information on climate in your area? (e.g. general climate of four seasons, average temperature and rainfall, etc.)

Climate: ………………………………………………………………………………………………

Q7. What do you think about climate change? Do you think that climate change is happening in your area? Could you explain climate change in your area?

Q8. Have you experienced climate extremes, such as extreme heat and cold, severe droughts and floods, strong wind and hail in the last 10 years? When? How often? Could you explain it?

Climate extremes

- Droughts: ………………………………………………………………………………………
- Floods: …………………………………………………………………………………………
- Wind: …………………………………………………………………………………………
- Hail: ……………………………………………………………………………………………
- Others: …………………………………………………………………………………………

<Main climate features and challenge>

Q9. What do you think is **<u>the main concern or issue about climate change</u>** at your farm?

Temperature (e.g. warmer winter and autumn, hot summer, and etc.): …………………………

Droughts or Floods: ………………………………………………………………………………

Pest, weeds and disease: …………………………………………………………………………

Frost (e.g. late spring frost risk): …………………………………………………………………

Strong wind: ………………………………………………………………………………………

Hail: ………………………………………………………………………………………………

Post-harvest: ………………………………………………………………………………………

Others: ……………………………………………………………………………………………

Q10. What do you think will be the most significant issue of climate change on your crop production in the future (during next 10 years)?

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3. <u>ADAPTATION RESPONSES TO ADDRESS CURRENT CLIMATE CHANGE</u>

<Current adaptation responses>

Q11. What adaptation responses (or management tools/systems) **<u>do you think are necessary</u>** to address current climate change?

High temperature (e.g. warmer winter and autumn, hot summer, and etc.): ……………………

Droughts or Floods: ………………………………………………………………………………

Pest, weeds and disease: ……………………………………………………..……………………

Frost risk: ………………………..…………………………………………………………………

Strong wind: ………………………………………………………………………………………

Hail: …………………………………………………………………………………………………

Post-harvest: ………………………………………………………………………………………

Others: ………………………………………………………………………………………………

Q12. What adaptation responses (or management tools/systems) **<u>are you making to</u>** address current climate change?

High temperature (e.g. warmer winter and autumn, hot summer, and etc.): …………………

Droughts or Floods: …………………………………………………………………………

Pest, weeds and disease: ……………………………………………..…………………

Frost risk: ……………………..……………………………………………………………

Strong wind: …………………………………………………………………………………

Hail: ……………………………………………………………………………………………

Post-harvest: …………………………………………………………………………………

Others: …………………………………………………………………………………………

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4. GOVERNMENT POLICY ON CLIMATE CHANGE

<Central government>

Q13. Do you know any of the government policies on climate change? If yes, what support or policies on climate change are you aware of? And where did you get information on them (information source)?

(e.g. Government supports or policies on climate change: technology developing and transferring, funds, local water supply schemes and Emission Trading Schemes (ETS))

Q14. Do you know about ETS? How do you think ETS will affect your farm management? What influence do you think ETS has on your farm management and crop production?

Q15. Do you participate in ETS? If yes, how do you prepare for ETS? If no, why did you not participate in ETS?

Q16. Do you know there are several MAF funding programmes for adaptation responses such as sustainable farming fund and community irrigation fund? Have you ever used these funds? If yes, which fund did you use, why and how? If no, why did you not use these funds?

Q17. MAF and related research institutes, such as Plant and Food Research, are developing and transferring technologies for climate change mitigation and adaptation. Do you know about that? And have you ever used these technologies?

Q18. Have you utilized others government supports or policies to address climate change? If yes, why and how did you utilize it?

Q19. How do you feel about the effectiveness of government supports or policies on climate change? Do you think that they are being implemented effectively at farm production level in order to address climate change?

Q20. What supports or policies do you think are required from central government to address climate change? Do you have any suggestions?

<Local governments>

Q21. Have you ever received any supports from local governments, such as regional council to address climate change? If yes, how did local governments help you? What is local government doing to address climate change?

Q22. How do you feel about the effectiveness of local government supports or policies on climate change? Do you think that they are being implemented effectively at farm production level in order to address climate change?

Q23. What supports or policies do you need from local government to address climate change? Do you have any suggestions?

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5. LOCAL COMMUNITY AND INDUSTRY

<Local community activities>

Q24. Is there any regional or crop specific community activities or farmers' meetings to discuss the issues on climate change?

(e.g. Hawke's Bay Climate Change Adaptation Group for discussing issues on climate change, adaptation responses and community irrigation schemes)

<Industry>

Q25. What has the industry or the growers' organization been doing to support farmer's adaptation response?

Q26. What supports do you need from the industry or the growers' organization to address climate change?

Appendix 4: Massey University HEC's confirmation of low risk

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

2 May 2012

Choul Kim
6 Battersea Place
Roslyn
PALMERSTON NORTH 4414

Dear Choul

Re: Effect of Climate Change on Horticulture

Thank you for your Low Risk Notification which was received on 26 April 2012.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

J. O'Neill

John G O'Neill (Professor)
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

cc Dr Nick Roskruge
Institute of Natural Resources
PN433

Prof Peter Kemp, HoI
Institute of Natural Resources
PN433

Massey University Human Ethics Committee
Accredited by the Health Research Council

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