

**FARM-LEVEL VULNERABILITY TO CLIMATE
CHANGE IN THE EASTERN BAY OF PLENTY,
NEW ZEALAND, IN THE CONTEXT OF
MULTIPLE STRESSORS.**

A thesis submitted in partial fulfilment
of the requirements for the Degree of
Doctorate of Philosophy in Geography
in the University of Canterbury by

NICHOLAS A. CRADOCK-HENRY

2011

Abstract

Climate change research is undergoing a monumental shift, from an almost exclusive focus on mitigation, and the reduction of greenhouse gases, to adaptation, and identifying the ways in which nations, communities and sectors might best respond to the reality of a changing climate. Vulnerability assessments are now being employed to identify the conditions to which socio ecological systems are exposed-sensitive and their capacity to adapt. Work has been conducted across a range of geographical locations and systems as diverse as healthcare and mining. There are however, few examples of analyses incorporating an assessment of the multiple climatic and non-climatic stressors to which agricultural producers are exposed.

This thesis examines farm-level vulnerability to climate change of agricultural producers from the Eastern Bay of Plenty, New Zealand. The study area has a diverse agricultural economy, founded upon pastoral farming (dairy and drystock) and kiwifruit. This dependence on agricultural production, and the likely influence of expected changes in climatic conditions in the future provided a unique setting in which to develop a place-based case study exploring vulnerability to future climatic variability and change. Using a mixed methods approach, including semi-structured interviews and temporal analogues, a conceptual framework of farm-level vulnerability was developed and applied. The application of the framework was conducted through an empirical study that relied on engagement with and insights from producers who identified current exposure-sensitivity and adaptive capacity. It is shown that pastoral farmers and kiwifruit growers are exposed-sensitive to a range of climatic and non-climatic conditions that affect production, yields and farm income and returns. It demonstrates that producers have in turn, developed a range of short- and long-term adaptive strategies in order to better manage climatic conditions. It shows that these responses are varied, and are not made in response to climatic conditions alone, illustrating the need to consider other, multiple stimuli. An assessment of future vulnerability is presented, based on the empirical work and the identification of those drivers of vulnerability that are likely to be of concern and that will shape the capacity of farmers and growers to respond to climatic variability and change.

The thesis as a whole not only provides a place-based case study on the vulnerability of farmers and kiwifruit growers in eastern New Zealand, but also demonstrates the need to engage with producers in order to develop an understanding of the complex ways in which climatic conditions interact with non-climatic stimuli beyond the farm-gate to influence vulnerability to climatic variability and change, both now and in the future.

Acknowledgements

The path to the completion of this PhD was at times, completely obscured, and I could not have done it without the unconditional support of my supervisory committee who have gone above and beyond what should have been asked of anyone. I owe a debt of gratitude Prof. Eric Pawson, my supervisor, and Dr. Julie Cupples my associate supervisor, and to Dr. Gavin Kenny of Earthwise Consulting in Hastings, New Zealand. Their unflagging and at times, undeserved support, wisdom, experience, friendship and grace have helped make this work possible. Thank you. A special thanks to Gavin, for his friendship, mentoring and encouragement, from the beginning and, in spite of it all, for helping shepherd this work through to completion. My sincere thanks to Dr. Willie Smith, Department of Geography, University of Auckland and Dr. Carina Keskitalo, Department of Social and Economic Geography, Umeå University, Sweden, for agreeing to be external examiners and for the insights and comments they bring to this work from their respective fields of expertise. Many thanks also to Dr. Bronwyn Hayward, for her support and encouragement throughout this study.

The Department of Geography at Canterbury provided generous support for conference travel and research funding. Thank you also to Education New Zealand for an International Doctoral Research Scholarship and the Social Sciences and Humanities Research Council of Canada for funding this research through a SSHRC Doctoral Fellowship.

Essential to this work was the participation of nearly eighty dairy and drystock farmers and kiwifruit growers in the eastern Bay of Plenty, who took time out of their busy schedules to accommodate the interviews and questions contained herein, and introduced me to the challenges and experience of farming in the area. My sincere thanks to you all, and I trust this work is a fair and accurate representation of relevant conditions and concerns and above all, of the practical wisdom and inherent capacity contained therein, for successful adaptation to climate change.

Among the numerous people I met during my research a special thanks goes to Michelle Lee and John Douglas of the Bay of Plenty Regional Council; Alan and Viv Barr for engaging conversation and home cooked meals; Keith Melville for the rental home; and Nada for showing me the East Cape.

I am grateful to Prof. Kenneth Hewitt, my Master's supervisor, who first challenged (and inspired) me as a natural scientist to think about the role, influence and importance of social conditions in risk analysis, and for his continued friendship. Thanks also to Dr. Leif Burge and the Department of Geography and Earth and Environmental Science at Okanagan College for the opportunity to lecture in physical geography during the completion of this research.

To my family who are scattered about Canada, and a most excellent of sisters currently living in London (I love you Moo!), thank you for everything, for believing and encouraging and for the trampoline to spring to ever greater heights. Thank you also to Christine and Peter and Co. in Turramurra for the home away from home these last couple of months. I can't tell you what it's meant. For tolerating (or maybe appreciating) my absences, overdue gratitude to friends in the Okanagan and former students (Crystal!) who've shouted out in these final weeks.

Woven in amongst the pages of this thesis are the colourful threads of what have surely been the most incredible and memorable years of my life. There are no words to describe how much the treasured relationship, company, laughter, holidaying, ambling, Lego-building, kite-flying, Smores-making, Clodhopper-eating, psychopath-riding, ‘What happened here and how?’ and all too brief moment in time that I was fortunate enough to enjoy with Ness and Jules, has meant to me. Thank you both for everything you are, for showing me life, laughter and being a family. For all that you gave me, for bringing a wonderful richness to my world and enlarging it in ways I can never repay and that would take a lifetime to sufficiently explain, I thank you. My life has never been the same for knowing and loving you, and never will be again. Both of you are loved so very much, forever and for always. The universe conspired and wild horses couldn’t drag me away.

“If what one finds is made of pure matter, it will never spoil. If what you had found was only a moment of light, like the explosion of a star, you would find nothing on your return”

- Paulo Coelho, *The Alchemist*

Table of Contents

Abstract	ii
Acknowledgements.....	iv
Table of Contents	vii
List of Figures	x
List of Tables.....	xi
List of Plates.....	xii
1. Introduction	1
1.1 Agriculture, climate change and multiple risks	1
1.2 Research objectives and questions	14
1.3 Thesis structure	16
1.4 Conclusion.....	19
2. Conceptualizing farm-level vulnerability.....	21
2.1 Introduction	21
2.2 Policy and research context	24
2.3 Vulnerability research.....	28
2.3.1 Conceptualizations of vulnerability	29
2.3.2 Current and emerging conceptualizations of vulnerability	33
2.3.3 Summary	36
2.4 Vulnerability and agriculture.....	37
2.4.1 Vulnerability assessments	39
2.4.2 Conceptualizing vulnerability in agriculture	42
2.4.3 Assessment of multiple stressors and dynamic vulnerability in agricultural systems: a conceptual framework.....	53
2.5 Conclusion.....	60
3. Ecological and Social Context of Vulnerability.....	63
3.1 Introduction	63
3.2 Case study area: Whakatane, Kawerau and Opotiki Districts	65
3.3 Historical and ecological contexts of regional agricultural production.....	68
3.3.1 Biophysical conditions: geology, soils, topography and hydrology.....	69
3.3.2 Climatic conditions.....	75
3.3.3 Historical precedents of agricultural production	79
3.3.4 Summary	87
3.4 Characteristics and conditions of agricultural production	88
3.4.1 Systems of agricultural production	89
3.4.1.1 Kiwifruit.....	91
3.4.1.2 Dairying	95
3.4.1.3 Drystock farming.....	97
3.4.2 Globalized and deregulated:agricultral production in New Zealand.....	99
3.4.2.1 A Deregulated Rural Economy	100

3.4.2.2 A Globalized Rural Economy	103
3.4.2.3 Governance and Legislation.....	107
3.5 Conclusion.....	110
4. Methodology and Analysis	112
4.1 Introduction	112
4.2 Methodology and analysis	114
4.2.1 Vulnerability case study	122
4.3 Research strategy	128
4.4 Research methods	130
4.4.1 Engaging participants, sampling and interviewing.....	133
4.5 Reflexivity and research	140
4.5.1 Reflections on fieldwork	140
4.5.2 Ethics.....	142
4.5.3 Seasonality and research strategies	142
4.5.4 Topic	143
4.5.5 Women in agriculture	144
4.6 Data analysis	146
4.7 Conclusion.....	148
5. Farm-level exposure to multiple stressors.....	150
5.1 Introduction	150
5.2 Farm-level exposure-sensitivity	153
5.3 Climatic conditions	158
5.3.1 Temperature and precipitation	159
5.3.2 Flood and drought.....	164
5.3.3 Climatic variability and extremes	168
5.4 Biophysical constraints and conditions	170
5.4.1 Pests, weeds, disease	172
5.4.2 Other biophysical constraints and conditiosn	173
5.4.3 Summary	176
5.5 Market and financial forces	177
5.5.1 Commodity prices and exchange rates	178
5.5.2 Input costs	182
5.5.3 Markets	186
5.6 Multiple stressors and the dynamics of exposure-sensitivity	189
5.7 Conclusion.....	201
6. Adaptation to climate and other stressors	203
6.1 Introduction	203
6.2 Theorizing adaptation in agriculture	206
6.2.1 Adaptation.....	207
6.2.2 Adaptive capacity	209
6.2.3 Adaptation in agriculture.....	210
6.3 Adaptive responses to climatic risks in agriculture	216
6.3.1 Adapting to climatic variability and extremes of temperature and precipitation	220
6.3.2 Adaptive strategies in horticulture	234

6.3.3 Summary	242
6.4 Adapting to market and financial risks	245
6.4.1 Changes in farm production practices.....	246
6.4.2 Diversification and "pluriactivity"	249
6.4.3 Opportunistic adaptive strategies and market risks	250
6.5 Conclusion.....	253
7. Future vulnerability to climate-related risks.....	261
7.1 Introduction	261
7.2 Future exposure-sensitivity.....	265
7.2.1 Future climate scenarios	266
7.2.2 Future climate-related exposure-sensitivity.....	270
7.2.2.1 Changes in temperature	273
7.2.2.2 Changes in precipitation	282
7.2.2.3 Changes in variability and extremes	283
7.2.3 Summary	284
7.3 Future adaptive capacity	287
7.3.1 Drivers of future adaptive capacity	288
7.3.1.1 Awareness.....	294
7.3.1.2 Technology	298
7.3.1.3 Social and human capital.....	300
7.3.1.4 Resources	303
7.3.1.5 Institutions	306
7.3.2 Summary	309
7.4 Conclusion.....	311
8. Writing Climate Change Research	313
8.1 Introduction	313
8.2 Identify relevant climatic and non-climatic exposures	314
8.3 Examine current adaptive strategies	317
8.4 Assess vulnerability to future climate change.....	319
8.5 Mainstreaming adaptation	321
8.6 Implications for further research	324
8.6.1 Regional, local and sectoral vulnerability assessments	324
8.6.2 Governance, institutions and political will	328
8.6.3 'Teleconnections' and the globalization of vulnerability	331
8.7 Implications for broader academic and methodological debates	334
8.8 Climate change adaptation in New Zealand agriculture	338
References	341
Appendix A	402

List of Figures

Figure 1.1 Location of Bay of Plenty region.....	5
Figure 1.2 Structure of thesis	17
Figure 2.1 Matrix of vulnerability	43
Figure 2.2 Coping range and extreme events	51
Figure 2.3 Conceptual model for assessing farm-level vulnerability	54
Figure 3.1 District boundaries.....	66
Figure 3.2 Catchment areas in the Bay of Plenty	74
Figure 3.3: Interannual variability of precipitation, Whakatane.....	77
Figure 3.4 Interannual variability of precipitation, Galatea.....	77
Figure 3.5: Interannual variability of precipitation, Edgecumbe.....	77
Figure 3.6 Rangitaiki Drainage c1867 and 1924.....	82
Figure 3.7 Kiwifruit exports to 2007	92
Figure 4.1 Two-step analytical framework.....	124
Figure 5.1 Chapter 5 within analytical framework.....	151
Figure 5.2 Interactive effects of multiple stressors	155
Figure 5.3 Risks that characterize bad years	190
Figure 5.4 Dynamic nature of exposure.	197
Figure 6.1 Chapter 6 within analytical framework.....	205
Figure 6.2 Adaptive capacity as a component of vulnerability.....	219
Figure 7.1 Chapter 7 within analytical framework.....	264

List of Tables

Table 2.1 Types of risk in agriculture	45
Table 2.2 Determinants of adaptive capacity.....	46
Table 2.3 General agricultural adaptation typology	49
Table 3.1 Weather data, Bay of Plenty	75
Table 3.2 Historical developments from the time of European settlement	80
Table 3.3 Selected flood events, Whakatane District.....	85
Table 3.4 Farms (%) in Whakatane District,	90
Table 3.5 “Farming” Land Use in the Whakatane District, 1985–2007.....	91
Table 3.6 DairyNZ classification of farm systems	95
Table 3.7 Summary of New Zealand herd statistics since 1974/1975	96
Table 3.8 Functions by level of government	108
Table 4.1 Research strategy and time line	129
Table 4.2 Research methods.....	131
Table 4.3 Approximate geographic distribution of farms	134
Table 5.1 Conditions influencing farm-level exposure-sensitivity	156
Table 5.2 Climatic conditions and related effects	159
Table 5.3 Effects of climatic conditions	160
Table 5.4 Effects of biophysical conditions.....	172
Table 5.5 Effects of market and economic forces	178
Table 5.6 Differences in exposure-sensitivity to payout/financial returns	180
Table 5.7 Differences in exposure-sensitivity to input costs.....	183
Table 6.1 Selected climatic and biophysical exposures and related adaptations	217
Table 6.2 Adaptations to manage drought risk in pastoral farming systems.....	222
Table 6.3 Types of adaptations (timing and duration) used to manage drought risk.....	230
Table 6.4 Adaptations to manage flood risk.....	233
Table 6.5 Adaptations to climatic risks in horticulture	235
Table 6.6 Adaptations in horticulture to manage frost, wind and hail.....	238
Table 6.7 Adaptive strategies according to timing and level of farmer control.....	255
Table 7.1 Projections of climate change in the Bay of Plenty	268
Table 7.2 Current and future climate related exposure-sensitivities.....	271
Table 7.3 Drivers and barriers to future adaptive capacity	290
Table 7.4 Future non-climatic exposures and influence on adaptive capacity	295

List of Plates

Plate 1.1 Interannual variability in precipitation	8
Plate 1.2 Agriculture is a multi-risk, multi-opportunity environment	12
Plate 3.1 Topography of the eastern Bay of Plenty	67
Plate 3.2 Ash from Tarawera eruption	70
Plate 3.3 Drainage canals, Rangitaiki Plains	73
Plate 3.4 Drainage of the Rangitaiki and old river course.....	83
Plate 3.5 Established Hayward (Zespri Green) orchard	94
Plate 3.6 Recently established Hayward (Zespri Green) orchard	94
Plate 6.1 Overhead frost protection, kiwifruit orchard.....	240
Plate 6.2 Feed pad.....	247

CHAPTER ONE: Introduction

1.1 Agriculture, climate change and multiple risks

“...the interpretive social sciences have a very particular role to play in relation to climate change. It is to restore to public view, and offer a framework in which to think about the human and the social in a climate that renders obsolete important prior categories of solidarity and experience. It is to make us more aware, less comfortable, and hence more reflective about how we intervene, in word or deed, in the changing order of things.”

- Sheila Jasanoff (2010, p.249)

In 2007, annual weather related agricultural losses in New Zealand topped the NZ\$1.0 billion dollar mark for the first time (MAF 2008). Since then, the country has endured near consecutive summer drought-like conditions (MAF 2010). In 2009, a widespread dry spell across the North Island resulted in a fifteen-percent drop in dairy production (DairyNZ 2010). Conditions during the summer of 2011 were the hottest and driest in Northland in almost sixty years, and created significant concern among farmers as it was the fourth droughty summer in a row (NIWA 2011). Globally, the Earth was 0.65°C warmer during 2010 than during the 1951 to 1980 mean, and the global temperature likely to exceed that of 2005, and be the warmest on record (Hansen et al. 2011). Data now shows that since the first scenario projections from the Intergovernmental Panel on Climate Change (IPCC) global temperatures have been tracking at the upper envelope of the scenario curves (Rahmstorf et al. 2007; Pielke Jr 2008). It is increasingly likely that attempts at mitigation have been largely ineffective, and that projections may in fact be conservative and the climate is changing faster than first presumed (Smith 2011).

The scientific basis for climate change has become increasingly clear (IPCC 2007; Ramanathan & Feng 2008). Since the early 1980s, climate change research has focused largely on measuring and characterizing changing climate conditions, predicting the future, and establishing a causal link with anthropogenic emissions (Bolin 2007). Climate models were developed that projected increasing temperatures and changes in precipitation which would alter the frequency, magnitude and geographic distribution of climate-related hazards including drought, flooding, and heat-waves; create new patterns of extreme weather; shift the distribution, abundance, and migratory behaviour of wildlife species; and reduce the areal extent and thickness of the Arctic sea-ice (IPCC 1990; IPCC 1995; IPCC 2001; IPCC 2007). Evidence across a diverse range of biotic systems now indicates that such changes are happening (Parmesan & Yohe 2003; Perry et al. 2005; Hinzman et al. 2005; Kurz et al. 2008; Rosenzweig et al. 2008; Hoegh-Guldberg & Bruno 2010; Kay et al. 2011; Min et al. 2011). Among climate scientists, it is now widely accepted that the climate *is* changing and will continue to do so at rates unprecedented in human history (Oreskes 2004; Rahmstorf et al. 2007; Doran & Kendall Zimmerman 2009; Anderegg et al. 2010). A dangerous threshold of 4°C is likely to be exceeded and will have wide-ranging consequences for human activity (Stern 2006; Garnaut 2008; McBean & Ajibade 2009; Smith et al. 2009).

As the link between anthropogenic greenhouse gas (GHG) emissions and climate change has been established, there have been increasing calls to enlarge the focus of climate change research to encompass a wider range of theoretical, methodological and conceptual perspectives as the quote at the head of this chapter indicates (Jasanoff 2010; Liverman 2010; O'Brien & Wolf 2010; Shove 2010; Hulme 2011). In his address to the 2009 Open Meeting of the International Human

Dimensions Programme, physicist Dr. Hans Joachim Schellnhuber said: “Speaking as a natural scientist I think ninety-percent of research [on global change] will have to be done by the social scientists” (Schellnhuber 2009). What is required is a shift in focus from an emphasis on the causes and nature of change to its implications for human activity and available response options (Smit & Wandel 2006; Bolin 2007; Trainor et al. 2007; Dovers 2009); and a shift as well from the global to the local; from models of atmospheric circulation to the scale of vulnerable communities, sectors, and systems (Liverman 2008; Hulme 2010; Moser 2010).

While all societies are maladjusted to climate to some degree (Hulme 2010), climate extremes and variability impose costs (as well as generating benefits). With climate change it is likely that agricultural producers in particular, will face ever increasing challenges (Salinger 2005b; Parry et al. 2007; Meinke et al. 2009) and the negative impacts will outweigh the positive (Pant 2009). These observed and anticipated changes in climate, will be superimposed upon natural climate variability observed over comparable time periods and are expected to increase climatic variability and alter the frequency and severity of climatic extremes (Katz & Brown 1992; Salinger 2005a; O’Gorman & Schneider 2009; Smith et al. 2009). These changes are likely to have the combined effect of reducing crop yields, increasing food insecurity and undermining traditional agricultural practices (Fischer et al. 2005; Howden et al. 2007; Parry et al. 2007). Furthermore, exposure to climatic conditions is not likely to occur in isolation, rather in conjunction with other multiple, non-climatic stressors (Young et al. 2006; Leichenko & O’Brien 2008; McCarthy & Martello 2010; Wilbanks & Kates 2010).

The research which follows seeks to characterize farm-level vulnerability through a place-based case study with the involvement and participation of stakeholders in the eastern Bay of Plenty, New Zealand (*Figure 1.1*). While the term has numerous definitions (Chambers 1989; Bohle et al. 1994; Kelly & Adger 2000; O'Brien et al. 2004; Wisner et al. 2004; Downing & Patwardhan 2005; Thomalla et al. 2006), vulnerability can be broadly defined as the potential for loss (Cutter 1996). In the climate change literature, it is often conceived of as being a function of the exposure-sensitivity of a system to stressors and its adaptive capacity (Smit & Pilifosova 2003). The IPCC (2007) defines it as: “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes”.

Assessing vulnerability is critical for places, as well as individual sectors and regional and national economies because changing environmental conditions will have major implications for economic viability and social and cultural well-being (Easterling 1996; Gay et al. 2006; Scott et al. 2006; Gössling & Hall 2006; Malone & Engle 2011). While progress has been made with respect to the identification of potential climate change impacts, our understanding of the vulnerability of particular systems, of the ways in which adaptation takes place, the adaptive capacity of actors – individually and collectively – and the role of awareness in preparing for the impacts of climate change remains limited (Moser 2010).

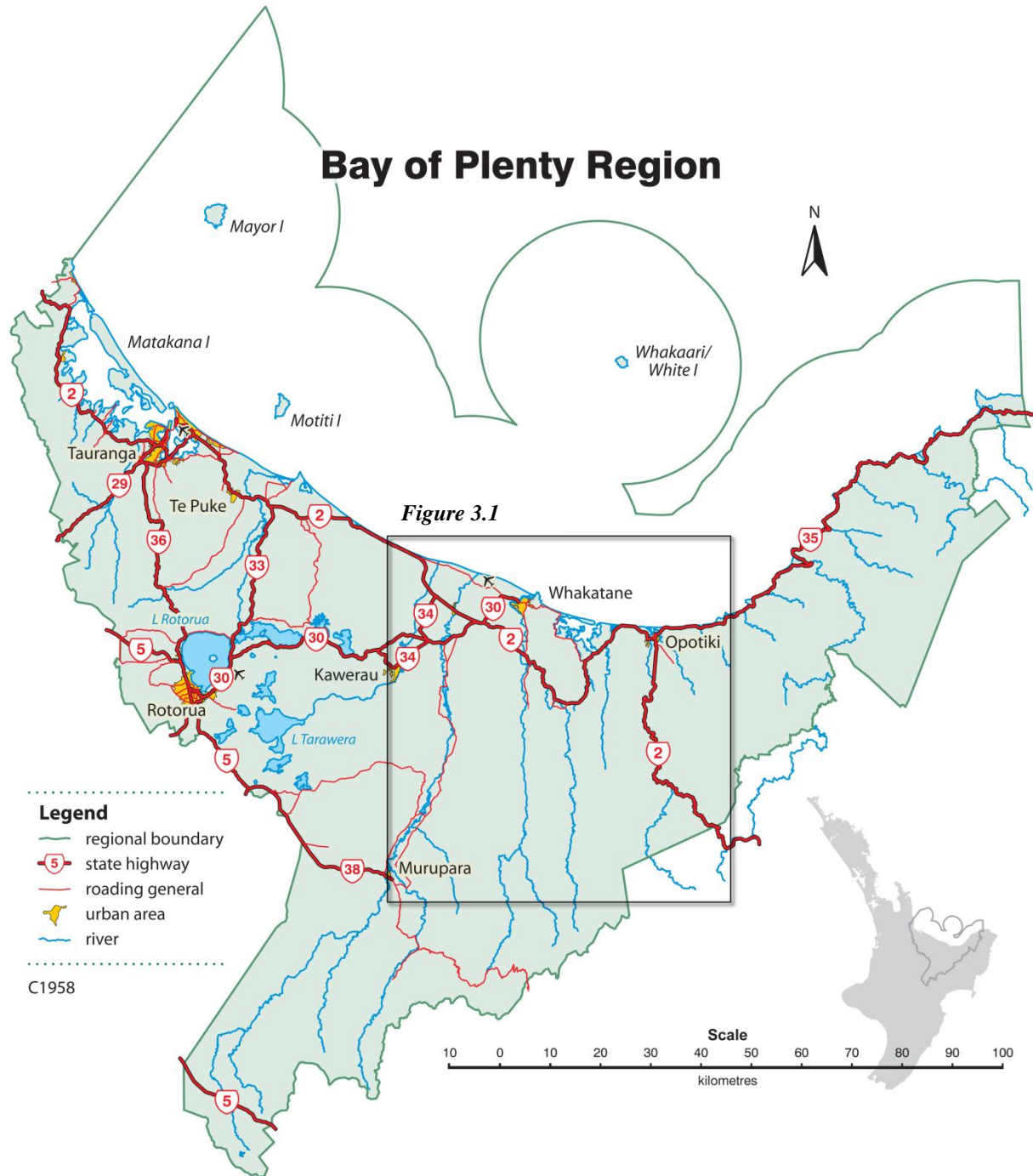


Figure 1.1 Location of Bay of Plenty region, with study area highlighted (Map courtesy of Bay of Plenty Regional Council 2010)

Agriculture is arguably, one of the most climate dependent of all human activities (Meinke et al. 2009), and encompasses aspects of social, economic, biophysical and climatic systems. Much of the work on agriculture and climate change however continues to be driven by a simplistic scenario-based methodology in which vulnerability – if acknowledged at all – is interpreted as a residual ‘endpoint’ (Kelly & Adger 2000; O’Brien et al. 2007). Often referred to as the “dumb farmer” approach (Easterling et al. 1992; Kaiser et al. 1993), this work relies on modelling studies of extremely simplified and hypothetical farming systems and for single crops (Parry et al. 2005; Tubiello et al. 2007; Tao et al. 2009). The linear analysis begins with a model of expected climatic change and then applies the results to an agricultural production model, using the mechanisms through which climate shapes production (Parry et al. 2004; Parry et al. 2005; Schmidhuber & Tubiello 2007; Hatfield et al. 2011). Any potential adaptation by producers is either arbitrarily assumed, or not even considered (Tol et al. 1998). This type of analysis fails to capture the complex influences on vulnerability between climatic and non-climatic stimuli and conditions; systems and networks of production, as well as market and economic conditions at regional, national and international scales; and the individual unit of exposure, the farm itself. Nor does it recognize the capacity of individual farmers to adapt to changing conditions (Smit & Skinner 2002; Bradshaw 2007; Meinke et al. 2009), responses which are likely to vary within any system according to the social, cultural and economic characteristics of actors (Adger et al. 2007). Lastly, while these models of climatic change are calculated for large regions of the Earth, it is at the scale of districts, communities and households where the impacts of climate change will be most acutely felt (Brooks 2003; Næss et al. 2005; Adger 2006; Füssel & Klein 2006; Moser 2010). The potential vulnerability of agriculture at the local scale is of significant concern.

Agricultural production is often the dominant economic activity for large regions, and the well-being of tertiary activities and local populations is dependent on its viability (Patterson et al. 2006).

This is of particular relevance for New Zealand, where agriculture remains a significant economic driver both nationally (Smith & Montgomery 2004; Winder 2009; Gray & Le Heron 2010), as well as being characteristic of numerous local and regional economies (Patterson et al. 2006). Nation-wide, agricultural exports for 2009/10 were worth over NZ\$18 billion (MAF 2010) and the country's trade-oriented agricultural economy is already markedly sensitive to climatic variability and extremes (Stroombergen et al. 2006), as demonstrated by the effect of floods and droughts on GDP and rural activity (Tait et al. 2005; Buckle et al. 2007). Pastoral farming (which in New Zealand has traditionally relied on year round grazing of animals in open pasture) (Jay 1999; Verkerk 2003; Clark et al. 2007), horticulture, viticulture, and forestry are sensitive to climate variability and extremes because of their immediate dependency on the natural environment. Agricultural production is also typically characterized by adaptation to variability around a long-term mean (Kane & Yohe 2000). Departure from that mean, and any changes in climatic conditions then will likely have widespread environmental, economic, and social implications for communities and individuals (Burton 1997; Bryant et al. 2000; Parry et al. 2007). Just as production of agricultural commodities is sensitive to climatic conditions, it might be anticipated that so too are those communities and regions that depend on agriculture uniquely susceptible in turn to the impacts of climate change as *Plate 1.1* ironically demonstrates with respect to the interannual variability of precipitation in New Zealand.



Plate 1.1 Interannual variability in precipitation has a direct influence on agriculture, communities and the economy (Fairfax Media © 2008 Reprinted, by permission)

The extent to which climate change will be detrimental or beneficial to agricultural producers and communities will be significantly influenced by the success of those exposed in adapting to changing conditions (Schneider et al. 2000; Burton & Lim 2005; Meinke et al. 2009; McCarthy & Martello 2010). Through adjustments in human use systems, stakeholders are in a unique position to minimize the damaging effects of climate change or realize beneficial opportunities. An emerging body of scholarship seeks to assess more closely climate impacts and adaptive options in many agricultural regions (e.g. Belliveau et al. 2006; Tarleton & Ramsay 2008; Reidsma et al. 2010; Hadarits 2011) through an assessment of vulnerability, though there are still pronounced gaps.

While there have been a number of vulnerability assessments completed overseas, they have largely been conducted at the scale of regions (Ford et al. 2008; Wandel et al. 2009; Osbahr et al. 2010) or nation-states (Sygna et al. 2004; O'Brien et al. 2006). As invaluable as they are, broad scale analysis obscures *local* vulnerability (O'Brien et al. 2006), which is a function of multiple stressors, operating at a range of scales and over time (Turner et al. 2003; Adger et al. 2005; Young et al. 2006). There is a growing literature on community-level vulnerability assessments, particularly for Arctic and Northern regions (Ford et al. 2006; Tyler et al. 2007; Keskitalo & Kulyasova 2009; Pearce et al. 2010; McNeeley & Shulski 2011) and developing countries (Sutherland et al. 2005; Barnett et al. 2007; Westerhoff & Smit 2008) but there are still few examples of research that explores and identifies the components of vulnerability at the farm-level. Studies of farm-level vulnerability in developed nations are largely absent from the literature (Belliveau et al. 2006; Reid et al. 2007; Tarleton & Ramsay 2008). The lack of work on adaptation in developed countries is further compounded by the fact that in many, including New Zealand (Kelly 2010), the emphasis has long been on GHG mitigation instead of adaptation (Greenaway & Carswell 2009; Burton 2011; Ford & Berrang-Ford 2011). The work on climate change impacts and agriculture in New Zealand that has been done, has utilized model-based, impacts approaches (Kenny et al. 1995; White et al. 1997; Clark et al. 2001; Green et al. 2008), economic modelling scenarios (Tait et al. 2005; Tait et al. 2008; Stroombergen et al. 2006) or analyzed related impacts across a region for a single stressor (Field & Forde 1990; McGlone 2001; Kenny 2006; Patterson et al. 2006). No previous study in New Zealand has examined the complexity of farm-level vulnerability and exposure to other, non-climatic stimuli (Cradock-Henry 2008).

This study contributes to the methodological, spatial and sectoral gaps identified by Hennessy et al. (2007) in the Australia and New Zealand section of the Fourth Assessment Report of the IPCC. The authors note there are very few examples of vulnerability assessments of ‘at risk’ systems, including agriculture, and no such studies for New Zealand; and “few integrated regional and sectoral assessments of impacts, adaptation and socio-economic risk. More are desirable, especially when set within the wider context of other multiple stresses” (Hennessy et al. 2007, p.530).

As this thesis seeks to demonstrate, at the farm-level the true complexity of the interactions between the components of vulnerability become clear. Exposure-sensitivity and adaptive capacity are shaped by conditions at scales operating beyond the farm gate, but are ultimately expressed as a function of interactions at the micro-scale between biophysical conditions, local governance, and the capacity of individuals. This research seeks to address the spatial and conceptual gaps in climate change and adaptation research, through the development of a place-based case study, in the eastern Bay of Plenty, New Zealand. To assist farmers in adaptation to climate change and climate conditions, it is necessary to understand farmers’ perceptions of climate and climate change, how they are affected by climatic conditions, the adaptive strategies that are available to them, and the constraints and opportunities for enhancing their adaptive capacity.

By examining farmers' perceptions and experiences of risk, the study assesses the vulnerability of agricultural producers in the eastern Bay of Plenty to climatic variability and change, within the context of the other multiple non-climatic stimuli to which they are exposed. Instead of assuming adaptive responses and their uptake, characteristic of previous literature (Nagy 2001; Sauchyn et al. 2005; Gameda et al. 2007) and constructing scenarios around such assumptions, this study seeks to identify actual adaptations and document the processes by which agricultural producers adapt to climatic and non-climatic exposures. In common with the work Kelly and Adger (2000), Schneider et al. (2000), Keskitalo (2004), and Liechenko and O'Brien (2008) this approach recognizes in advance, that climate change will be experienced in conjunction with many other stresses and adaptation will occur via processes already operating at various scales (Turner et al. 2003; Adger et al. 2005; Eakin & Luers 2006; Young et al. 2006; Wilbanks & Kates 2010).

The study which follows is based on engagement with agricultural producers in the Whakatane, Kawerau, Galatea and Opotiki districts, in the eastern Bay of Plenty on New Zealand's North Island (*Figure 1.1*, see also *Figure 3.1*). The area was selected for its diversity, the significance of agriculture to the local economy and the potential for the development of a historical analogue. The case study area is unique in New Zealand for the diversity of agricultural production within a relatively small region. Pastoral farming, which includes a large dairy industry centred on the lowland Rangitaiki Plains and drystock – sheep and beef – farms in the forested upland regions, is the largest agricultural land-use. In addition, the Bay of Plenty is responsible for ninety-percent of New Zealand's NZ\$1.5 billion export-based kiwifruit production, and horticulture accounts for twenty-percent of the region's GDP (EBoP 2004).

Agriculture is inherently sensitive to climatic conditions and likely to be impacted by changes in climatic variability and extremes (Howden et al. 2007; Lobell et al. 2008; Tait et al. 2008; Fedoroff et al. 2010; Wreford & Adger 2010). Given the diversity and importance agricultural production to the economic and social structure of the region it is important to assess the range of effects that may be associated with changing climatic conditions. Finally, when selecting the case study area, consideration was given to recent flood events in the district in 2004, 2005, and 2009 which might have served as a historical analogue to help understand farmers' responses to adverse climatic conditions.



Plate 1.2 Agriculture is a multi-risk, multi-opportunity environment (Sammons dairy farm, Galatea Valley, eastern Bay of Plenty, New Zealand)

Unlike other scenario-based studies which begin with projected changes in climatic conditions, this research started at the farm gate. Instead of assuming *a priori* the stressors to be analysed – crop yield, temperature or precipitation values – and the response to them, it actively sought to engage stakeholders to identify the climatic and non-climatic stressors that are relevant to them. This type of work provides insights into the place of climate and climate-change within the decision-making framework of individuals and aggregated across a region (Defoer 2002; Conde & Lonsdale 2004; Sutherland et al. 2005; Wall & Smit 2005). The research began from the ‘bottom-up’ (Dessai et al. 2004; van Aalst et al. 2008), by meeting with agricultural producers who themselves identified relevant exposures and how adaptation to climate change might occur in the context of multiple risks (Adger et al. 2005; Young et al. 2006).

The empirical analysis relied on in-depth interviews, development of analogues, and analysis of secondary sources, and was informed by engagement with the literature from a range of fields including agriculture and agricultural systems science, hazards research, climate- and global environmental change, and environmental science. Agricultural producers identified the climatic and non-climatic risks relevant to them and the strategies employed to manage these risks. Producers are vulnerable not only to climatic conditions that affect crop yield, but also to other environmental hazards including earthquakes, flood, drought, and salt-water intrusion, as well as non-climatic variables that affect their ability to compete in or sell to the market. The research seeks to widen the focus of traditional ‘top-down’, impacts based studies by further contextualizing the presence of multiple exposures which affect the way in which producers are vulnerable.

1.2 Research objectives and questions

This research examines the vulnerability of agricultural producers in the eastern Bay of Plenty to climatic variability and change, within the context of other risks or exposures. The four objectives of the research are:

1. Identify relevant climatic and non-climatic stressors agricultural producers in the eastern Bay of Plenty are exposed-sensitive to;
2. Identify current adaptive strategies for mitigating risks that have been adopted by producers;
3. Evaluate the vulnerability of the varied farm types in the study area to likely changes in climatic variability and extremes; and
4. Contribute to the emerging discussions on mainstreaming adaptation into economic development and policy formation pertaining to farming and horticulture in the study area, through the production of ‘actionable information’ (Vogel et al. 2007).

Guiding the research were five major questions:

1. What are the past and current risks (as identified by producers) to agriculture in the Rangitaiki Plains and surrounding area of the eastern Bay of Plenty?
2. What position does climate occupy in the suite of identified risks?
3. What adaptive strategies are employed to manage these risks?
4. What are projected or future vulnerabilities? and
5. How will the sociocultural, economic, environmental and political context affect successful – or unsuccessful – adaptation to changing climatic conditions?

The research seeks to answer these questions through an interdisciplinary engagement and mixed methods approach, drawing insights from natural and social science (see *Figure 1.2*). It employs a vulnerability-based perspective in which engaging with agricultural producers was central to identifying relevant climatic- and non-climatic stimuli exposure-sensitivities and adaptive

strategies. It seeks to analyse the vulnerability of farmers in the eastern Bay of Plenty to respond to climate change within the context of other risks. It aims to fill a spatial, sectoral and methodological gap in the literature by providing an in-depth, place-based case study which can serve as a template for other research across New Zealand; and broaden the scope of the vulnerability literature by developing and applying the concept to a local agricultural system in a developed economy. It sets out to counter the emphasis in New Zealand on 'top-down' research approaches (Kenny et al. 2000; Stroombergen et al. 2006; Wratt et al. 2006; Tait et al. 2008) and strategies, exemplified by the inordinate emphasis on mitigation at a national-level (Baisden 2006; Metcalfe et al. 2009), and the reduction of GHG emissions in the agricultural sector through technology (Smith et al. 2008; Leslie et al. 2008) by engaging with producers from the bottom-up to identify available adaptive responses. It also aims to demonstrate the dynamic nature of vulnerability whereby adaptations made to climate and other risks can change the way in which the system is vulnerable to other stresses, and illustrate the complexity of the interactions between exposure-sensitivity and adaptive capacity, at the farm level, and larger-scale social, economic, environmental and political conditions.

1.3 Thesis structure

The remainder of this thesis is divided into seven chapters (*Figure 1.2* overleaf). Chapter 2 outlines the theoretical framework used to answer the research questions and describes the approach that was developed to assess farm-level vulnerability. The study draws on natural and social science perspectives and insights from stakeholders, who identified relevant exposure-sensitivities and adaptive strategies. It takes into the account the various climatic and non-climatic stimuli to which farmers are exposed, the influence of these multiple risks and the organizational structure of the agricultural system, synthesizing scholarship on climate change, farm management, risks, hazards, and vulnerability and adaptation.

Systems can be identified at various scales (IPCC 2007). At the farm level, as with the other scales of system definition, farms are seen as entities operating within the political economy framework, operating within external economic, institutional, technological, and social environments, as well as the natural environment (Smithers & Smit 1997). Chapter 3 locates the unit of exposure, within the broader context of biophysical and socioeconomic conditions; situating farm-level vulnerability spatially and temporally within historical, social and ecological developments and influences at a range of scales.

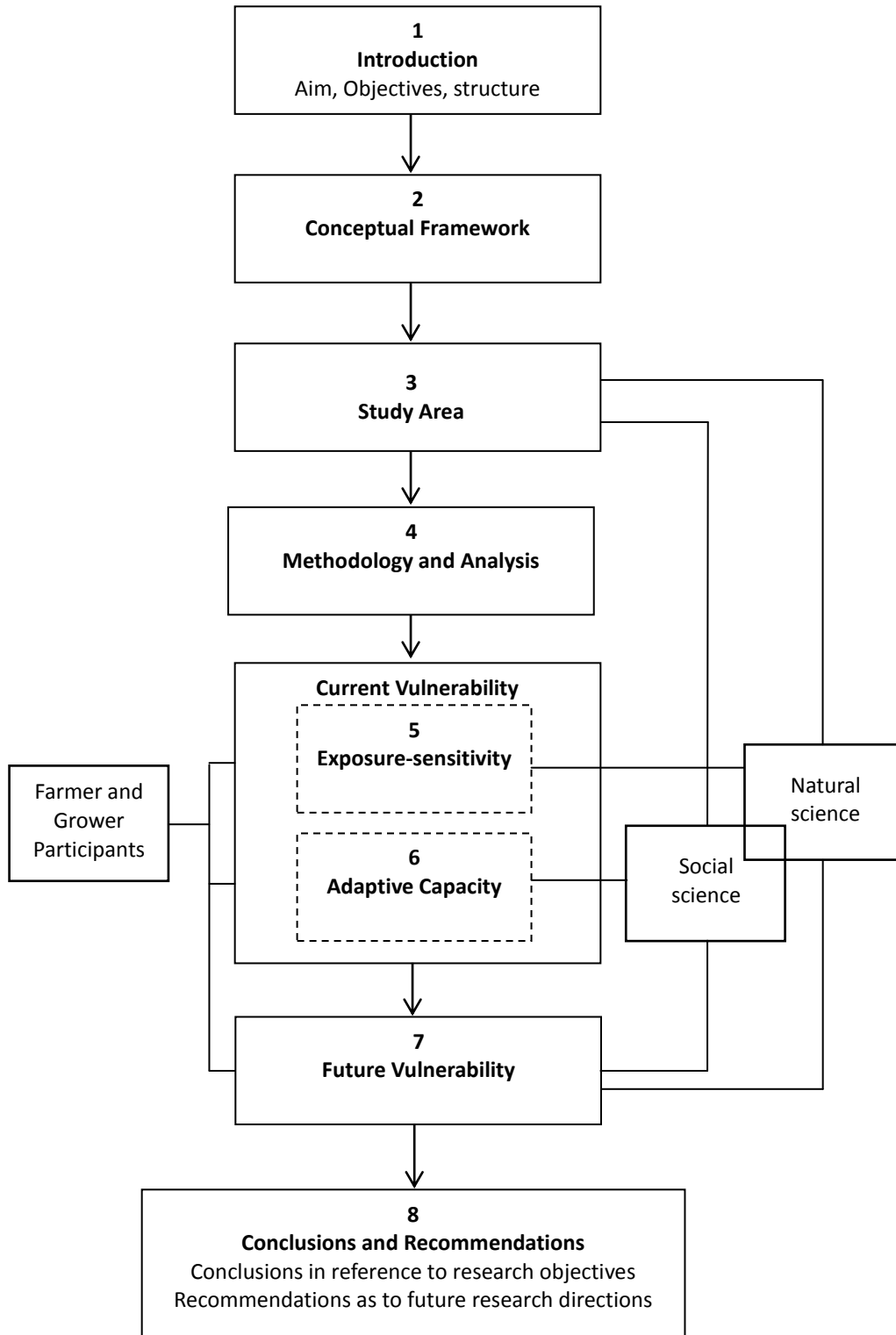


Figure 1.2 Structure of thesis

Chapter 4 presents the methodology and methods used in the collection of the empirical data, including the development of a network of actors, who were canvassed for their insights into relevant exposure-sensitivities and adaptive strategies as they influence farm-level vulnerability in the eastern Bay of Plenty. The methods of interviewee selection and recruitment, transcription and analysis are presented. The chapter also provides an opportunity to acknowledge my position as a scientist-researcher engaging with actors.

The conceptualization of vulnerability as a function of exposure-sensitivity and adaptive capacity guides the remaining chapters. Using the conceptual framework as the foundation for the discussion, Chapter 5 presents the results of the empirical work, outlining the exposures that were identified by producers in the course of the research. These exposures were not limited to climatic risks, but included non-climatic conditions and stimuli to which farms are sensitive. Producers have developed a range of strategies however, for managing current vulnerabilities to a range of exposures. Chapter 6 describes the ways in which risks are managed at the farm level, in the dairying, horticultural and dry stock sectors in the Whakatane District.

By documenting and empirically grounding current vulnerability in the study-area, Chapter 7 assesses future vulnerability by examining changes in climate and related conditions. Changes in temperature and precipitation, shifts in climatic variability and extremes and related impacts are discussed in terms of the interactive effect of farm-level exposure and sensitivity, and the capacity of farmers and kiwifruit growers to adapt. Chapter 8 reviews the main ideas of the thesis and reflects on the implications of the findings, and outlines directions for future research.

1.4 Conclusion

As noted earlier in this chapter, the focus of climate science has been on the acquisition of greater knowledge of the global climate system and the influence of anthropogenic GHG emissions. Despite the overwhelming evidence however, the net result of this knowledge has been continued inaction relative to making meaningful changes in society (Schipper 2006; Pielke Jr et al. 2007; Sarewitz & Pielke 2007; Parry et al. 2009). This is disastrously irrational. As Maxwell (2008) notes, if academic inquiry were to help promote human welfare rationally, it would give intellectual priority to the tasks of articulating problems of living and proposing possible solutions and real actions. The work which follows is guided by a desire to contribute to the efforts being made to move the discussion of climate change from the abstract, to the realm of lived experience. It is motivated in part by my own values and personal and academic background. Having grown up on a small farm in Canada, and later taking advantage of opportunities – academically through Master’s research in the Karakoram Himalaya on mass-wasting processes (Cradock-Henry 2001; Cradock-Henry & Flanagan 2002); professionally as a consultant on conservation and community-forestry initiatives; and personally, through overseas travel and work experience – I have sought to integrate research with practice, and to draw on both natural and social-science perspectives and individual experience (Cradock-Henry 2008). This thesis represents then, in part, a shift in my own thinking, an attempt to engage with an alternative viewpoint, one very different from my training as a natural scientist with a background in surficial geology and ecosystem-based land use planning. As Jasanoff (2010) quoted at the opening of this chapter states, it is “to think about the human and the social”, rather than simply (or exclusively) the meteorological. Climate change is a scientific concern, but also a social one. As climate scientist Prof. Diana Liverman (2010, p.22) has written:

Our dismal predictions and technical discussion of uncertainties seem distant and intangible from everyday lives; perhaps we have exhausted public willingness to listen to our warnings and our ideas for alternative lower carbon futures. Within science there has sometimes been a tendency for natural scientists to see social scientists as their public relations consultants to help the public better understand what scientists are telling them. But social science can be just as academic in its efforts to explain how human actions are changing the natural environment, how human vulnerabilities exacerbate environmental impacts, and how human choices can move us towards sustainability.

What follows then is an effort to employ the “technologies of humility” – “disciplined methods to accommodate the partiality of scientific knowledge and to act under irredeemable uncertainty” (Jasanoff 2007, p.33) – by learning from the experiences and “practical wisdom” (Schwartz & Sharpe 2006) of agricultural producers to uncover the vulnerabilities of daily life and agricultural practice in a variable and changing climate. This thesis seeks to support the capacity for creative solutions and resilience in the face of an uncertain future “from the ground up”, rather than relying upon a predictive model of both climatic conditions and human behaviour.

CHAPTER TWO: Conceptualizing farm-level vulnerability

2.1 Introduction

The investigation of risks is at once a scientific activity and an expression of culture.

- Roger E. Kasperson et al. (1988, p.177)

As Kasperson and colleagues (1988) note, the investigation of risk has both a scientific dimension and a human one. How people in any given area are affected by climate change will depend not only on the climatic changes themselves, but also the interactive effect of other, non-climatic stressors and the influence of relevant ecological, social and economic conditions (Adger & Kelly 1999; Mendelsohn et al. 2006; Wilbanks & Kates 2010). People's ability to adapt, likewise depends on a variety of factors including the availability of resources for adaptation, motivation, and information about the changing state of the environment and the links between human decisions and the environment (Fankhauser et al. 1999; Berkes & Jolly 2002; Adger 2003; Lambin 2005).

Adaptation is used in the climate change literature to describe the adjustments adopted at a variety of scales to reduce the risks from, or take advantage of, opportunities presented by climate change, variable climatic conditions or weather events (Smit & Pilifosova 2003; Adger et al. 2005; Parry et al. 2007). Much of the research exploring the impacts of climate change and adaptive strategies of agricultural producers continues to work from the basis of what Wenger (2000) refers to as the 'single stressor–single endpoint' approach, in which a single exposure (i.e., climate) is assumed to be the biggest risk. Yet agricultural producers work in a complex,

‘multi-risk multi-opportunity’ (Bradshaw 2007) environment. Decisions made at the farm-level are multi-dimensional, with economic, financial, sociocultural, political and environmental considerations (Bryant et al. 2000; Nelson et al. 2010; Rodriguez et al. 2011). While adaptation to climatic conditions is common in the agricultural sector (Salinger et al. 2000; Howden et al. 2007; Stringer et al. 2009), adaptive strategies are unlikely to be made solely in response to climatic conditions or risks, but as part of an integrated risk management strategy, as producers respond to the joint effects of exposure to multiple forces (Smit & Skinner 2002). In order to account for the presence of these multiple-stressors a different analytical framework is required. It must be able to account for the presence of stimuli operating over a range of time periods and scales, as well as the differences between individuals in terms of risk management and decision making (Bradshaw 2007; Meinke et al. 2009). Consideration must also be given to the ability of producers to adapt to changing conditions, and the presence of adaptive strategies employed by agricultural producers to mitigate exposure to existing climatic variability.

Vulnerability assessment offers the basis for developing one such framework. Vulnerability is a term increasingly employed in the literature to describe the risks posed to nations, regions, communities and systems by climatic variability and change. It is well suited for this type of analysis, because it is an inherently spatial concept: risks or abilities to cope vary across physical space and among and within social groups (Wisner 2004). It is scale-dependent, both across time and space and is dynamic (Adger 2006): the characteristics that shape vulnerability change over time, in response to changing biophysical and socio-economic conditions (Vogel & O’Brien 2004). This chapter argues that through the interpretive lens of vulnerability, a framework can be

developed in order to analyse exposure-sensitivity and adaptive capacity at the farm-level. The chapter investigates vulnerability in more detail and develops a conceptual and analytical framework for the empirical work which follows.

The chapter begins by briefly reviewing the policy and research environment, in order to place the research within the broader context of climate change research in New Zealand and abroad. A consideration of the key developments as they relate to conceptualizations of vulnerability then leads to exploration of approaches and key concepts of particular use to this research. Finally, a conceptual framework is proposed to guide the analysis of farm-level vulnerability. The framework draws on the recognized formulation of vulnerability as a function of exposure-sensitivity and adaptive capacity (Smit & Pilifosova 2001; Turner et al. 2003; Keskitalo 2004; Smit & Wandel 2006). It seeks to establish a means of effectively *locating* climate risks relative to other non-climatic risks, including production, marketing and finance, in order to assess the interactions among various external stimuli, and their influence on vulnerability at the farm level. The chapter concludes by presenting this conceptual framework. The framework is used in subsequent chapters to analyse farm-level vulnerability; to explore the dynamic nature of vulnerability and multiple climatic and non-climatic stressors. It enables an integrated assessment, through a holistic and reflexive investigation, of the conditions to which farms and farmers in the eastern Bay of Plenty are exposed-sensitive; and the adaptive strategies employed to manage that exposure; and explore scenarios of future vulnerability to likely changes in climate.

2.2 Policy and research context

There is an increasing sense of urgency among researchers, policy makers, and civil society engaged “in a race against time to understand how adaptation can be facilitated, supported, and ultimately sustained, in societies at risk from climate change impacts” (Coulthard 2008, p.479). The demand for research to inform adaptation throughout society has arisen from a growing awareness of the potential threat posed by a changing climate (IPCC 2007). This is evident in two significant transformations in the international research and policy environment (Nelson et al. 2010). First, there is a growing debate on how best to respond to the challenges of climate change; the priority and attention given to mitigation – the reduction of GHG emissions – towards greater consideration of adaptation, the modification of behaviour believed to either alleviate adverse impacts or to realize new opportunities in response to observed or expected changes in climate and associated extreme weather events (Smit & Pilifosova 2003; Adger et al. 2005).

Some degree of climatic change is inevitable (Lowe et al. 2009; Smith et al. 2009), and adaptation unavoidable (Howden et al. 2007). However, even with dramatic and immediate reductions, historical GHG emissions will continue to influence temperature for several centuries (Schneider 2009; Solomon et al. 2009; Matthews et al. 2009). Evidence from biotic systems indicates there is a high probability that climate change is *already* occurring (Parmesan & Yohe 2003; Rosenzweig et al. 2008; Lenoir et al. 2008). Mitigation is no longer seen as the only option and adaptation the “fatalistic strategy” (Schipper 2006). Adaptation has become a necessary part

of climate change discourse and a fundamental response to the threat posed by climatic changes that will occur, or are already occurring as a result of anthropogenic GHG emissions (Ford 2007).

Second, while there is a high degree of confidence in the fact that the climate will continue to change in significant ways, the exact nature and consequences of these changes remain highly uncertain, owing to the complex feedback mechanisms between the differing components of the climate system (IPCC 2007). This uncertainty with respect to climate change is precipitating a rethink of traditional approaches to risk management. Historically, climate-related science and policy have emphasised the analysis of scientific systems for the purpose of predicting extreme events such as storms, floods and droughts, and modelling estimates of their likely impacts (Dale et al. 2001; Keenan et al. 2011). Beginning with a changed climate, models are used to describe the impacts on agricultural production and determine what the characteristics of regional climate patterns might be in the future (Parry et al. 2005; Schubert et al. 2008) in a linear fashion.

Exploring the impacts of climate change on agriculture however, need not be examined with the use of computer-based models exclusively. Given that the extent to which the management of climate variability is intrinsic to agricultural production, this has the potential to provide a foundation from which adaptation to climate change can occur (Howden et al. 2007). This advantage has proven difficult to realize. This is because adaptation to climate variability and change has often been conceptualized as a linear sequence of technical responses to clearly identified, measurable and predictable sources of risk (O'Brien et al. 2007; Nelson et al. 2010). A narrow focus on forms of risk that can be quantified and predicted can have the unintended

consequence of under-emphasising the longer-term and more holistic opportunities to build adaptive capacity. It also overlooks fundamental limits to predictability in the global climate system (Barnston et al. 2005), and tends to focus on the drivers of climate variability and change which cannot be influenced by decision makers (Nelson et al. 2007; Meinke et al. 2009).

The majority of work on climate change impacts in New Zealand has operated from this basis (Fitzharris 2007; Hennessy et al. 2007). The CLIMFACTS program (Kenny et al. 2000; Kenny et al. 1995; Warrick et al. 1996) at the University of Waikato focused on modelling the potential impacts of climate change on agricultural production. While it made important progress in demonstrating effects on pastoral farm production (Clark et al. 2001), horticulture and kiwifruit (Kenny et al. 2000; Hall et al. 2001), variable regional impacts (Kenny et al. 2001), and the need for more comprehensive impact assessment, it was predictive and ‘top-down’. While addressing potential impacts of climate change on agricultural production it neglected the roles of human behaviour and the impact of other, non-climatic stressors.

In light of these considerations, there have been calls for empirically-based assessments of vulnerability that explore *actual*, rather than predicted impacts and adaptive behaviour in particular places over particular periods of time (Kelly & Adger 2000; Meinke et al. 2009; Wilbanks & Kates 2010; Liverman 2010). Such case studies or ‘temporal analogues’ (Tol et al. 1998) have not been widely done in an agricultural context (Meinke et al. 2006). However, on the basis of analyzing farmers’ responses to inter-periodic climatic variability and other, non-climatic stressors and opportunities, it may provide insights into understanding the capacity for future adaptation (Howden et al. 2007). The need for such participatory and empirical

assessments in agriculture has been formally noted in Roncoli (2006) and Meinke et al. (2009). Pioneering work in New Zealand has been done by Kenny (Kenny & Fisher 2003) through an engagement with farmers on ideas about resilience. Kenny (2011) inverts the traditional impact-assessment model prevalent in previous research, and demonstrates the need to engage with agricultural producers “from the bottom up” (van Aalst et al. 2008).

As the focus of concern in climate change research has shifted from mitigation to a greater consideration of the role of adaptation, attention has been given to employing other conceptual and analytical frameworks to address questions surrounding the ability of human systems to adapt to climate change, including changes in the frequency and variability of extremes (Schröter et al. 2005; Füssel 2007). There is a substantial literature from the fields of risks and hazards, and climate change vulnerability assessments of health, communities, and sectors (Sutherland et al. 2005; Eriksen et al. 2005; Pearce et al. 2010; Ford, Berrang-Ford, et al. 2010). Researchers have employed techniques associated with Integrated Assessment, Participatory Impact Assessment, Rural Livelihoods Analysis, and Community Risk Assessment (Kruse et al. 2004; van Aalst et al. 2008; Moser & Stein 2010; Romieu et al. 2010), as well as those from resilience science (Olsson & Folke 2001; Holling 2001). Other analytical frameworks have been employed in the CAVIAR Program in Northern Regions (Smit et al. 2010), and those of Turner et al. (2003) and Keskitalo (2004).

Central to many these alternatives to a traditional, scientific modelling approach are a recognition or awareness of vulnerability (Nelson 2011), and an emphasis on the involvement of stakeholders (van Aalst et al. 2008) – those most likely to be impacted by changes in climatic conditions. These studies also often have an applied focus, with the explicit aim of contributing to ‘actionable information’ or to inform policy (Vogel et al. 2007). The following section reviews the conceptualization of vulnerability in the literature to inform the development of a place-based conceptual framework to assess the impacts of climate change and the adaptive capacity of producer-stakeholders, within the context of other, multiple non-climatic stressors.

2.3 Vulnerability Research

Conceptualizations of vulnerability have evolved considerably since its origins in environmental hazards research (Baird et al. 1975; O’Keefe et al. 1976; Wisner et al. 1977). It has subsequently been adopted by scholars to assess the capacity of individuals, communities, and regions to respond to climate change within the context of other stimuli (Young et al. 2006; Leichenko & O’Brien 2008; Wilbanks & Kates 2010). Theoretical developments in ‘resilience’ (Holling 2001; Folke 2006) and ‘sustainability science’ (Lambin 2005; Kajikawa 2008; Eriksen & Brown 2011; Eriksen et al. 2011), have also informed current theoretical perspectives (Adger & Brown 2009; Zhou et al. 2009; Ford et al. 2010; Turner 2010; Nelson 2011) and new integrative analytical models (Heltberg et al. 2009; Nelson et al. 2010a) and metrics (Vincent 2007; Eakin & Bojórquez-Tapia 2008). Vulnerability has a critical place in global climate change research, conceptually and theoretically (Ford et al. 2010) and the proliferation of vulnerability assessments across a wide range of scales and sectors, have demonstrated its potential to contribute to basic, use-inspired, and applied research, though more are required (Moser 2010).

The evolution of vulnerability is discussed as the basis for the development of a conceptual framework which is then empirically applied and used to assess the vulnerability of farming in the eastern Bay of Plenty to climatic variability and change, within the context of other risks.

2.3.1 Conceptualizations of vulnerability

Despite more than three decades' worth of collective research experience, vulnerability still means different things to different people in different fields (Chambers 1989; Dow 1992; Ribot 1995; O'Brien et al. 2004; Zhou et al. 2009). Many of the discrepancies in meaning arise from different epistemological orientations and subsequent methodological practices, as well as a lack of communication between scholars working in different fields (Adger 2006) and across a range of disciplines including geography, ecology, political science and anthropology (Janssen et al. 2006). Within the climate change literature, distinctions have been made between epistemologies (McLaughlin & Thomas Dietz 2008), processes and analytical approaches (Kelly & Adger 2000; Dessai & Hulme 2004; Füssel & Klein 2006). From a review of the literature, three distinct perspectives are evident: vulnerability as exposure to a hazard; vulnerability as a social construct, and synthetic or 'contextual vulnerability' (O'Brien et al. 2007).

Vulnerability as "risk of exposure" is associated with what Hewitt (1983) refers to as the "dominant view" or the 'behavioural paradigm' (Pelling 2003; Smith & Petley 2009), in hazards research. Disasters are 'Acts of God', striking helpless, and often unaware, populations (McEntire 2001). Vulnerability is defined as a function of exposure to exogenous biophysical threats; the physical stimulus is itself the point of departure and the vulnerability of the system described in terms of the outcome: lives lost, area flooded, or yield decline. Remediation and

mitigation focus on managing the physical risk, often through engineered or technical responses and prediction. Vulnerability is related to proximity to exposure, addressing the physical parameters of a hazard such as magnitude, frequency, duration, and spatial distribution (Hufschmidt 2011).

This has been the prevailing interpretation of vulnerability in climate change impacts research as well. Vulnerability is a function of modelling the response of the system to external stimulus (Allison et al. 2009; Döll 2009; Lindner et al. 2010). “How will climate affect magnitude, frequency, duration and the spatial distribution of hazards?” (Rosenzweig & Parry 1994; McCarthy et al. 2001; Parry et al. 2005). It has been described as ‘outcome vulnerability’ (O’Brien et al. 2007), the ‘end-point’ or ‘wounded soldier’ approach (Kelly & Adger 2000). Vulnerability is the “end point of a sequence of analyses beginning with projections of future emissions trends, moving on to the development of climate scenarios, and thence to biophysical impact studies and the identification of adaptive options” (Kelly & Adger 2000, p.326).

In relation to the inadequacy of the dominant view in explaining the causes and consequences of disasters and their seemingly growing frequency, a number of alternative views emerged (Hewitt 1983; Watts & Bohle 1993b; Blaikie et al. 1994; Hewitt 1997) among them a social constructionist, or ‘structural paradigm’ associated with Sen’s (1981) ‘entitlement’ approach. Smith and Petley (2009, p.4) use the term ‘structural paradigm’ to express that “it emphasises the constraints which are placed on individual action by more powerful institutional forces”. In a social constructionist view, the focus is less on the hazard itself than it is on the characteristics of the system that make it vulnerable. Vulnerability is a state, socially differentiated, and influenced

by social, economic, political, cultural, historical processes which inhibit the ability of communities/individuals to cope and respond (Hewitt 1983). Within this second framework are two main epistemological orientations: political economy and social/cultural constructivism.

In the political economy view, “social vulnerability” was an attempt to disaggregate poverty and to emphasize the relational position of individuals, households and social groups in the context of a specific society (Watts & Bohle 1993b; Bohle et al. 1994). Vulnerability was a cumulative process of long-term transformations and short-term events triggered by economic, political, social and cultural processes, possibly deteriorating as a result of unstable ecological conditions. When taken together these had a negative impact on the well-being or security of a population (Watts & Bohle 1993a). These processes were further developed in the influential ‘disaster pressure and release model’ of Blaikie et al. (1994), initially to account for land degradation in the Sahel (Blaikie 1981; Blaikie 1985; Blaikie & Brookfield 1987; Blaikie 1989). The model connects the impacts of a disaster on people through a series of levels of social factors that generate vulnerability. Vulnerability is defined in terms of the characteristics of a person or group's capacity to anticipate, cope with, resist and recover from the impact of an extreme event (Wisner 2004). Disasters then are discrete events (bounded by time and space), in which the scale and patterns of damage are a function of vulnerability.

The political ecology heritage of vulnerability as function of exposure-sensitivity and adaptive capacity is related to Chambers’ (1989) characterization. Chambers (1989) introduced the idea that vulnerability has an internal and external dimension, relating to the capacity to anticipate, cope, or recover from the impacts of a hazard, and to the exposure to risks of the hazard,

respectively. “Vulnerability thus has two sides: an external side of risks, shocks and stress to which an individual or household is subject to; and an internal side which is defenselessness, meaning a lack of means to cope with damaging loss” (Chambers 1989, p.1). It is now recognized that communities, households and individuals are not defenseless, but that adaptive strategies can be employed to mitigate losses, and realize opportunities associated with various stimuli (Smit et al. 2000; Yohe & Tol 2002; Adger 2006). The most vulnerable individuals, groups, classes and regions are those most exposed to perturbations, who possess the most limited coping capabilities, who suffer the most from crisis impact and who are endowed with the most circumscribed capacity for recovery. Vulnerability can, in other words, be defined in terms of exposure, capacity and potentiality (Smit & Pilifosova 2003).

Social and cultural constructivist perspectives on risks and hazards – including climate change – and vulnerability are also evident in the literature. Here the focus is on human agency and culture, the role of gender, for example, in work on climate change (Denton 2002; Nelson et al. 2002), climate hazards in Bangladesh (Cannon 2002), and earthquake risks (Fordham 2004), and the role of cultural institutions on defining and limiting vulnerability.

2.3.2 Current and emerging conceptualizations of vulnerability

While the early scholarship on vulnerability was focused on environmental hazards and food security, and remains a central concept in those fields (Gaillard 2010; McEntire et al. 2010), it was subsequently adopted for use in early climate change research (Bohle et al. 1994; Handmer et al. 1999). Adger (1996; 1999) built on Blaikie et al.'s (1994) work, focusing on capacity and entitlement in understanding vulnerability and adaptive capacity (Adger & Kelly 1999).

Leichenko and O'Brien's (2008) concept of "double exposure" has also drawn on this perspective, with respect to climate change occurring in conjunction with processes of economic globalization. More recent 'contextual vulnerability' (O'Brien et al. 2007) approaches, also draw on the political ecology heritage of this early work. Vulnerability in climate change research is also being informed growing body of literature employing a resilience framework; sustainable livelihoods and social justice; and the recognition of 'multiple stressors' (Ford et al. 2010).

Resilience is based in systems theory, and was first used by Holling (1973) to describe the condition of an ecological system that enables it to re-organize and regain core functions following significant disturbance. It "determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variable, driving variables, and parameters, and still persist" (Holling 1973, p.17). With respect to social systems, resilience has led to the development of the idea of 'coupled social-ecological systems' (Berkes & Folke 2000; Berkes & Jolly 2002; Engle & Lemos 2010; Nelson 2011) which describe human activities and environmental processes as mutually dependent, co-evolving and linked through complex feedback relationships.

In the field of climate change and agriculture, a number of case studies have employed a resilience framework in which the focus is on social-ecological systems at a range of scales from households to regions and nation states (Fraser 2003; Neudoerffer & Waltner-Toews 2007; Biggs 2011; Darnhofer et al. 2010; Kenny 2011). These studies examine the magnitude of climate change that can be absorbed before a system changes to a different state as well as the capacity to self-organize and adapt to emerging circumstances.

Resilience captures many features of vulnerability and has been used in global environmental change research—particularly with respect to the capacity of a population, individual or place to resist, cope with or recover from shocks and stress (Walker et al. 2004; Chapin et al. 2006).

Resilience was first developed in population ecology and ecosystem management, and it is still often mathematically based and model oriented in its current application (Allison & Hobbs 2004; Marshall & Marshall 2007; Fazey et al. 2010). There are several different definitions of resilience used in the literature: resilience as a biophysical attribute, a social attribute, a social-ecological system (SES) attribute, and an attribute of specific areas (Engle 2011). ‘Resilience’ comprises a distinct knowledge domain, associated with a specific disciplinary tradition and its own conceptual framing and terminology. With respect to vulnerability, resilience has been described as a parallel – as opposed to converging – scholarly theme (Adger & Brown 2009; Zhou et al. 2009; Turner 2010). ‘Resilience’ is used in this work in synonymously ‘adaptive capacity’, and is consistent with its use elsewhere (Turner et al. 2003; McCarthy & Martello 2010), rather than representing an engagement with a particular analytical framework.

Another important development has been recognition of the ways in which multiple stressors interact in creating vulnerability. The term “multiple stressors” has emerged in the literature as an important concept, as a result of empirical work (O’Brien et al. 2004; Belliveau et al. 2006; Westerhoff & Smit 2008; Paavola 2008) showing that vulnerability to climate change cannot be understood through the traditional ‘single stressor-single endpoint’ (Wenger 2000) paradigm. The impacts of climate change will interact with other non-climatic stressors (Wilbanks & Kates 2010). Globalization, economic and institutional changes such as price shocks, currency devaluations and neo-liberal resource management policies (Moss et al. 2001; Eakin 2005; Eakin et al. 2009; Turner et al. 2003; Silva et al. 2010; Young et al. 2006), and ecological change and conditions (Misselhorn 2005; Settele et al. 2010; Schweiger et al. 2010) are examples of stressors that have been identified as significant drivers of vulnerability, independently and in interaction with climate change. Social-ecological systems, communities or individuals often experience these stressors simultaneously and sometimes synergistically. Their responses are thus conditioned not only by their perception of one particular source of change, but the aggregation of a diversity of stressors operating together (Leichenko & O’Brien 2008; Wilbanks & Kates 2010).

2.3.3 Summary

Although vulnerability has numerous definitions, differences in approaches and usage, and policy implications, there are three defining features. First, it is inherently a differential concept because risks or changes and abilities to cope vary across physical space and among and within social groups. Although a region may not be considered vulnerable, there are likely to be households or groups within that region that are. Second, vulnerability is scale-dependent, both across time and space. It varies depending on the unit of analysis, from ‘individual’, ‘farm’ or ‘household’ to ‘class’, or ‘region’. Third, vulnerability is dynamic. The characteristics that shape vulnerability change over time, in response to changing biophysical and socio-economic conditions (Vogel & O’Brien 2004).

A conceptual model of vulnerability has emerged in the climate change literature (Kelly & Adger 2000; Smit & Pilifosova 2003; Yohe et al. 2003; Smit & Wandel 2006). The vulnerability of any system (at any scale) is reflective of (or is a function of) both the exposure and/or sensitivity of that system to hazardous conditions and the ability or capacity or resilience of that system to cope, adapt or recover from the effects of those conditions. This definition acknowledges both the external exposure to hazards or stress and the internal ability to cope, recover, or adapt to such stresses, which is linked to the sensitivity of the system (Kasperson et al. 2005). The sensitivity can be seen as the likelihood of negative impacts based on endogenous characteristics, while the resilience or adaptive capacity is the ability of the actor or system to absorb or adapt to stress (Adger et al. 2005; Brooks et al. 2005). The following section reviews in more detail the concepts of exposure-sensitivity and adaptive capacity, to develop a conceptual framework for the analysis of farm-level vulnerability.

2.4 Vulnerability and agriculture

Adaptation to climate change – and any policies, or other support mechanisms that go along with it – must anticipate that climate is only one stress in a complex environment (Wilbanks & Kates 2010). Stakeholders in various sectors are impacted by climate and employ a variety of approaches that are relevant to their context, enabling them to address challenges and respond to multiple pressures (Adger et al. 2005). This context is social, cultural, political and economic, and will impact on the success – or failure – of adaptive strategies (Lorenzoni et al. 2005; Masuda & Garvin 2006).

For agricultural systems, climate change is expected to present both risks and opportunities (Rosenzweig et al. 2001; Howden et al. 2007). Globally, there is evidence to suggest some of these effects are already being experienced, including earlier shooting and flowering of plants, and shifting biological communities (Gitay et al. 2001; Walther et al. 2002; Lenoir et al. 2008). In addition to a global rise in temperatures, it is projected that some extreme events will increase in frequency and severity as a result of a shift in mean conditions and/or a change in the natural variability of climate (Easterling et al. 2000; Smith et al. 2009). It is these extreme events and climatic variability that will likely be the most challenging for farmers as climatic variation is already the dominant source of interannual variability of production (Howden et al. 2007). Farmers have the ability to reduce the adverse effects of climate change or seize opportunities by adapting to the changing conditions (Easterling 1996; Wheaton & MacIver 1999; Bryant et al. 2000; Smit & Skinner 2002). However, the process through which adaptation in agriculture will occur is not well understood (Brklacich et al. 1997; Lemmen & Warren 2004; Meinke et al. 2006; Roncoli 2006).

In early climate change research consideration of adaptation was embedded within a stepwise hierarchical framework involving scenarios of climate change, identification of impacts and consideration of adaptation options. This stepwise approach to impacts and adaptation assessment was formalized through the work of Carter (1994), Parry and Carter (1998) and Feenstra et al. (1998) and evolved out of early studies on climate change impacts, many of which were focused on agriculture (Parry & Carter 1989; Carter et al. 1991; Porter et al. 1991; Kenny & Harrison 1992). Within these studies, adaptation was largely considered as adjustments in farm management, farm infrastructure, strategic research, and agricultural policy. Adaptation was for the most part, seen as a scientific, technological and policy oriented process. Key research questions that emerged through this work revolved around how to address the issue of uncertainty in the science of climate change, in the extent of future climate change, and in scaling from global to regional and local scales. Within New Zealand, the CLIMPACTS program sought to provide an integrated framework for addressing the uncertainty questions and to provide a basis for national, regional and local adaptation responses (Kenny et al. 1995; Warrick et al. 1996; Kenny et al. 2000).

Hierarchical and modelled studies however, fail to account for the presence of other, non-climatic variables. Farmers work within an environment characterized by highly variable political, economic, institutional, and biophysical conditions (Fleisher 1990; Brklacich et al. 2000; Kandlikar & Risbey 2000; Rodriguez et al. 2011). These multiple exposures interact to influence farmers' decisions, or more precisely their management practices, and hence agricultural adaptations to climatic variability and change cannot be conceived by stress-response or economic models (Smit et al. 2000; Bradshaw 2007; Wreford & Adger 2010). The

interactive effect of multiple exposures has the potential to be experienced and responded to by individual farmers in highly variable ways, owing to differing personalities, farming systems and circumstances (Smit et al. 1996; Kandlikar & Risbey 2000; Eakin 2005), requiring new ways of conceptualizing and analysing the impacts of climate change at the farm level (Meinke et al. 2009).

2.4.1 Vulnerability assessment

The theoretical and methodological framework used in this research has been developed against this background. The research is premised on the understanding that climate variability and change represents just one source of risk (or opportunity) for farmers and kiwifruit growers in the eastern Bay of Plenty. Agriculture is a ‘multi-risk multi-opportunity’ (Bradshaw 2007) environment. Non-climatic stimuli are likely to influence decision making at the farm level, and therefore cannot be conceptualized using simple single-stress (i.e., climate), single response models (Risbey et al. 1999; Wenger 2000). Producers must also respond to fluctuations in payout and commodity prices, legislative changes, interest rates, the loss of export markets, increasing competition, and the risk of personal injury (Harwood et al. 1999; Hardaker et al. 2004; Kay et al. 2007; Flaten et al. 2011). Furthermore, farmers experience and must respond to ‘interperiodic variability’ (Yohe 2000), and not just long-term climate change alone, adding to the difficulty in predicting farm level responses. Lastly, individual farmers can respond to similar external stimuli in very different ways. Attitudes towards risk, access to capital, age, social networks, personal history and access to technology can all influence the ways in which farmers perceive and manage risks (Smit & Skinner 2002; Tarleton & Ramsay 2008).

While this is recognized in some of the work on climate change impacts and agriculture (Brklacich et al. 2000; Belliveau et al. 2006; Bryant et al. 2007) there are still few examples of work that explicitly places climatic *and* non-climatic stimuli into the wider context of agricultural production. The aim of this research is to explore the exposure-sensitivity of farmers and growers in the eastern Bay of Plenty to multiple stressors, and their capacity to adapt. Unlike previous work that relies on a ‘top-down’, and linear analytical or modeled approach, this research seeks to develop a conceptual framework for the assessment of vulnerability that begins from the bottom up. It draws on elements of farm-decision making and vulnerability assessment to enable an integrated assessment of the conditions to which farms and farmers in the eastern Bay of Plenty are exposed-sensitive and the adaptive strategies employed.

Vulnerability assessments related to climate change can be conducted in a number of different ways, including participatory, simulation-model-based and indicator based approaches (Hinkel 2011). The vulnerability-based approach used here recognizes that there are pertinent climatic attributes to which agricultural systems are sensitive, and that these attributes can be used as a platform for analysing the implications of climate change (Kates 1985; Downing 1991; Carter et al. 1994). It aims to identify the climatic attributes relevant to specific agricultural systems, examine how these attributes are experienced through the variability and extremes associated with climate change and considers adaptation strategies in light climatic stimuli and other conditions that influence decision-making. It seeks to identify the ways in which sensitivity differs within specific agricultural systems, the types of adaptation that have been attempted, and

provide insights into the conditions under which adaptive decisions are made both now, and in the future (Luers et al. 2003; Berry et al. 2006; Tingem & Rivington 2008; Vásquez-León 2009; Pearson et al. 2011).

Where vulnerability assessments have been conducted elsewhere, the focus has typically been on the need for and mechanisms of, adaptation in a particular region or community or socio-ecological system in order to identify the means of implementing adaptation initiatives or to enhance adaptive capacity (Meinke et al. 2009; Giordano et al. 2010; Young 2010). The focus is on local conditions (Roncoli 2006; Acosta-Michlik & Espaldon 2008; Byg & Salick 2009). The purpose is practical – to characterize vulnerability and adaptive capacity in order to initiate adaptive measures or practices, or in order to improve the adaptive capacity (Sutherland et al. 2005; Næss 2006; Pouliotte et al. 2009; Young et al. 2009); and emphasises the ways in which a community or system experiences changing conditions and on the processes of decision making within the system that may accommodate adaptations or may provide means of improving adaptive capacity (Adger & Brown 2009).

This approach identifies the features and conditions that make up the broad elements of vulnerability and characterizes the processes that contribute to it. Several features are noted:

- Experience and knowledge of those members of a community or system of interest are used to characterize pertinent conditions, sensitivities, adaptive strategies and decision-making processes related to adaptive capacity or resilience (Pearce 2005; van Aalst et al. 2008).
- The motivation is to identify what can be done, in what way and by whom, in order to moderate the vulnerability to the conditions that are most problematic (Pahl-Wostl 2002; Moss et al. 2001; Young et al. 2009)
- Risks (and opportunities) associated with climate change (or other environmental changes) are addressed in decision making at some practical level. Adaptive responses are rarely if ever, made in light of climate change alone (Handmer et al. 1999; Huq & Reid 2004; Meinke et al. 2006; Young et al. 2009)

Research following this approach results in distinctive and practical information about adaptive capacity generated from applying these characteristics.

2.4.2 Conceptualizing vulnerability in agriculture

Vulnerability can be summarized formally (Smit & Pilifosova 2003; and as per *Figure 1.1*) as follows:

$$V_{ist} = f(ES_{ist}, AC_{ist})$$

Where V_{ist} = Vulnerability of a system i to climate stimulus s in time t ; is a function (f) of ES_{ist} = Exposure-sensitivity of i to s in t ; AC_{ist} = Adaptive Capacity of i to deal with s in t . This formulation provides the basis for explaining the approach employed in this study, and it makes explicit the logical structure that guides the empirical work. The model indicates that vulnerability (V) is a property of a system (i , in this case, individual farms, which can in turn be aggregated to describe a regional system, consistent with nested or hierarchical

conceptualizations of vulnerability (Smit et al. 1996; Adger et al. 2009; Eakin et al. 2009)), and varies from farm to farm, varies according to the type (or types) of climate stimulus, and varies over time (it is dynamic). The two key components of vulnerability are the manner and degree to which the farm is exposed to conditions or stimuli to which it is sensitive, and the capacity to adapt, both of which are also farm-specific, as well as specific to both stimuli and time periods. All things being equal, as one increases one decreases; if adaptive capacity increases then exposure decreases, and vice-versa. *Figure 2.1* illustrates this relationship between vulnerability, exposure-sensitivity and adaptive capacity. Low adaptive capacity, and a high degree of exposure or sensitivity would suggest the farm or other unit of exposure is more vulnerable than one in which adaptive capacity was high, but exposure-sensitivity was low.

		Exposure-sensitivity		
		High	Moderate	Low
Adaptive capacity	Low	High	High	Moderate
	Moderate	High	Moderate	Low
	High	Moderate	Low	Low

Figure 2.1 Vulnerability is shown in the boxes of the matrix as a function of exposure-sensitivity and adaptive capacity (Redrawn after Nelson et al. 2010))

Exposure-Sensitivity describes the susceptibility to an external stress; defining the degree to which the farm experiences stress, which is reflective of both the nature of the unit of exposure (ie. characteristics of the farm and farmer, such as location, type, awareness) and the nature of the stress. It reflects the interaction of the characteristics of the system and the range of climatic and non-climatic conditions to which the system is sensitive (sometimes referred to as external stimuli, stress, or hazard) (Nicholls & Hoozemans 2005; Smit & Wandel 2006; Hufschmidt 2011). For instance, a farmer whose production is highly dependent on water resources is more exposed and sensitive to drought than one facing equivalent moisture conditions but producing an agricultural commodity that is less dependent on the availability of water. Local conditions that influence exposure-sensitivity (e.g. soil type, location, land-uses, crop produced, etc.) reflect the broader social, economic, cultural, political and environmental conditions (Adger & Kelly 1999; Smit & Wandel 2006).

Exposure-sensitivity is not limited to climatic stressors. Producers must contend not only with inter-periodic variability in climate, but several other types of exposure, unrelated to weather conditions (*Table 2.1*).

Production or yield risk	Chances of losses in output or yield as a result of events that are often beyond the farmer's control, often related to weather, and/or related to technology
Market or price risk	Risk associated with changes in prices of inputs or outputs, which are seldom known when producers make choices about products and inputs; may include market access.
Financial Risks	Risk resulting from the way in which the farm's capital is obtained and financed; related to borrowing, uncertainty about future interest rates, the ability to meet debt repayments, and lender's willingness to continue lending.
Legal and Environmental Risks	Risk related to changes in government policies and regulations; may impose unanticipated constraints on production practices, or new costs or taxes
Human Resource Management Risks (Human or personal risk)	Risk associated with the people who operate the farm, as when death, divorce, illness or injury, may result in disruption of farm production and profitability.

Table 2.1 Types of risk in agriculture (Harwood et al. 1999; Hardaker et al. 2004; Kay et al. 2007)

In short, exposure-sensitivity and adaptive capacity to climate change cannot be understood independently of the various other forces which affect the farm system and to which farmers must adapt. The effects of changing climate conditions are felt synergistically with the effects of changing economic, political, social, cultural and technological conditions (Adger & Kelly 1999; Kasperson & Kasperson 2001; Tschakert 2007; Wilbanks & Kates 2010).

Adaptive capacity describes a system’s potential or ability to adjust to exposures in order to moderate damages, take advantage of opportunities or cope with effects (Brooks et al. 2005; Tol & Yohe 2007; Sydneysmith et al. 2010; Young 2010). Adaptive capacity varies between countries, communities, among social groups and individuals, systems and over time (Adger et al. 2005). It is scale dependent (Vincent 2007). Adaptive capacity of a system under observation is a dynamic function of local processes and conditions which in turn are influenced by broader socio-economic and political processes (Brooks et al. 2005; Engle 2011). Adaptive capacity is influenced by assets and access to resources such as economic wealth, technology, information, infrastructure, knowledge and skills, social capital and institutions (Watts & Bohle 1993a; Adger 2003; Smith et al. 2003; Smit & Wandel 2006).

Determinant	Description
Awareness	The ability to accurately identify the signals of change and their implications
Technology	The availability of and access to technological options for adaptation
Resources	The availability of resources for adapting (including financial capital and physical resources)
Institutions	The structure of critical institutions, including the allocation of decision-making authority
Human capital	The skills, education, experiences, and general abilities of individuals
Social capital	The informal social networks and collective life of a community, as it influences the ability and willingness of residents to work together for common community goals
Risk management	The ability of a system to manage risks, including sharing the risk amongst the stakeholders
Information management	The ability of decision-makers to manage information; including the processes by which information is acquired and assessed

Table 2.2 Determinants of adaptive capacity (Yohe & Tol 2002; Smit & Pilifosova 2003)

For example, two farms equally exposed to flooding, one may have more resources to move materials and rebuild than the other. Enhancement of adaptive capacity represents a practical means of addressing changes or risks, and may reflect the resilience, stability, robustness, flexibility and other related characteristic of the system (Smit et al. 2000; Turner et al. 2003). The system is also influenced by internal changes, such that adaptive responses or coping mechanisms for dealing with climatic variability (the short-term fluctuations, or inter-periodic variability), may increase exposure in other areas. For example an increasing reliance on imported feed will increase the capacity to tolerate extended periods of dry weather, but increases exposure to rising input costs. This interpretation is consistent with the ‘pressure and release’ conceptualization of Blaikie et al. (Blaikie et al. 1993; Wisner et al. 2004) in that the vulnerability of people or a system in a particular area (local scale) will reflect the interaction of both biophysical conditions (including climatic variability and change) and socio-economic conditions, both sets of which will have manifestations at scales from global to local, and both of which are dynamic.

Adaptations or adaptive strategies refer to “adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts” (Smit et al. 2000, p.6). It describes activities that represent changes in some attribute of the agricultural system (the agricultural sector or the farms within it) directly related to reducing vulnerability, not simply to climatic risks, but to non-climatic stimuli as well. These responses can vary according to timing (anticipatory or reactive), or by duration (tactical or strategic). Reactive adaptation occurs after the initial impacts of climate change become evident; anticipatory adaptation occurs before the impacts are obvious. Tactical adaptations are typically short-term strategies undertaken within

the growing season to deal with a problem; strategic adaptations are long-term capital investments in infrastructure – such as irrigation – or management decisions, such as changing pasture species, i.e. observable changes in a farming system, beyond a single season (Smit et al. 1996; Smithers & Smit 1997; Risbey et al. 1999).

Adaptive strategies in agriculture vary depending on the climatic conditions to which producers are responding, farm type, location, and economic, political and institutional conditions (Bryant et al. 2000; Smit & Skinner 2002). Adaptive strategies can take a wide range of forms (managerial, technical and financial), scales (local, regional and global) and actors (farmers, industries and governments) (Reidsma et al. 2010). Adaptations are mediated through their relative adaptive capacities, indicating that adaptive strategies may or may not be accessed according to the distribution of various types of resources such as physical or social capital (Adger & Kelly 1999). Components of exposure-sensitivity and adaptive capacity overlap, indicating the interaction and occasional commonality between their respective processes (Smit & Wandel 2006). Adaptive strategies in agriculture have been broadly classified as (1) technological developments, (2) government programs and insurance, (3) farm production practices and (4) farm financial management (Smit & Skinner 2002) and are shown in *Table 2.3* (overleaf).

In agriculture, a crop-based farming system for example that is exposed to a hazard (drought) will be susceptible to declining yields and economic loss (sensitivity). This exposure-sensitivity can be moderated by adaptive strategies such as irrigation, crop insurance, adoption of less moisture-reliant cultivars, and the farmer's management ability. The availability and use of such strategies reflect the system's adaptive capacity. A modest change in climate may then have little direct effect on a system that is not highly sensitive to the hazards (e.g., dairy farmers reliant on imported feed) or a system that is highly adaptable (e.g., farmers with irrigation). The same changes however might have dramatic consequences for a system with both high sensitivity and low adaptability (e.g., a non-irrigated farm, facing a low payout and higher costs for imported feed).

System-wide/ public agencies, institutions, agribusiness	Technological	Development of new crop types Weather information systems Innovations for farm management such as pesticides, irrigation technologies
	Government programs	Financial support following extreme events (e.g. flood, drought) Insurance
Individual farm unit	Market/Financial programs	
	Farmer practices	Diversification/expansion Change of timing of operations Change of intensity of production Change location of crops on existing land Abandon land Purchase crop insurance Participate in futures market
	Farm-level financial management	Participate in government programs Seek off-farm employment opportunities

Table 2.3 General agricultural adaptation typology (after Smit & Skinner 2002)

A related concept and one of prime importance for agricultural producers under a changing climate is a system's coping range. This term is defined by the range of conditions within which a system can function, accommodate, adapt and recover (Smit et al. 2000; Jones 2001; De Loe et al. 2001; Smit & Pilifosova 2003). New Zealand agricultural producers have historically coped with (or adapted to) existing climatic conditions, and deviations from the mean to some degree (Salinger 2005). This is what Yohe (2000) labels 'inter-periodic variability'. Exposures involving extreme events that lie outside the coping range may exceed the adaptive capacity of the farm or community however.

A system's adaptive capacity or coping range is not static. Coping ranges are flexible and respond to changes in economic, social, political and institutional conditions over time. For instance soil erosion may reduce a farming system's coping ability and narrow its coping range. At the same time the farmer may have increased financial resources from non-farm income, adopt technological changes that increase yields or diversify operations into non-crop production/diversify income streams, all of which may lead to an increase in adaptive capacity (de Vries 1985; Smit & Pilifosova 2003; Folke et al. 2005; Young 2010) or what Rodriguez et al. (2011) refer to as the inherent 'plasticity' of the farm or the capacity of the system to opportunistically respond to variability.

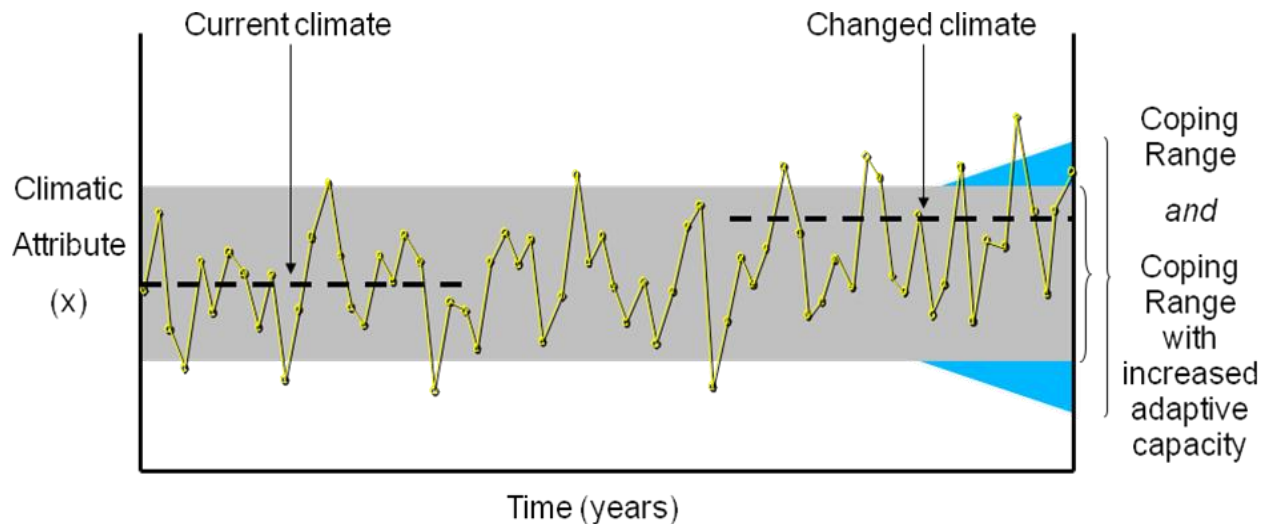


Figure 2.2 Coping range and extreme events (after Smit and Pilifosova 2003)

Figure 2.2 illustrates how a system's coping range reflects adaptive capacity relative to exposure and how these relate to vulnerability. An agricultural system might be sensitive to changes in moisture. Moisture deficits and the occurrence and severity of drought vary from year to year, yet the system depicted is able to cope with a degree of variation around the mean or average conditions. The amount of variation the system can manage is its 'coping range' (it could also be called the 'adaptive capacity threshold' of the system) (Smit & Wandel 2006). With climate change, it is expected that for some agricultural regions within New Zealand, mean moisture deficits will increase (Mullan et al. 2005). As it does so, the system will experience, and be more exposed to, an increase in the frequency and magnitude of events beyond the coping range. *Ceteris paribus* this would increase vulnerability. To the extent that the system may be able to expand the coping range or enhance its adaptive capacity to deal with these exposures, it will reduce its vulnerability to drought risk. The forces that influence the ability of the system to

increase adaptive capacity are the driving forces, external factors, influencing processes, and determinants of adaptive capacity (Yohe & Tol 2002; Adger et al. 2004; Brooks et al. 2005; Tol & Yohe 2007; Keskitalo et al. 2010).

This conceptualization of vulnerability recognizes that vulnerability can vary within a region, and is context specific, reflecting the characteristics of the location of the system in question, as well as dynamic. Vulnerability changes over time as a result of evolving external conditions, changing internal characteristics, and interactions between stakeholder-producers and their environment. Adaptations at the farm level are understood as being dynamic, changing in reaction to the various stimuli. Experiences of vulnerability will also change as a result of broad scale social and economic processes manifesting at local scales. Lastly, exposures and adaptive capacity are not considered independently, but may be influenced by many of the same issues or conditions, both at the local levels as well as through broader forces, such as regional, national or international socio-economic conditions. In this dynamic process, feedbacks are likely to occur; for example when an adaptive response to one stress alters the exposure or adaptability to another stress (Turner et al. 2003).

2.4.3 Assessment of multiple stressors and dynamic vulnerability in agricultural systems: A conceptual framework

In order to consider the processes and prospects for agricultural adaptation to climatic and non-climatic stresses, it is necessary to recognize the multifaceted and hierarchical nature of agricultural systems themselves. In other words, Who, to what, and how is it that they adapt? A vulnerability-based conceptual model illustrating how climatic and non-climatic conditions at a range of scales interact to influence exposure-sensitivity and adaptive capacity at the farm-scale is presented in *Figure 2.3*. The framework draws on the conceptualization of vulnerability as a function of exposure-sensitivity and adaptive capacity (Smit & Pilifosova 2003). It seeks to account for the influence of *both* climatic and non-climatic stimuli on farm management. It draws upon scholarship in vulnerability science and agricultural decision-making, in order to structure the identification and characterization of the climatic and non-climatic processes shaping farm-level vulnerability. It allows for the analysis of interconnected processes at a range of scales, reflecting the dynamic characteristics of the system as well as the broader conditions within which the system operates (Handmer et al. 1999; Wilbanks & Kates 1999; O'Brien et al. 2004). As presented here, the framework does not attempt to represent all factors, interactions, scales or feedbacks, although these have been developed in other analytical models (see Turner et al. 2003; Smit & Wandel 2006). The framework instead aims to highlight those generic elements of vulnerability that apply at a local scale, reflective of the broader scale processes and relating to adaptation strategies, and which was used to guide the case study of the eastern Bay of Plenty.

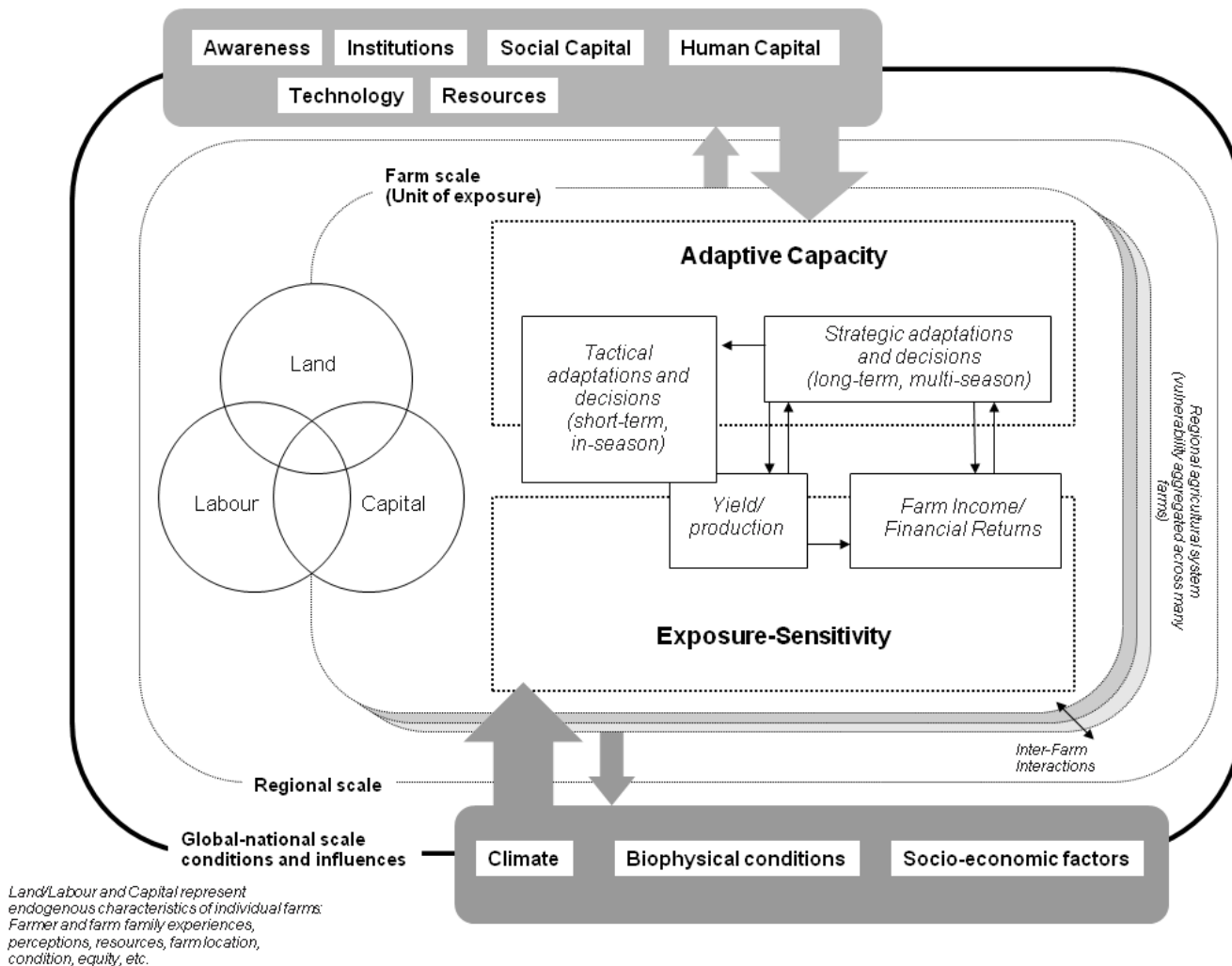


Figure 2.3 A vulnerability-based model for assessing multi-scale factors influencing farm-level vulnerability of pastoral farmers and kiwifruit growers in the eastern Bay of Plenty. The model is a schematic representation of the factors and conditions that influence exposure-sensitivity and adaptive capacity at the farm level. It demonstrates the interconnected and nested nature of a farm or orchard, including: multiple dimensions of external variables and internal interactions determining the vulnerability of the system. Vulnerability is dynamic; exposure-sensitivity and adaptive capacity both change as the properties of the system change.

The individual farm is the unit of exposure and focus of analysis. Agricultural systems can be identified as farms, plantations, regional and national agricultures (Spedding 1988) or as a nested hierarchy or agroecosystems, comprising ecological, economic and human dimensions and ranging from the field or plot to the region and beyond (Conway 1987; Izac & Swift 1994; Giampietro 2004). The level of analysis is particularly important in the study of agricultural systems because the relevant attributes change as consideration progresses from micro (or farm) to macro (or system) scales (Vincent 2007; Reidsma et al. 2010). For example, an analysis of implications of environmental change for crop production might focus on soil-plant relations at the level of the farm field, but at broader spatial scales the relevant attribute on this same dimension would be quite different, regional yield levels or national production (Hillel & Rosenzweig 2010). At each level there is a variety of components and attributes that are potentially subject to change and a corresponding series of scale dependent indicators (Giampietro 2004).

Historically, in agricultural research, the most appropriate level of analysis for agriculture has been the farm (Olmstead 1970; Altieri & Trujillo 1987; Dover & Talbot 1987). This places key importance on the intersection of ecological, economic and human factors at the scale where performance is first assessed and decisions are made regarding intervention and resource allocation. More recent research examining agricultural adjustment to political and economic change focusing on farmers as decision makers has also been conducted at farm scale (Eakin 2003; Darnhofer et al. 2010; Mwinjaka et al. 2010; Reidsma et al. 2010; Head et al. 2011). In this approach, as at other scales of system definition, farms are seen as functioning within external economic, institutional, technological and social environments - all with potential to act as forces

of change or adjustment or as constraints on responses to environmental and other stimuli. The framework shows regional, or aggregated vulnerability, across the diversity of farms and orchards in the study area, to be a function of the collective conditions to which producers are exposed-sensitive and adaptive strategies employed to manage those exposures.

The farm is conceptualized as the main exposure unit and unit of analysis. Consistent with the literature on agricultural decision-making, the farm is understood to comprise elements of land, labour, and capital (Morgan & Munton 1971). The endogenous characteristics of the farm include farmers and farm family experiences, awareness, resources, farm location, farm type, condition, indebtedness and equity, among other features. The farm operates within and changes in response to, external, interconnected systems (Olmstead 1970; Bowler 1992; Bryant & Johnston 1992; Giampietro 2004). External forces provide risks, opportunities, and constraints to the functioning of the farm, and influence in turn, decision-making (Bryant & Johnston 1992). It follows then that these external forces and local farm characteristics influence the farm system's exposure, sensitivity and adaptive capacity, and hence its vulnerability (Belliveau et al. 2006; Wandel et al. 2007; Darnhofer et al. 2010).

Farm-level vulnerability is shown as a function of exposure-sensitivity and adaptive capacity (Smit & Pilifosova 2003). Exposure-sensitivity and adaptive capacity are nested within and teleconnected to, processes and systems at multiple temporal and spatial scales (Young et al. 2006; Eakin et al. 2009). At the scale of the individual farm unit, vulnerability is shown to be influenced by processes operating at a range of scales, including global pressures and stressors emanating at a regional scale through to local impacts. Potential pathways include biophysical linkages and feedbacks, economic market linkages, and flows of resources, people, and information (Adger et al. 2009). Factors influencing exposure-sensitivity, shown in the bottom-right, include broad scale climatic conditions, such as ENSO/IPO, that have an effect on precipitation patterns; biophysical conditions including soil type, topography, hydrology and geology; socio-economic factors, such as currency fluctuations and access to global markets; and the institutional and governmental environment within which producers operate.

The determinants of adaptive capacity are likewise influenced and shaped by conditions at scales beyond the farm gate. Adaptive capacity influences the vulnerability of individual farms and farmers. The vulnerability of individual farmers is a function of the tools and resources available on the farm, the characteristics of the farmer themselves and aspects of the farms location which will influence exposure-sensitivity and adaptive capacity. This might include farm income, access to credit, levels of indebtedness, capabilities of the farmer in terms of his/her skills, age and awareness of risk, represented by land, labour and capital (Morgan & Munton 1971). As shown earlier in *Table 2.2*, adaptive capacity is influenced by assets and access to resources such as economic wealth, technology, information, infrastructure, knowledge and skills, social capital and institutions (Watts & Bohle 1993b; Smith et al. 2003; Adger 2003; Smit & Wandel 2006).

Individual producers employ a range of strategies to manage their exposure to climatic and non-climatic stimuli. These can range from short-term, tactical responses undertaken in response to conditions within a single season; to longer-term, strategic adaptations. The framework shows that vulnerability is experienced most directly as impacts on production and yield, and in turn, farm income or orchard gate returns, linking it to exposure-sensitivity. The conditions to which producers are sensitive will vary from farm-to-farm, and between the types of commodity produced.

The farm is vulnerable to climatic and non-climatic exposures to the degree that they are detrimental to the operation and to the degree that the farmer is unable to adapt, due to constraints to adaptation and/or adaptive capacity (Smit & Pilifosova 2003; Adger 2006). While the external drivers of exposure and the determinants of adaptive capacity may be common or similar among farms in a region, the endogenous characteristics of farms can vary greatly (Smithers & Smit 1997). Among farms in any given area, differences in location, farm characteristics and farmer attributes will result in differential sensitivities and vulnerabilities. Nonetheless, the vulnerability of a regional agricultural system will reflect the aggregation of the many farms in the region (Reid et al. 2007; Hadarits 2011). Decisions on one farm will also be informed by the experience of others, and decisions on farms and characteristics of the regional agricultural system will feed back to some of the sources of exposure and determinants of adaptive capacity.

Vulnerability is understood to be dynamic, and shifts over time and in response to adaptive strategies, and due to the interaction between biophysical and socioeconomic conditions also at a range of scales. The model highlights these feedback relationships between adaptation strategies and adaptive capacity, and exposure-sensitivity. The framework is presented here in its skeletal form, without including the particular factors, variables, linkages etc. in the components.

Consistent with the ‘bottom up’ methodology and conceptual framing, in the research which follows, details regarding relevant stimuli and adaptive strategies were not assumed *a priori*. The exact pathways through which these processes affect agricultural production and its relationship to vulnerability, are not shown but were developed and traced as the study progressed. The exact nature of exposure-sensitivity and adaptive capacity were also identified empirically as the case study developed, by the farmers themselves. The conceptual framework guides the discussion of subsequent chapters.

2.5 Conclusion

It is increasingly apparent that adaptation to climate change will be necessary, regardless of efforts to reduce GHG emissions. The relatively recent shift in focus from mitigation to adaptation has contributed to the evolution of different approaches to research in the field of climate change impacts. While there is still an emphasis on model-based impacts research (Schmidhuber & Tubiello 2007; Kurz et al. 2008; Allison et al. 2009; Cheung et al. 2009; Junk et al. 2011), more recent studies have sought to address vulnerability across a wide range of communities, systems, and sectors (Pouliotte et al. 2009; Perch-Nielsen 2009; Few & Tran 2010; Hovelsrud et al. 2010; Hadarits 2011). A major lesson from this work is that climate change is just one of many relevant factors in the analysis and that adaptation depends on complex relationships between processes in many subsystems – social, technological, economic and ecological (Brooks 2003; Füssel & Klein 2006; Thomalla et al. 2006). Similarly, the concepts of ‘double exposure’ (O’Brien & Leichenko 2000; Leichenko & O’Brien 2008) and ‘multiple stressors’ (O’Brien et al. 2004; Westerhoff & Smit 2008; Paavola 2008; Casale et al. 2009; Wilbanks & Kates 2010) capture how economic globalization, institutional change, or the presence of other, non-climatic risks, can interact *with* climate to increase vulnerability.

Conceptualizations of vulnerability have been informed by developments in the fields of natural hazards (Burton et al. 1993; Cutter et al. 2003; McEntire 2005), ecology (Holling 1973; Holling 2001; Folke 2006), political ecology (Watts & Bohle 1993a; Blaikie et al. 1994; Wisner et al. 2004), food security (Sen 1981; Dilley & Boudreau 2001), and sustainable livelihoods (Chambers & Conway 1992; Turner et al. 2003). It has emerged in the field of climate change research as a key concept relating to adaptation in both scholarly and policy debates. Action on

adaptation has increasingly moved from attempts to measure levels or relative scales of vulnerability to attempts to outline the processes underlying vulnerability and to identify opportunities to reduce it by promoting adaptation. Vulnerability is now widely used to characterize and understand the implications of climate change at the local level (Few 2003; Næss et al. 2005; Gamble et al. 2010; Keskitalo 2010).

Interpretations of vulnerability have evolved, and yet there is still a great deal of variation in the literature (McEntire 2005; Thywissen 2006; Zhou et al. 2009; Hinkel 2011). Studies continue to characterize vulnerability in terms of physical stimuli and their impacts or residual effects, focusing on the nature and distribution of a hazardous condition as it affects human-environment systems and the degree of loss associated with the occurrence of a particular event (Pearson et al. 2011), while others view it as a pre-existing state of a social system or community that renders it susceptible to harm. This interpretation highlights the conditions or processes that influence a society's exposure to stimuli and its ability to deal with hazards (Kasperson & Kasperson 2001; Downing 2003; Polsky et al. 2007).

In the conceptual framework presented earlier, vulnerability is defined as being a function of exposure-sensitivity, and adaptive capacity (Smit & Pilifosova 2003). It seeks to identify and explain the multiple underlying political, socioeconomic, and environmental forces that influence the ways in which farmers and farming systems are exposed and sensitive to climatic risks, within the context of other, non-climatic stimuli. Factors contributing to vulnerability are not assumed *a priori* but identified on the basis of farmers' experiences, allowing for differentiated

vulnerabilities within the region. The framework was empirically applied in order to assess farm-level vulnerability in the eastern Bay of Plenty; it guided the research strategy and also provides the structural basis for the remainder of this thesis.

For Turner et al. (2003) social and physical approaches to vulnerability are both essential parts of a comprehensive framework for understanding the vulnerability of coupled human–environment systems. They suggest looking at coupled human–environment systems, instead of one or the other constituent system, highlighting the role of the sequence and interactions of stressors, complexities and non-linearities, and issues of scale in vulnerability analysis (Turner et al. 2003; Turner et al. 2003b). The greater resolution of this approach renders it “place-based” because the conditions of the coupled human–environment system are highly contextual (Adger et al. 2003; Smit & Wandel 2006; Liu et al. 2007).

The analysis which follows acknowledges that environmental and social systems together construct the vulnerability of agriculture in a context-dependent way. Current exposure-sensitivities are rooted in historical antecedents, and biophysical conditions. The following chapter establishes a context for the empirical analysis by discussing the sociocultural and environmental characteristics of the region, as they relate to the conceptual framework.

Vulnerability is influenced not only by changing biophysical conditions but by dynamic social, economic, political, institutional, and technological structures and processes, i.e. contextual conditions (O’Brien et al. 2007), requiring further analysis be informed by an in-depth review of local place.

CHAPTER THREE: Ecological and Social Context of Vulnerability

3.1 Introduction

The Rangitaiki Plains is surrounded by hills, and that was part of the Bay of Plenty, and the Maoris lived around the edge – because this was all swamp. Originally it was a bigger Bay of Plenty, and as the water and the floods came and the earthquakes, all the mixture of soils ended up to form the Rangitaiki Plains. You get peat, rotten vegetation; pumice out of the Taupo eruption and ash – it's all in there.

- Malcolm Law (1923-2008), Second-generation dairy farmer on the Rangitaiki Plains, *pers. comm.*

As shown in Chapter Two, vulnerability is neither a predominantly climatic- nor other biophysical-event based condition, but rather derives its significance from the interaction of natural conditions and society (Hewitt 1983; Kates 1985; Varley 1994; Kasperson et al. 2005). The analytical components of vulnerability – exposure-sensitivity and adaptive capacity – are both influenced by and dependent on the climatic, biophysical and socio-economic characteristics of the unit of analysis (Smit & Pilifosova 2003; Schröter et al. 2005; O'Brien et al. 2007). The empirical assessment of farm-level vulnerability to climatic and non-climatic stimuli requires the analysis then be grounded in the unique characteristics of the area (Cutter et al. 2003; Turner et al. 2003; Ford & Smit 2004; Keskitalo 2004). As shown in the conceptual framework (*Figure 2.3*) farm level vulnerability is shaped and influenced by conditions operating at multiple scales beyond the farm gate. These conditions can be identified at global, national, and regional scales, and at the local or farm level (Adger et al. 2005; Vincent 2007). They include climatic and biophysical conditions, weather-related phenomena and the influences of topography and hydrology. Furthermore, farms, as with the other scales of system definition, are

seen as entities operating within external economic, institutional, technological, and social environments, as well as within the natural environment (Smithers & Smit 1997).

The aims of this chapter are as follows: First, it seeks to establish a baseline and context for the empirical analysis. By situating agricultural production within the broader social and ecological environment, the chapter aims to identify and contextualize the systems and networks within which producers operate and function, and provide a context for the components of farm-level vulnerability later identified by producers. The chapter argues that in order to understand farm-level vulnerability, those conditions internal and external to the unit of exposure must be considered as per *Figure 2.3*. This includes the biophysical environment producers operate within, as well as stimuli originating in political, governmental and market structures. These conditions are relevant insofar as they are likely to influence the vulnerability of producers to long-term changes in climatic conditions.

Second, the chapter suggests that contemporary regional agricultural production can be understood as a function of the opportunities associated with the unique climatic and biophysical conditions of the study area, and historical trajectories and processes of land transformation and resource use. Changing land-use and settlement patterns have both shifted in response to, and reshaped the physical environment of the Whakatane District over the last one-hundred and fifty years. Producers have taken advantage of localized soil conditions and favourable climate, as well as extensively modifying the physical landscape for the purposes of agricultural production. The result is a diverse agricultural economy, centred on pastoral farming and horticultural production.

Finally, changes in the physical and economic landscape can be used to illustrate the dynamic nature of vulnerability. Drainage and subsequent lowering of the landscape through tectonic movement and consolidation has increased exposure to flood events, while removal of agricultural subsidies in 1984 exposed producers to market and financial risks to which they were previously impervious. In this way, vulnerability can be seen to be a product of the “legacy effects” (Liu et al. 2007) of the historical development of the area and patterns of settlement, local environmental conditions as well as economic forces beyond farmers’ control. The chapter begins with an introduction to the location of the study area followed by a review of the physical landscape, linking it to the establishment of a diverse agricultural economy in the eastern Bay of Plenty, New Zealand.

3.2 Case-study area: Whakatane, Kawerau and Opotiki Districts

The research was completed with the participation of farmers and kiwifruit growers in the Whaktane, Kawerau and Opotiki Districts in the Bay of Plenty Regional District. The study area is located on the east coast of New Zealand’s North Island (*Figures 1.1 and 3.1*). The Regional Council District is one of marked socioeconomic contrast between the increasingly urban and fast-growing west, and predominantly rural east (EBoP 2004). The city of Tauranga (pop. 106,500) and Western Bay of Plenty districts are the fastest growing areas in New Zealand with respect to population, outside of Auckland, while the eastern districts are among the most deprived districts in New Zealand, marked by high-unemployment and lower annual median incomes (EBoP 2004; Statistics New Zealand 2006).



Figure 3.1 District boundaries of the case study area, eastern Bay of Plenty, New Zealand (Map courtesy of M. Oulton)

The physical environment has been shaped by earthquakes, volcanic eruption and floods (Pullar 1985; Nairn & Beanland 1989) and extensively modified for human use (Gibbons 1990). It is tectonically active; the eruptions of Taupo (1850 BP), Kaharoa (600 BP) and Tarawera (1886 CE) left extensive tephra deposits which in turn altered river flow regimes, and contributed to soil formation (Lowe et al. 1998); seismic activity has resulted in continued downward faulting along much of the coast (Froggatt & Lowe 1990; McGlone & Jones 2004); a prograding shoreline has left remnant beaches and dune deposits inland, and frequent flood events have reworked and redistributed alluvium over vast areas, producing some of the most fertile agricultural land in the country (Pullar 1985).



Plate 3.1 The topography of the eastern Bay of Plenty has been shaped by tectonic and volcanic activity, and environmental change resulting from human modification of the landscape (MacDonald dairy farm, with Mt Edgecumbe in the distance, Rangitaiki Plains, eastern Bay of Plenty, New Zealand)

Major topographic features in the area include the low-lying Rangitaiki Plains; terrace-like coastal lands; the Galatea Basin and hill-country and steepplands (>25 degrees) (Rijske & Guinto 2010). There are three main catchments which contribute flow to the six main rivers: the Rangitaiki, Tarawera, Whakatane, Waimana, Waiouka and Otara. The Rangitaiki Plains is further drained by nearly three-hundred kilometres worth of canals drains diverting excess water into the Tarawera, Rangitaiki and Whakatane Rivers.

3.3 Historical and ecological contexts of regional agricultural production

As shown in the conceptual framework (*Figure 2.3*), exposure-sensitivity at the farm level is influenced by climatic and biophysical, as well as social and economic conditions originating in and operating at, a range of temporal and spatial scales. This includes interannual and interdecadal climatic variability, and multi-decadal processes of soil formation, and hydrology. The vulnerability of agricultural producers is also related to historical trajectories of land management and economic development. The following discussion establishes a context for the analysis which follows as it pertains to land-management practices and the vulnerability of farmers and growers in the district. Current agricultural production has been shaped by the unique soil, climatic and hydrological conditions that have fostered the historical development of a diverse agricultural economy based on pastoral farming and horticultural production.

3.3.1 Biophysical conditions: geology, soils, topography and hydrology

Agricultural production in the eastern Bay of Plenty takes place within the context of a dynamic physical environment shaped by volcanic eruption, earthquake and floods (Pullar 1985; Froggatt & Lowe 1990; Lowe et al. 1998; McGlone & Jones 2004). It consists of a combination of coastal riverine floodplains ('flats') and uplifted marine terraces ('tablelands') used for both dairying and horticulture (Rijske & Guinto 2010). It is located within the Taupo Volcanic Zone. The main geologic feature of the region is the Whakatane Graben (Nairn & Beanland 1989) within which the lowland plains have subsided and filled with sediments from adjacent catchments while the surrounding hills have risen.

Volcanic activity has influenced conditions throughout the area. The surface has frequently been covered with volcanic ash (tephra). Main tephra are the Whakatane Ash (c.5500 BP), Taupo Pumice (c.1850 BP) (Nairn & Beanland 1989; Froggatt & Lowe 1990), Kaharoa Tephra (cal.600 BP) (Lowe et al. 1998) and Tarawera Tephra of 1886 CE. Tephra layers are found in the upper sediments of deposits throughout the region (McGlone & Jones 2004). Soils that develop on tephra are free-draining and often have good fertility (Rijske & Guinto 2010). The Tarawera eruption in 10 June 1886 was felt in Whakatane: the whole district was affected by its ash and extensive flooding that forced some people from their homes and destroyed some settlements (Irwin 2004). Opotiki district, further east, consists predominantly of greywacke, which has been mantled by loess and more recent volcanic ash and pumice from the Rotorua and Taupo volcanic centres (Iso et al. 1982).



Plate 3.2 Ash from the Tarawera (c. 1886) eruption, affects pasture growth and a farm's sensitivity to drought conditions (Clark dairy farm, Rangitaiki Plains, eastern Bay of Plenty, New Zealand)

Earthquakes are common in Whakatane and Kawerau districts. There is lower-earthquake risk in Opotiki as it lies just off to the east of major fault lines (Iso et al. 1982). Very severe earthquakes were recorded in March 1890 and another in December 1908. The 'Edgecumbe Earthquake' on 2 March 1987 affected buildings and infrastructure throughout the region. The Tasman paper mill at Kawerau sustained extensive damage; and at Bay Milk Products in Edgecumbe, steel tanks, storage racks, foundations and milk-processing equipment were destroyed (Beanland et al. 1990). In inflation adjusted (2007) dollars, the Edgecumbe Earthquake was the costliest event to affect the area, NZ\$330 million (ICNZ 2009). A considerable drop in ground elevation was associated with the normal faulting, severely affecting drainage and flood-control on the Plains (EBoP 2008). Land to the north-west dropped by up to 2 metres, making it more prone to flooding (McVerry et al. 1989).

The major topographic features and related agricultural land-uses in the area include the low-lying Rangitaiki Plains and flat coastal areas near Opotiki. Land use on the versatile soils includes dairying, dry stock and horticulture. Inland, is terrace-like flattish country with thick layers of tephra. Soils are well drained, and used for dairying, dry stock and horticulture. The Galatea Basin consists chiefly of terrace-like surfaces covered by tephra, mostly pumice. It is drought prone and very well drained, and used for dairying and dry stock. Hill country forms much of the background of much of the above landforms, and tephra covered steepplands (slopes >25 degrees) occur throughout the study area, on which dry stock and dairying are the main land uses. At a smaller scale, are coastal and inland dunes used for kiwifruit orchards, and backswamp lowlands and peat swamps, as well as a natural levees system of rivers and streams and floodplains of largely mixed alluvium (Rijske & Guinto 2010).

Soil characteristics influence land-use and were identified by producers as important factors related to their exposure-sensitivity. Soils range from ash to peat, and vary with respect to slope, depth, texture, drainage, and other characteristics (e.g. depth of tephra layers). Most soils are loams derived from volcanic ash which crumble easily and are free draining and drought prone, with limited moisture holding capacity and low fertility, requiring large amounts of superphosphate fertiliser, to which they respond well (Leamy & Fieldes 1976). Well-drained coastal soils are formed from older ash (Leamy & Fieldes 1976; Pullar 1985), those derived from the more recent addition of the Kaharoa ash are friable and free-draining. They have good moisture holding capacity, and are productive soils, but require fertilising for sustained use (Rijske 1993). Most of the plains have layers of consolidated peat which are deepest in the eastern areas and in low lying areas between sand ridges, and along the Omeheu (Pullar & Patel

1972). Deep drains are required to lower the water table in order to develop pasture on these soils. As the peat decomposes and shrinks, the land sinks, especially near the drains, forming a domed landscape. Sinkage can be as much as 14–33 mm/yr, and can disrupt fences and buildings. The rate of sinking can be reduced by damming the drains in spring to manage the level of the water table (Gibbons 1990).

The Plains are interspersed with wind-blown sand ridges, lying generally parallel to the coast. The dunes formed over some 7000 years as the coast prograded approximately 10 km (Irwin 2004). These are covered or mixed with ash and tephra; near Kawerau, dune reach up to a height of about 30 m asl (Pullar & Selby 1971; Pullar & Patel 1972). The dunes are extremely susceptible to drought – grass burns off quickly – but the free-draining sandy soil is well suited for kiwifruit production.

Three main catchments in the study area contribute flow to six main rivers, all of which are flood prone. Flood risk is most pronounced on the lower reaches of the Whakatane-Tarawera and Rangitaiki catchments (EBoP 2008) where maximum recorded floods have only been two to three times normal flow (McKerchar & Henderson 2003). The Rangitaiki Plains is further drained by the 88 kilometres of major canals, and 240 kilometres of drains, comprising the Rangitaiki Drainage Scheme, which relies on gravity to divert excess water from the plains into the Tarawera, Rangitaiki and Whakatane Rivers (*Figure 3.2, overleaf*).



Plate 3.3 Drainage canals on the Rangitaiki are managed in conjunction with the regional district and a farmer run co-operative. Adequate fall is increasingly problematic, owing to subsidence and tectonic movement (Rangitaiki Plains, eastern Bay of Plenty, New Zealand)

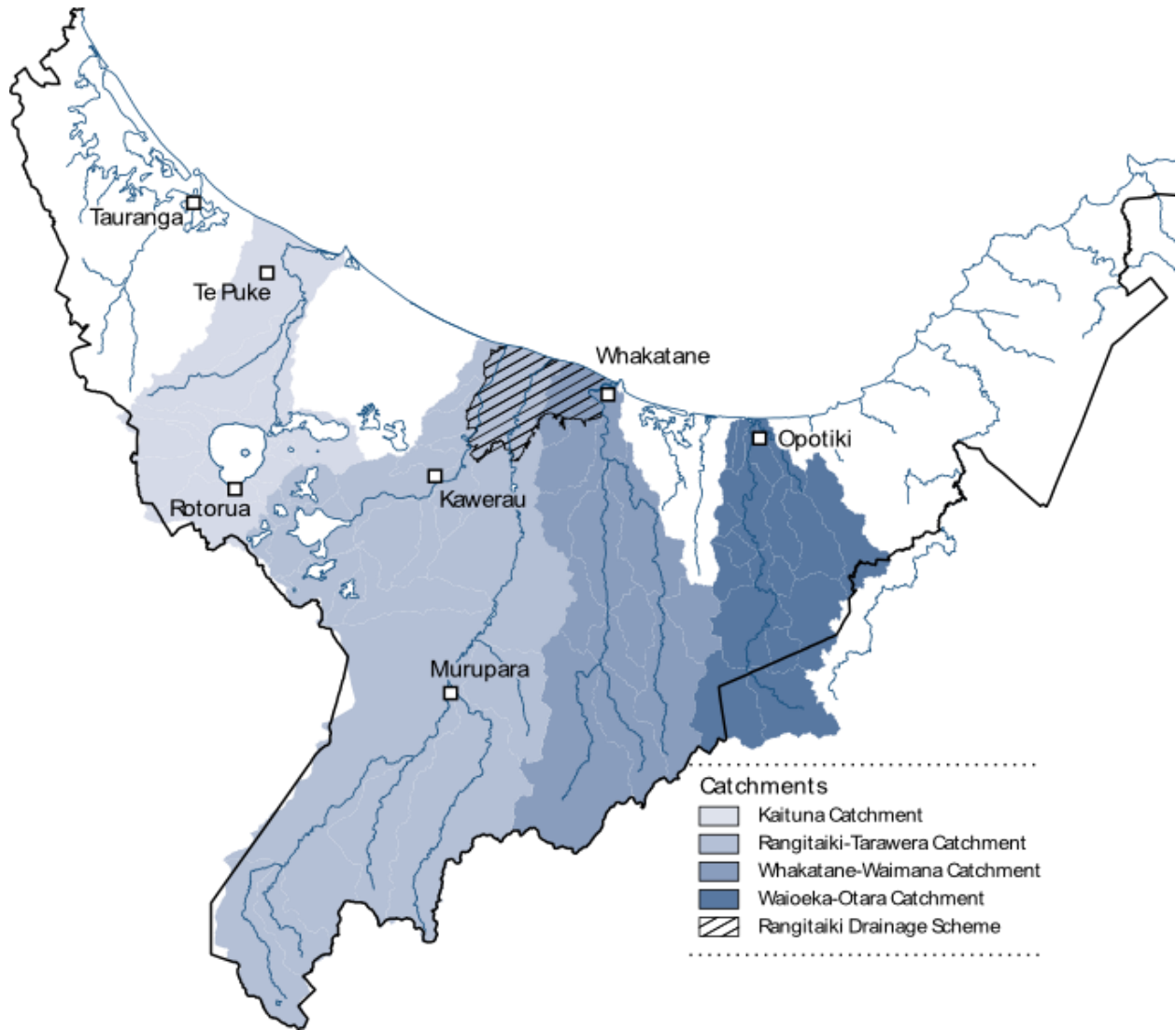


Figure 3.2 Catchment areas in the Bay of Plenty (EBoP 2004)

3.3.2 Climatic conditions

The climate in the study area is currently well-suited to agricultural production. Climate here refers not only to the long-term averages of weather elements, but also the range of likely values and the occurrence of extremes (Griffiths et al. 2003). It is considered sub-tropical, with warm humid summers and mild winters; somewhat sheltered from the prevailing winds by the high country of the North Island. Consequently, the region has a sunny climate with dry spells, but may have prolonged periods of heavy rainfall as shown in *Table 3.1*.

Month	Rainfall (mm)		Growing degree days ¹ (GDD)		
	2007/08	2008/09	Average	2007/08	2008/09
June	179	209	143	34	29
July	224	271	164	33	24
August	125	200	158	40	28
September	96	89	126	64	76
October	105	114	143	112	108
November	27	71	110	150	149
December	93	121	129	226	226
January	45	32	106	286	274
February	174	304	110	245	270
March	96	325	132	249	202
April	274	130	142	162	130
May	106	82	138	52	76
Total	1544	1965	1600	1653	1566

Note

1 GDD – growing degree days. GDDs are a measure of heat accumulation and are calculated by taking the average of the daily high and low temperatures each day compared with a baseline (usually 10 degrees centigrade). They help to predict the date that a flower will bloom or a crop reach maturity.

Table 3.1 Weather data, Bay of Plenty (Source: NIWA, Te Puke)

Typical summer daytime maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C; winter daytime maximum air temperatures range from 9°C to 16°C. During the warmest months the temperature averages 23°C, while the region's reasonably warm winters average a 14.7°C daily high. Annual sunshine hours average 2000 in many areas, but the coastal region from Tauranga to Whakatane is much sunnier with at least 2200 hours. SW winds prevail for much of the year. Sea breezes often occur on warm summer days.

Annual rainfall ranges from about 1200 mm at the coast to over 2000 mm inland at higher elevations. Precipitation is highly variable in the study area, temporally and spatially. Rainfall at Waihi varies from a record wet year in 1928 (3234 mm) to a record dry year in 1982 (1249 mm), a difference of nearly 2 metres (Griffiths et al. 2003); Whakatane receives an average of 1198 mm of rainfall. Precipitation decreases inland, and some inland basins – such as Galatea (see *Figure 3.4*) – are drought prone, though this is not only a function of low rainfall but pumice soils, with low soil-moisture capacity (Rijske & Guinto 2010). Precipitation is markedly seasonal, with over 45% of the annual rainfall between May to August (Griffiths et al. 2003). Extremes of precipitation are not uncommon during this time, creating significant problems for pastoral farmers as these are critical months of the production season, with pugging (waterlogged pastures) and increased flood risk (McKerchar & Henderson 2003). The driest period is from November to February (Griffiths et al. 2003). *Figures 3.3, 3.4 and 3.5* (overleaf) show precipitation data from Whakatane, Galatea and Edgecumbe [refer to *Figure 3.1 for locations*] and demonstrate the pronounced inter-annual variability, related to short- to medium-term (inter-decadal) climatic influences, as well as the varying influences of topography.

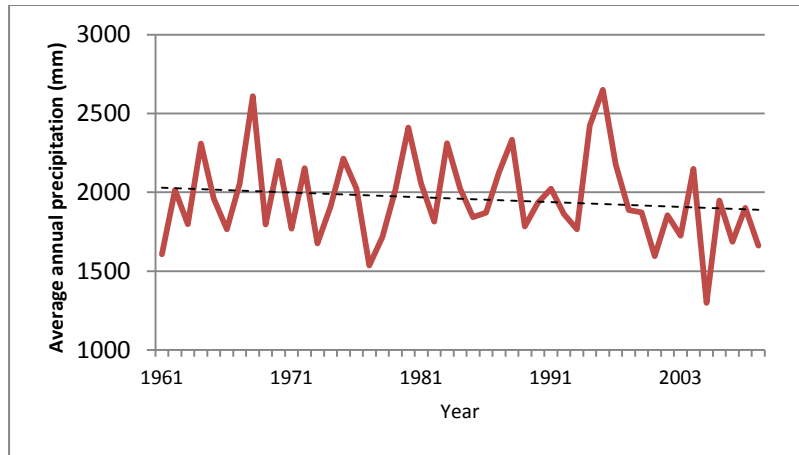


Figure 3.3: Interannual variability of precipitation, Whakatane (1961-2009) (Source data: NIWA)

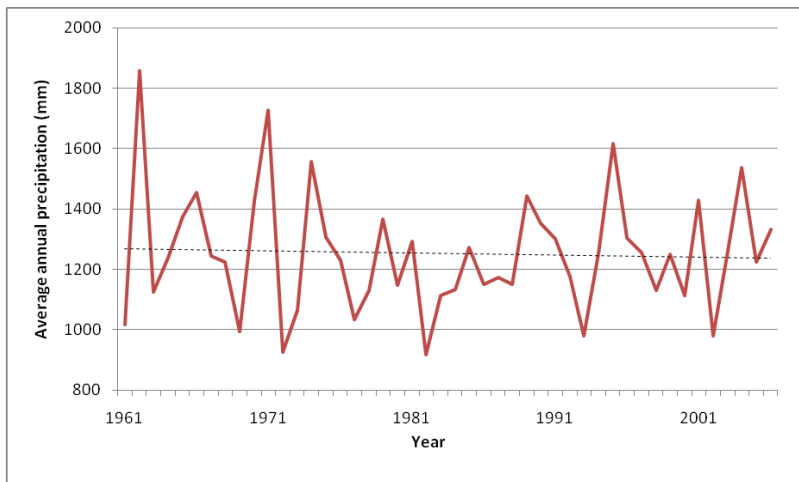


Figure 3.4 Interannual variability of precipitation, Galatea (1961-2007) (Source data: NIWA)

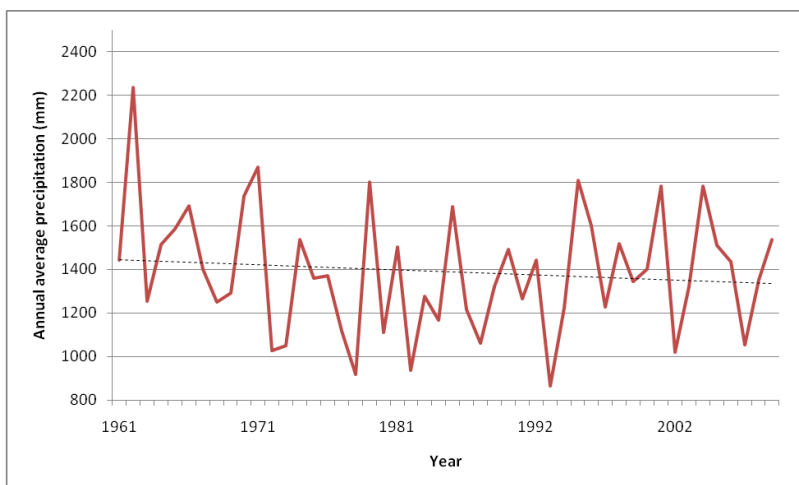


Figure 3.5: Interannual variability of precipitation, Edgecumbe (1961-2009) (Source data: NIWA)

Although the area is regarded as ‘summer-safe’, milk production during summer/autumn 2009 was down approximately fifteen per cent on average, even on land that traditionally holds up well in drier years (MAF 2010). The summer of 2009 was the third dry summer in a row on the Rangitaiki Plains. While total rainfall has decreased since the 1960s, there is no evidence for long-term changes in the frequency or intensity of rainfall extremes (Griffiths et al. 2003).

The climatic conditions described above are inherently variable. In individual years, annual temperatures nation-wide can deviate from the long-term average by up to $\pm 1^{\circ}\text{C}$. Annual rainfall also deviates from its long-term average, by ± 20 percent (Mullan 1998). Some of the shortest term temperature fluctuations arise due to natural variability in the weather and its random fluctuations or ‘chaos’, however other changes are associated with large-scale climate patterns over the Southern Hemisphere or the Pacific Ocean, the El Niño-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) (Griffiths et al. 2003; Fowler & Adams 2004).

Agricultural production furthermore, is inherently sensitive to climatic conditions (Howden et al. 2007; Tubiello et al. 2007; Fedoroff et al. 2010) including variability and extremes. Between 15% and 35% of global yield variation in wheat, oilseeds, and coarse grains is due to ENSO-related cycles of drought and flood (Ferris 1999) and it has been estimated that, on average, year-to-year climatic variability is responsible for about NZ\$600m in losses in New Zealand’s agricultural production (Buckle et al. 2007). This existing sensitivity explains why a changing climate will have subsequent impacts on agriculture (Wratt 2002; Stroombergen et al. 2006; Tait et al. 2008) and it is these shifts in variability and extremes related to climate change which are likely to have the biggest impact on agriculture in the eastern Bay of Plenty.

3.3.3 Historical precedents of agricultural production

The vulnerability of farms and communities can be understood to be a function of the characteristics of the local, physical environment as well as a result of social and historical conditions and decisions regarding resource management and settlement patterns (Keskitalo 2004; Ford et al. 2008; Young et al. 2009; Pearce et al. 2010). As discussed earlier, the physical environment of the eastern Bay of Plenty is a product of volcanic and tectonic activity, which has produced a landscape of high-country and escarpments and flat, lowland plains. This physical landscape has subsequently been transformed by human activity, particularly since the time of the first European settlement in the early 19th century. Producers have taken advantage of the opportunities associated with the natural environment and overcome many of its constraints through extensive modification of biophysical conditions and changes in patterns of resource use. *Table 3.2* summarizes historical patterns of land use, economic and legislative change, and related impacts. Farm-level vulnerability is grounded in historical conditions including the transformation of the landscape from swamp to productive low-land plains, as well as more recent processes of agricultural restructuring.

Date	Change	Related impacts
1830s	European settlements established in eastern Bay of Plenty	Agriculture limited to flax milling and arable cropping (maize and wheat).
1880s	Dry stock established	Limited dry stock industry established in hill country; ‘bush-sickness’ prevalent, owing to cobalt deficiency in soils; large areas of forestry plantation established.
	10 June 1886, Tarawera eruption	Mt Tarawera volcanic eruption; ash deposits of 50-150mm across Rangitaiki Plains; extensive flooding.
1890s	Increased pressure for expansion of agricultural land base	First surveys undertaken of the Rangitaiki Swamp undertaken. Allotments taken up in 1892, during dry-year. Many settlers abandoned properties the following season, as the area flooded.
1900s	Significant drainage works established on Rangitaiki Plains	Large-scale drainage works begun to turn Rangitaiki Plains into productive agricultural land; rivers straightened and stop banked, completed in 1924.
1920s	Lowland dairy industry established	Lowland dairy industry on the Plains is established following nearly 30 years of grazing heavy stock to compact the recently drained soil.
1970s	Kiwifruit industry established.	Kiwifruit industry established in the eastern Bay of Plenty following boom in western districts.
1980s	1984 Agricultural restructuring	Government implements economic reforms which effectively, exposed the nation’s farmers to the vagaries of the global market including rapid removal of agricultural input subsidies and price supports.
	2 March 1987, Edgecumbe earthquake	Magnitude 4.5 earthquake at Edgecumbe; results in significant disruption across Eastern Bay, including infrastructure. Land subsidence >2m, reversing flow and increasing low-land flood risk.
2000s	Expansion and intensification of agriculture.	Repeated flood and drought events, demonstrate the interannual variability of climatic conditions, and have significant effects on agricultural production. Diverse agricultural production based on horticulture, dairy and dry stock farming. Growers and farmers have taken advantage of unique soil and climatic conditions, and have adapted to a range of climatic and non-climatic exposures. Characterized by intensification and continued diversification of farm income.

Table 3.2 Historical developments from the time of European settlement (*Drawn from:* Pullar 1985; Williamson 1985; Gibbons 1990; Campbell et al. 1997; Park 2002; EBoP 2004)

Lowland coastal forest, inimical to human habitation, was likely the predominant land cover at the time of Maori settlement (700-750 YBP) (McGlone & Jones 2004; Irwin 2004), with extensive wetlands consisting of dense vegetation on Rangitaiki Plains and other low-land areas (Pullar & Patel 1972; Campbell et al. 1973). Systematic destruction of forest through burning was begun in order to increase the potential of the area to support humans (McGlone & Jones 2004) and continued regularly. A cover of remnant forest patches surrounded by regenerating forest and scrub was established soon after (McGlone 1983), and remained virtually unaltered until the arrival of European settlers in the early 19th century (Irwin 2004).

While this environment was suited for small-scale cultivation and harvesting of freshwater swamp resources (Irwin et al. 2004), Europeans arriving in the early 19th century, found it impractical. The mild moist climate, poor soils and thickly forested slopes were ill-suited for running sheep (Williamson 1985; Gibbons 1990). Arable farming and dairying had potential, but were limited by the availability of land and the poorly developed transportation networks (Gibbons 1990). So as pressure for arable land in the colony increased, politicians began to pay great interest in the development of swampland (Gibbons 1990; Park 2002).

Following a series of moderately successful prior attempts to remove the water, the government took over drainage of the entire area in 1910 (Gibbons 1990). Drainage was complicated by the loss of adequate fall. Water initially drained under the influence of gravity. As the underlying peat consolidated however, fall was lost – a metre of peat on the Rangitaiki, when dried becomes only ten centimetres of soil (Pullar 1985) – requiring significantly more work than originally thought. By 1924, the Rangitaiki and Tarawera Rivers had been diverted out to sea, the

floodplains drained; river courses straightened and stop banked (Park 2002). This completed the transformation from dense forest to swamp to fertile lowland plain, providing the foundation for a diverse agricultural economy, but also increasing exposure-sensitivity to natural climatic variability and flood risk (Figure 3.6).

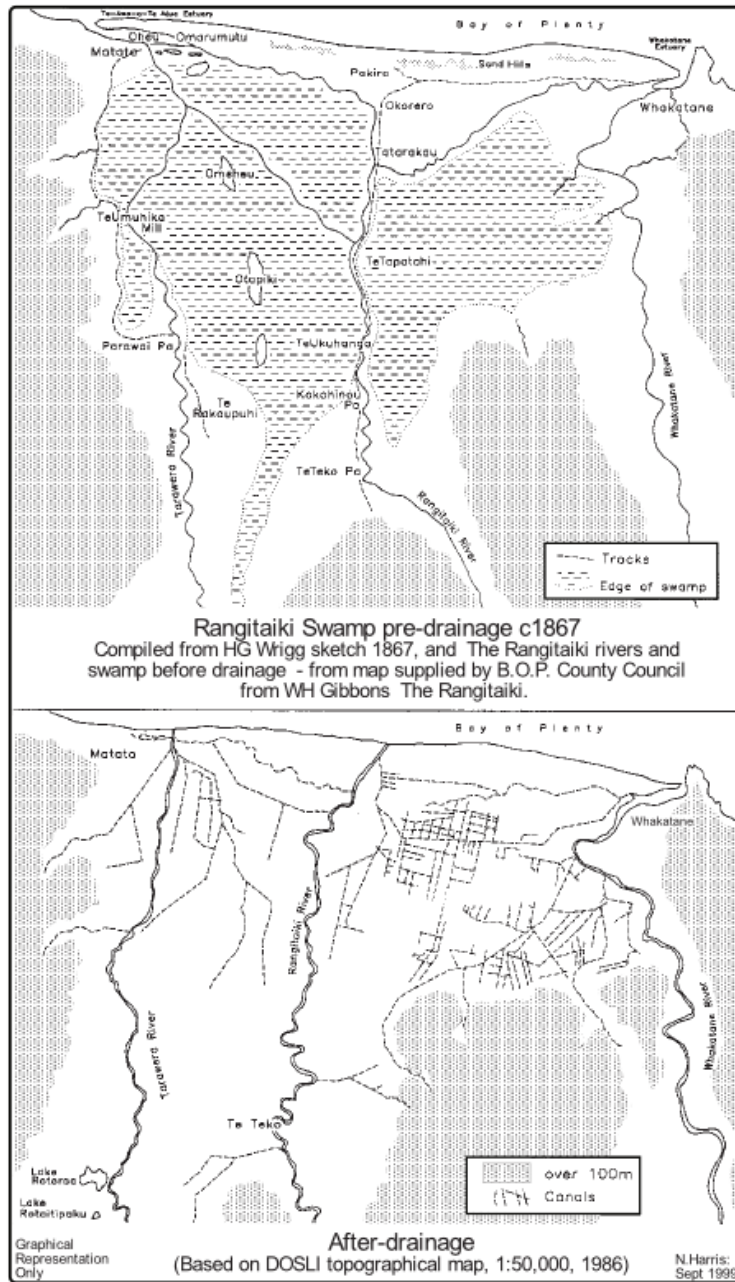


Figure 3.6 Rangitaiki Drainage c1867 and 1924 (Waitangi Tribunal)



Plate 3.4 Drainage of the Rangitaiki has significantly altered local topography. Relict river courses – many of which run through existing farms – are more prone to drought given poorly developed soils (Rangaitaki River, eastern Bay of Plenty, New Zealand) (Photo courtesy of Alan Law)

With the exception of horticulture, the foundations of a diverse agricultural production system in the eastern Bay of Plenty were established soon after drainage (Gibbons 1990). Grazing heavy beef cattle was initially a cost-effective solution for consolidating the recently drained soil and it remained the primary land use for almost thirty years (Gibbons 1990). Dairying expanded slowly as more land was consolidated and turned into pasture, and as the necessary transportation and related infrastructure was established through the early 1900s (Gibbons 1990). Further clearing of remaining native vegetation – now already confined to steep hillsides – encouraged the grazing of sheep and dry stock production. Bush sickness, which had plagued the first ruminant herds, was diagnosed as cobalt deficiency overcome with nutrient application (Williamson

1985). The flat land and mild climate was also well suited for horticulture. Orchards producing citrus, passion fruit and tamarillos were common in the Bay of Plenty in the first half of the 20th century, while in the latter half, kiwifruit became the predominant crop (Gibbons 1990; Campbell et al. 1997).

Drainage of the swamp and settlement of the floodplain increased exposure-sensitivity to flood events through changes in hydrology and lowering of the land surface. It is likely that clearance may have led to faster run-off from surrounding catchments and therefore greater flooding and less interception and re-evaporation of rainfall by the vegetation cover (McGlone 1983), making low-lying areas such as the Rangitaiki Plains, wetter (McGlone & Jones 2004). Drainage and consolidation of the peat beds altered the degree to which agricultural producers and production are exposed to damaging events, and reduced the absorptive capacity of the surrounding landscape. Wetlands play an important role in flood control (Mitsch & Gosselink 2000; Nicholls 2004) and their loss likely further increased the variability of annual flooding as demonstrated elsewhere (Hey & Philippi 1995; Nicholls et al. 1999). Given their topographic location and sedimentary structure, most floodplains are characterised by high water tables (Burt et al. 2002). Drainage of surface water on the Plains may have contributed to the development of a highly variable water table due to faster runoff and absorption (Euliss & Mushet 1996; Brock et al. 1999). This variability is problematic for kiwifruit growers, and exposes producers to salt-water intrusion and damaging floods. The intensification of pastoral farming and expansion of horticulture exacerbate this trend by placing productive activity and infrastructure at risk. Nationwide, floods are the most damaging and costly hazard (McKerchar & Pearson 2001).

Exposure to floods has also increased as the underlying peat beds have dried. Large portions of the Rangitaiki Plains continue to fall and this was exacerbated considerably by the 1987 Edgecumbe earthquake (*Plate 3.2*). Today, significant areas of the Plains are below sea level or below the perched river levels of the Rangitaiki and Tarawera (EBoP 2008). Drainage near Whakatane West began in 1919 and levels taken between 1928 and 1944 show that the land sunk about 1.5 m, and between 1944 and 1958 a further 1.0 m (Pullar 1985). In the Maketu basin the land has not been as intensively developed for farming as on the Rangitaiki and so surface sinking is less marked, nonetheless between 1951 and 1967 the land sunk 0.3 to 0.6 m (Campbell et al. 1973). Further surface sinking followed the 1987 earthquake at Edgecumbe, and the drains on a number of farms reversed flow as the land shifted and consolidated (R. MacDonald 2009, *pers. comm.*). Whakatane District has experienced frequent severe flooding in the recent past as well as undocumented floods prior to the 1850s (*Table 3.3*).

Date	Description
2-24 May 1925	The biggest floods experienced for 20 years caused extensive and widespread flooding throughout the district. Rangitaiki River was in high flood, but no inundation occurred along the river.
24-25 June 1925	The Rangitaiki River caused much flooding, and serious stock losses were reported in the area.
28-29 June 1925	Further flooding of the Whakatane and Rangitaiki Rivers, following heavy rain caused extensive inundation over the Rangitaiki Plains. 12,141 ha (30,000 acres) were flooded and considerable damage was done to pastures, stock and fences. Roads suffered severe damage, and many small bridges were washed away.
22-23 July 1925	A strong north-easterly gale, accompanied by heavy rain brought floods to the Bay of Plenty area. The Rangitaiki River overflowed above Riversleigh, but stock losses generally were small because of timely warning.
8-10 October 1926	Heavy rain throughout the district caused most of the rivers to rise, but although some local flooding resulted no serious damage occurred. Some roads were blocked in the Rotorua district, and the Rangitaiki River overflowed its banks and flooded an area of 2,833 ha (7,000 acres).
12-13 February 1934	An exceptionally long spell of wet weather was followed by torrential downpours of rain in some areas. The Rangitaiki River overflowed at Thornton, and the Whakatane River inundated some land above Whakatane. Numerous slips occurred on roads and flood waters making some roads impassable.

20-21 June 1934	Heavy rain in the eastern end of the district caused serious damage to roads throughout the district through slipping and washouts. Rivers were in high flood and at Te Teko the highway bridge was 1 m (3 feet) under water. Some stock losses were reported.
24-25 June 1935	Serious flooding occurred in many parts of the district as a result of heavy rain. The Rangitaiki River overflowed its banks near Edgecumbe flooding areas on the east bank, and the nearby dairy factory to a depth of 225 mm.
23 February 1944	Heavy rain caused the Rangitaiki River to rise, and flooding on an extensive scale took place on the Rangitaiki Plains, with large stock losses.
21 May 1962	On Monday, 21 May 1962 the Rangitaiki River was flowing almost bank full following heavy rain of up to 250 mm (10 inches) centred near Waiohau. A stopbank was breached in the late afternoon, flooding a portion of the Plains.
1 June 1962	Further heavy rain causes second flood peak, Friday, 1 June the newly repaired bank breached with severe flooding. Overnight the Tarawera River overtopped and breached right bank, Saturday, 2 June the Kopeopeo West Canal burst its banks, flooding over 3,238 ha.
February 1965	High floods on the Rangitaiki River, inundates approximately 1,416 ha.
February 1967	High floods occurred again in February 1967, flooded approximately 1,440 ha.
February 1971	Failure of the left bank of Rangitaiki River, flooding between the Matata-Edgecumbe Road and State Highway 2.
February 1979	A stop bank failure occurred on the Tarawera River.
1-16 July 1998	Over the period 1-16 July 1998 the Bay of Plenty and in particular the eastern Bay of Plenty was subjected to heavy rainfall. During this 16-day period, four storms caused four flow peaks in the Bay of Plenty rivers. Return period floods in the Tarawera River ranged between 5-10 year flood and in the Rangitaiki River between 10-20 year flood.
14-18 July 2004	Heavy rain began falling in the Bay of Plenty on Thursday, 15 July 2004 and continued for the following three days. Between 14 and 18 July some 284 mm of rainfall was recorded at Edgecumbe. Rainfall caused widespread flooding throughout the region effecting Edgecumbe, the Rangitaiki Plains, Whakatane and Opotiki. Improper management of the Matahina dam is blamed for exacerbating flood conditions.
1-8 June 2010	Heavy rain in Whakatane causes widespread flooding both in town and on the Plains. Over 160 homes damaged. Flood occurred during calving, most affected were low-lying dairy farms.

Table 3.3 Selected flood events, Whakatane District (*Drawn from:* BoPCC 1985; Cowie 1957; Gibbons 1990; Ellory 2000; McKerchar & Henderson 2003; MacBrayne 2004; EBoP 2004, 2005; NZPA 2010)

Farming on the Rangitaiki Plains is now only possible through continual drain maintenance and pumping (24 hours) in order to maintain the integrity of pasture through wet winter conditions. Drainage is farmer-managed in conjunction with the regional council, Bay of Plenty Regional Council (BoPRC), which is responsible for monitoring drainage canals which includes some 300 kilometres of major canals and drains servicing 27,000 hectares; twenty-two culvert and flapgate structures; over a kilometre of low stopbanks and four erosion control structures. In addition to which, there is an extensive network of on-farm drainage and a farmer-run co-operative scheme maintaining a network of flood pumps.

3.3.4 Summary

Agricultural producers in rural eastern Bay of Plenty have taken advantage of the opportunities associated with the natural environment and overcome many of its constraints through extensive modification of biophysical conditions and changes in patterns of resource use. Value was originally placed on small scale microclimatic and soil conditions when the region was characterised by dispersed settlements on terraced and scarp-hill country (Irwin 2004). Drainage of the swampland by European settlers in the early 20th century further altered the landscape (Park 2002) creating large tracts of fertile agricultural land. This made it possible to establish more intensive agricultural production in the area but also resulted in significant changes in local topography. This increased exposure-sensitivity and reduced adaptive capacity to flood, saltwater intrusion and fluctuations in the water table. There is now an established and diverse agricultural economy centred on pastoral farming (drystock and dairying), as well as kiwifruit. These industries remain, however, grounded in the unique constraints and opportunities associated with biophysical conditions, and networks and systems within which individual farmers operate.

Producers have developed a range of adaptive strategies in order to take advantage of biophysical conditions, and limit their exposure-sensitivity to damaging events. However, certain adaptive strategies can also change the nature of the unit of exposure (location, structure, organization) such that it is more or less exposed-sensitive, or exposed-sensitive in a different way (Smit & Pilifosova 2003; Adger et al. 2005; Engle 2011). In creating a fertile lowland producers have exacerbated exposure-sensitivity to biophysical conditions, firmly tying rural production in the eastern Bay of Plenty to the dynamic environment which in turn shapes and influences the opportunities, exposures, sensitivities and limitations of the biophysical characteristics of place. Producers have adapted to the 'dry years and wet years' with varying degrees of success, through landholding, management systems and modification of the landscape. Farmers also operate within established networks and systems of governance and marketing which may influence aspects of their vulnerability. The following section details those characteristics of current agricultural production as they pertain to the empirical work on vulnerability, highlighting the importance of climatic and non-climatic conditions to which producers are likely to be exposed sensitive.

3.4 Characteristics and conditions of agricultural production

Agricultural producers in the study area have taken advantage of the combination of soil types, topography and climatic conditions, to build a rural economy based on dairying, horticulture and drystock production. This is contrasted with exposure to a significant flood risk, related to settlement patterns and modification of historic floodplains and swamp land, as well as seismic activity. Dry conditions that affect production are not uncommon and relate to long-term interperiodic climatic variability most closely correlated to ENSO/IPO (Griffiths et al. 2003).

Farmers and growers also operate within a broader socio-economic context; in which systems of farm management, marketing and sales of agricultural commodities and governance also influence vulnerability (refer to *Figure 2.3*). Some of these conditions are not unique to farmers in the Bay of Plenty, but nonetheless, influence vulnerability at the farm-level to varying degrees. The following sections discuss regional agricultural production and outline the nature of marketing, distribution, institutional and governance systems as a means of further establishing a context for the subsequent empirical analysis of exposure-sensitivity and adaptive capacity at the farm-level.

3.4.1 Systems of agricultural production

Agricultural production in Whakatane District is diverse (*Table 3.4*), and covers approximately half of the total land area of 4442 km². Of the over 1000 farms in the district, 45% are dairy units supporting the main industry of the Rangitaiki Plains, Fonterra Edgecumbe processing plant. Horticultural activities in the district include market gardens, apple, avocado and floriculture. Kiwifruit production is the largest horticultural activity in terms of area and dollar value. Kiwifruit have been grown commercially in the eastern Bay of Plenty since the 1950s and on a larger scale in Whakatane District from the early 1970s (Campbell et al. 1997; Beverland 2001). There was a spike in the land area devoted to horticulture coinciding with a boom in kiwifruit in the 1980s, and though the actual land area involved remains relatively small, developments in horticulture are significant because of their geographical focus in the Rangitaiki Plain and their high rates of return (Joseph et al. 2004). Agriculture accounts for 10 percent of GDP for the region (Statistics New Zealand 2006). There is a growing degree of diversification away from

these core agricultural activities, evidenced by the 700 or more lifestyle blocks in the district (AgFirst Consultants 1997).

Horticulture and fruit	Grain, Sheep, Beef	Dairy	Poultry	Other livestock	Other crop	Services to agriculture	Hunting and Trapping	Forestry and Logging
13.56	22.38	45.42	0.33	14.73	0.5	15.64	0.5	8

Table 3.4 Farms (%) in Whakatane District, *n*=1002 (Whakatane District Council 2007)

There have been significant changes over the last 30 years, as per the data in *Table 3.5* including declines in drystock and a drop in horticultural production from its high during the mid-1980s boom. The number of farms in the area has decreased substantially. This may reflect the decrease in the total amount of land area devoted to agriculture as well as the nation-wide trend towards consolidation of neighbouring farms to boost production (MacLeod & Moller 2006; Mulet-Marquis & Fairweather 2008; Basset-Mens et al. 2009). Land area devoted to plantation forestry has increased, while the area of grassland (drystock) has gone steadily down, likely in response to poor returns (Jay 1999; Haggerty et al. 2009; White et al. 2010). The research was completed with the participation of dairy farmers, kiwifruit growers and dry stock farmers. Each of these production systems take advantage of regional and localized soil and climatic conditions, and are exposed-sensitive in varying degrees to climatic and non-climatic stimuli.

Year	Number of farms	Grassland	Horticulture	Other crops	Plantations	Other land	Total land
1985	1614	83461	2256	570	64239		287490
1990	1503	80944	2172	2,538	72617		225687
1991	1475	82550	1873		64452	71008	219883
1994	1089	..S	..S	..S	106500	..S	209601
2002	1000	68144	1379	2,236	121322	..C	216054
2007	1002	57602	1609	2,518	115748	3010	186744

Table 3.5 “Farming” Land Use in the Whakatane District, 1985–2007 (Source: Whakatane District Plan 2003, 2007; Statistics New Zealand 2002; Statistics New Zealand: Agricultural Production Census 2007)

Symbols:

..C Confidential

..S Suppressed for reasons of poor quality

3.4.1.1 Kiwifruit

Kiwifruit production is centred on the nutrient-rich, free draining volcanic soils of the Rangitaiki Plains (Pullar 1985; Rijske 1993). Growers are exposed-sensitive to a fluctuating water table that can adversely affect production and yield. Relict dunes left by the prograding coastline are therefore the preferred sites for orchards, though these areas are in limited supply. Kiwifruit are also grown in Opotiki. ‘Tablelands’ is a combination of floodplain and dissected terraces with alluvial soils and soils derived from volcanic ash (Rijske & Guinto 2010). Kiwifruit is a significant economic driver. Current production in the Bay of Plenty is over 100 million trays annually (MAF 2010). This has been rising steadily from 4 million trays in 1982, to 10 million in 1983 to 46 million in 1987 (Campbell et al. 1997). New Zealand exported 106 million trays of kiwifruit during the year ended 31 March 2009 (MAF 2010). Record export revenues of more than \$1 billion are expected in the year ending 31 March 2010, due to increased export volumes and favourable exchange rates (MAF 2010).

The largest percentage of vines is Hayward (Zespri Green). Hayward has been the preferred cultivar given its large size, long storage time, relative durability when handled, and distinctive taste (Sale & Lyford 1990). Zespri Gold (HORT16A) is also grown in the eastern Bay of Plenty. The fruit was developed for the Asian market (Beverland 2001) and gives growers both higher returns per tray, as well as more fruit per hectare (Patterson et al. 2003). Zespri Gold however is more vulnerable to climatic conditions: it is more susceptible to bruising and scuffing by wind events; more likely to be affected by unseasonal frosts; and generally regarded as a more ‘difficult’ vine to manage properly (Amos et al. 2002; Patterson et al. 2003).

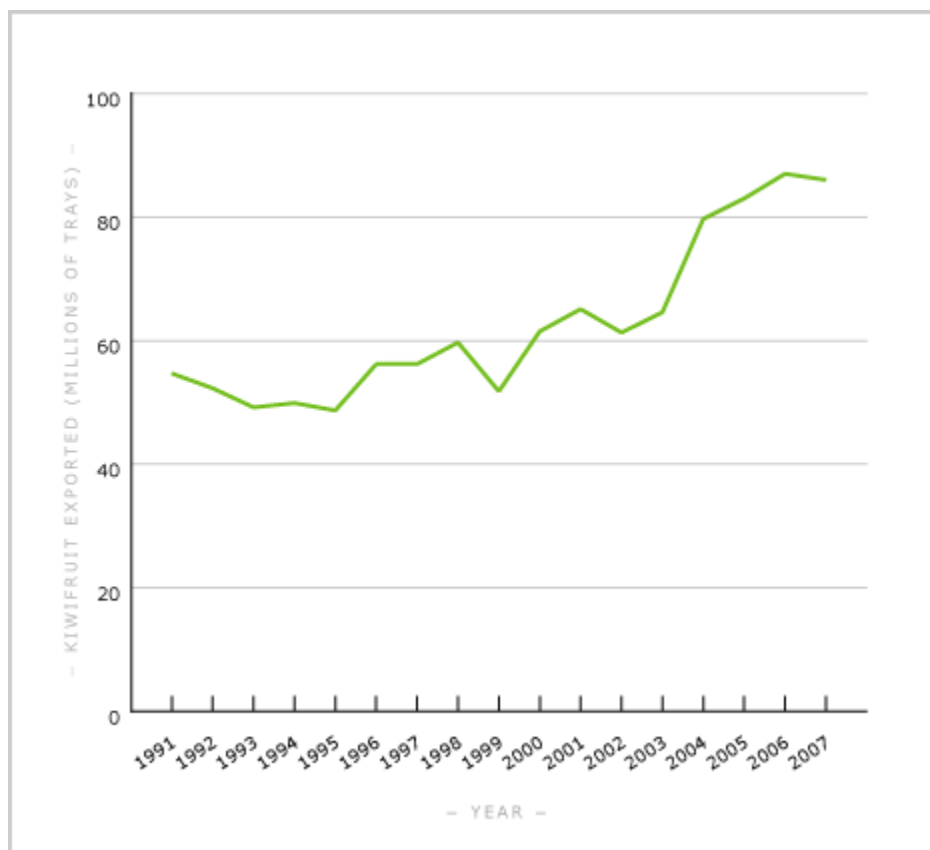


Figure 3.7 Kiwifruit exports to 2007 (MAF 2008)

Kiwifruit production is uniquely sensitive to climatic conditions at different times of the growing season. Following winter pruning, the actual number and health of flowers that are produced in spring is heavily dependent on the amount of winter chilling experienced by the vines: colder winters give more and better quality flowers (Linsley-Noakes 1989; Sale & Lyford 1990). However, freezing temperatures during winter, and both spring and autumn frosts, can adversely affect production. Budbreak is high (>50%) when winters are cool, but can fall below 20% in warm temperate regions, with flower numbers below economic levels for crop production (Erez 1995). Since 1988, hydrogen cyanamide (HC or 'Hi-Cane') has been used as a spray to improve bud burst and compensate for warm winter temperatures (McPherson et al. 2001). Pollination is also weather dependent. Calm, windless and rain-free weather is required; either for artificial pollination or to ensure natural pollination from honey bees that are often placed in orchards (Goodwin & Steven 1993). Late frost, hail, and wind events can also dramatically affect production, and will be discussed in more detail in Chapter 5.



Plate 3.5 Established Hayward (Zespri Green) kiwifruit orchard, Opotiki, Bay of Plenty, New Zealand



Plate 3.6 Recently established orchard, Waimana, eastern Bay of Plenty, New Zealand

3.4.1.2 Dairying

With annual exports in excess of NZ\$11 billion and accounting for 7 percent of GDP, the dairy industry is New Zealand’s biggest export earner, making up one-third of the international dairy trade (DairyNZ 2010). The country is also the world's largest exporter of dairy products (Gray & Le Heron 2010). In the eastern Bay of Plenty, dairy production is the predominant agricultural land-use activity in terms of area, after forestry. Milk production takes place on the fertile soils of the Rangitaiki Plains, coastal lowlands, river valleys and uplifted terraces; and output varies between farms and areas due to differences in moisture availability, soil type, and management system. New Zealand’s seasonal milk production system has traditionally relied on highly productive, rotationally grazed pasture (Verkerk 2003), though there has been a shift in recent years towards more intensive production systems that rely more heavily on imported feeds (*Table 3.6*).

System	Definition	Description
1	All grass, self-contained, all stock on the dairy platform	No feed is imported. No supplement fed to the herd except supplement harvested off the effective milking area and dry cows are not grazed off the effective milking area.
2	Feed imported, either supplement or grazing-off, for dry cows	Approx 4-14% of total feed is imported. Large variation in % as in high rainfall areas and cold climates such as Southland, most of the cows are wintered off.
3	Feed imported to extend lactation (typically autumn feed) and for dry cows	Approx 10-20% of total feed is imported. Feed to extend lactation may be imported in spring rather than autumn.
4	Feed imported and used at both ends of lactation and for dry cows	Approx 20-30% of total feed is imported onto the farm.
5	Imported feed used all year, throughout lactation and for dry cows	Approx 25-40% (but can be up to 55%) of total feed is imported.

Table 3.6 DairyNZ classification of farm systems (Source: DairyNZ 2010)

The efficiency of the grass-based system has enabled farmers to produce milk substantially below average world costs (Basset-Mens et al. 2009; Gray & Le Heron 2010); giving New Zealand dairy farmers a competitive advantage that may be eroded with higher inputs (Mulet-Marquis & Fairweather 2008). Producers utilizing a grass-based system are more exposed-sensitive to climatic variability and extremes than those on feed-based ones. Reliance on pasture production can be mitigated through the use of supplemental feeds and a shift to higher inputs, however, as Chapter 5 will argue, this may increase exposure-sensitivity elsewhere in the system.

In response to economic pressures, changing market conditions, and government deregulation, there has been an increasing drive towards intensification (Jay & Munir Morad 2006; Basset Mens et al. 2009). At the farm-level, farmers have sought to create economies of scale by increasing total farm milk production through adopting intensive grazing and feeding regimes (Parker & Holmes 1997), increasing production per hectare or increasing the number of hectares in dairy use, or both. At the milk processing level, the industry has sought both to process all the milk that it receives (since the milk suppliers are the owners of the facilities), and to increase the value of the processed products through more sophisticated processing technologies, packaging and marketing (Morad & Jay 1999; Gray & Le Heron 2010).

Area	Year	Herd (n)	Total cows	Av. Herd size	Kg/Milkfat/cow	Av. Effective ha.	Av. Cows/ha
New Zealand	1974	16907	2,039,902	121	142	<60	<2.0
	2009	11618	4,252,881	366	184	131	2.8
<i>Whakatane</i>	2009	316	96,579	306	180	110	2.91
<i>Opoktiki</i>	2009	80	24,723	309	178	113	2.73

Table 3.7 Summary of New Zealand herd statistics since 1974/1975 (Source data: LIC 2010)

As the data in *Table 3.7* shows, since 1975 the average size of farms has increased; the average size of herd has increased; average production per cow has increased (through selective breeding) and the number of cows per hectare has increased (through more intensive pasture production and pasture management). Many smaller dairy units have been bought out and amalgamated to make larger units (Morad & Jay 1999). These trends are apparent both nationally, as well as within the study area; farms in the study area, for which data is available, show a smaller than national average farm size, with slightly higher than average stocking rates. In the past twenty years, the number of dairy farms has fallen, but average farm and herd sizes have increased, while productivity, both per hectare and per cow, has improved (DairyNZ 2010).

3.4.1.3 Drystock farming

With European settlement and the introduction of drystock farming, forest, swamp and grasslands in New Zealand were transformed (Park 2002; Smith et al. 2007; Winder 2009). Intensive rearing of sheep, beef and some deer, is based on favourable climatic conditions which promote pasture growth. Pasture can provide over 95% of the diet of sheep (Morris 2009). In the study area, production systems include intensive sheep and beef cattle farms, as well as just sheep in higher, steeper country not suited for dairying. New Zealand grasslands can be divided on the basis of topography and elevation into three broad farming groups: high, hill and flat to rolling country (Hodgson et al. 2005). Drystock units in the eastern Bay of Plenty are situated on 'hill country': uplifted marine terraces and escarpments with slopes >16 degrees (NWASCO 1975). The terrain is subject to frequent earthquakes, and rates of uplift are high (Nairn & Beanland 1989). Steep slopes are prone to erosion, and often have poorly developed soils with low fertility (Blaschke et al. 1992).

Weather can be changeable, with frequent extremes both of temperature and precipitation (Griffiths et al. 2003).

Morris (2009) summarizes the characteristics of New Zealand sheep farms as follows: a low cost production, in order to be able to compete on export markets, requiring large flocks, low labour input and efficient utilization of pasture. Farms typically utilize clover, and apply phosphate fertilizer to increase pasture production. Pastures are subdivided with fences in order to enable controlled grazing, more efficient pasture utilization and high annual production per hectare. Stock handling facilities are used to minimize labour input, and specialised operations such as shearing, fertilizer application and (sometimes) fencing are contracted out.

In the Whakatane District, there are 189 sheep and beef units; with an average effective farm area of 477 ha. Sheep and beef complement one another in pasture based grazing systems, utilizing grass at different times of the year. Pasture-based farming systems are challenged by the variation and uncertainty of feed supply because of inter- and intra-annual variation in pasture growth rates. Farmers adapt to this variation by timing lambing/calving so the period of maximum pasture growth in spring coincides with maximum feed demand. Sheep are raised both for the meat as well as wool markets.

Profits on drystock farms have fallen in recent years (Morris 2009). In the 2007–08 season farmers did not meet their costs of production, whereas in 2008–09 lamb prices were roughly on par with costs of production (Morris 2009). Drystock farmers have benefited in recent years from intensification in the dairy industry, and the rise in land values (Green 2008). Anxious to free

land on the milking platform to increase production, dairy farmers often now farm young stock out to drystock farms, for which they can earn a regular income. As the dairy industry has also increased its contribution to beef production through culled dairy cows and bulls, some farms have also diversified into deer and begun to grow arable crops to reduce business risk (Jay 1999). As in the dairy industry, there is a move towards the intensification of production as well (Haggerty et al. 2009; White et al. 2010). Major drivers of intensification include increasing costs (operating, regulatory and compliance), steeply rising land values and the removal of price support for agricultural products during the general deregulation of the NZ economy in the 1980s (MacLeod & Moller 2006).

3.4.2 Globalized and deregulated: agricultural production in New Zealand

New Zealand's agricultural sector is almost unique in its dependence on, and connectivity to, global markets and economic conditions overseas (Buckle et al. 2007; Gillmore & Briggs 2010). This connectivity is in part a function of the reliance on exports: over 80 percent of total agricultural output is exported (MAF 2009) only 4% of milk produced in New Zealand, for example, is for domestic consumption (Jay 2007). The other distinguishing characteristic of agricultural sector is that since the early 1980s, all state support, and subsidies have been removed (McMillan 1998). New Zealand is now almost unique among developed countries in that the agricultural sector is totally exposed to international markets since subsidies, tax concessions and price supports were eliminated (Buckle et al. 2007).

This high degree of dependence on, and exposure to conditions overseas, means agricultural producers have the potential to be highly exposed-sensitive to stimuli originating at a global scale – including financial and commodity markets. As shown in the conceptual framework (*Figure 2.3*), through biophysical linkages and feedbacks, economic market linkages, and flows of resources, people, and information (Adger et al. 2009) stressors and stimuli originating at these larger scales may be experienced by producers as local impacts. This unique dependence on (and sensitivity to) global markets is likely to continue to shape the agricultural economy (Smith & Montgomery 2004; Stroombergen et al. 2006; Gray & Le Heron 2010), in conjunction with future climatic variability and change. The following section seeks to locate farm-level production within the broader context of interlinked temporal and spatial scales of systems of marketing and distribution, governance, and institutions. It outlines changes in market conditions and the rural economy as they pertain to current exposure-sensitivities identified producers in Chapter 5. While these influences and pathways vary among the different farm production systems identified above and are not unique to producers in the Bay of Plenty, they are an important influence on vulnerability to both the climatic and non-climatic conditions identified later in the study.

3.4.2.1 A Deregulated Rural Economy

The rural economy in New Zealand has undergone a significant transformation in recent decades (Le Heron & Pawson 1996). In the mid-1980s, the government implemented a number of radical economic reforms in response to deteriorating national finances (Evans et al. 1996; McMillan 1998; Dalziel 2002). While the focus was economy-wide, as part of these reforms agricultural production was deregulated, effectively exposing the nation's farmers to the vagaries of the

global market. The rapid removal of previously existing agricultural input subsidies and price supports, together with widespread macroeconomic reform, came at a time when international prices for agricultural commodities were in decline. The result was that many New Zealand farmers suffered extreme financial hardship (Wilson 1994) as the agricultural sector was transformed (Le Heron 1991; Cloke 1996; Le Heron & Pawson 1996).

In 1984, nearly forty-percent of the average income of New Zealand's sheep and beef farmers came from government subsidies. Within 12 months this was reduced to nearly zero (Federated Farmers 2001). The farming community was generally supportive of the reforms. Many believed the removal of subsidies would be offset by increased competitiveness, as the New Zealand dollar was also deliberately devalued (Evans et al. 1996). The reforms however led to an increase in input costs, due to higher interest rates. The removal of subsidies on fertilisers and pesticides also had a dramatic effect on farm finances. The net result was a decline in the profitability of sheep meat and wool production which began to contract. Other impacts in the reduction of farm support included a downward slide in incomes, land prices and farm equities, increased debt, reduced stocking rates and a reduction in employed labour (Cloke 1989; Sandrey & Reynolds 1990). Land prices fell by up to fifty-percent, and many farmers were bankrupted (Evans et al. 1996). Rural extension and consultancy services were also privatized and farmers must now pay for previously free outreach and advice (Cloke 1996).

The impacts of deregulation on agriculture have been widely studied. There is a vast body of literature documenting the various adjustment strategies adopted during the subsequent 'rural downturn' (Wilson 1995) as farmers tried to maintain the economic viability of their farm enterprises. These studies encompass both extensive macro-level quantitative research and intensive qualitative case studies (Le Heron 1989; Wilson 1994; Bradshaw et al. 1998; Johnsen 1999; Johnsen 2003; Daugbjerg & Studsgaard 2005). One of the most significant was that by removing price buffer schemes, deregulation passes the onus of risk from the collective back to the individual (Johnson 1989). New Zealand is now almost unique among developed countries as the agricultural sector is totally exposed to fluctuations in international markets (Buckle et al. 2007). These changes in commodity prices, currency valuations and input costs have the potential to influence vulnerability at the farm level in significant ways. The farmer now carries the majority of the risk, though an important mechanism through which market risks are mediated, are co-operative and producer marketing boards, which are still prevalent in both dairy and horticultural industries.

Research has also shown that the removal of subsidies and other incentives has had other, wide-ranging implications, particularly for the environment (Smith & Saunders 1995; Jay 2005; Barnett & Pauling 2005). Bradshaw et al. (1998) in a study on farm-level stewardship showed that while it is has continued, farmers are now less likely to undertake programs or activities related to environmental stewardship, as the full cost of such activities must be borne by the farmer, though some district councils now provide grants for landscape remediation, such as planting in riparian zones, fencing of native bush and waterways, and tree planting for erosion control. Smith and Saunders (1995; 1996) and Smith and Montgomery (2004), describe

decreased pasture health and fertility as well as unabated soil erosion following the agricultural and economic reforms. Stocking rates, which declined rapidly initially, also returned, and in many cases, sheep were substituted for dairy cows. The expansion and subsequent intensification of the dairy industry following deregulation, has also had widespread environmental impacts (Barnett & Pauling 2005; Jay 2005).

As it pertains directly to this study, the most significant consequence of deregulation is that described by Smith and Montgomery (2004, p.109): “By 1993, New Zealand agriculture could be characterized as having moved from a relatively high income, protected, low risk environment to a low income, unprotected environment in which the farmers themselves now carried the primary risk”. Farmers are now more exposed to fluctuations in commodity prices, currency valuations and input costs, than previously. There are marked spatial and sectoral variations, however (Smith & Montgomery 2004). Marketing and producer boards also shield some producers from the vagaries of a ‘true’ market, by removing some of the fluctuation, and increasing capacity through ownership structure and reduced competition (Moran et al. 1996).

3.4.2.2 A Globalized Rural Economy

New Zealand agriculture has long been export oriented and systems and institutions for marketing and distributing agricultural commodities vary. These differences may influence the degree to which producers are exposed-sensitive to market forces. Both dairy products and kiwifruit are connected with large, producer-owned co-operatives or marketing boards, which perform a major function in the regulation of the agricultural industry, while drystock farmers sell directly to processing plants which in turn are responsible for marketing and distribution.

The structures of these vary: dairy products for example are sold through a co-operative while kiwifruit, under the brand name Zespri, are controlled by a directorate constituting a majority of producer representatives. These export producer institutions effectively retain considerable regulatory power over their product sectors (McMillan 1998), and are important pathways through which producers are likely to be exposed-sensitive to changing market and financial conditions beyond their control.

Deregulation prompted the amalgamation and consolidation of previously independent dairy factories. In 2001, the mega co-operative Fonterra was formed. Fonterra represents 95% of New Zealand's dairy farmers and in the 2008-2009 season, received more than 16 billion litres of milk (Gray & Le Heron 2010). It has 25 processing factories nationally, including one at Edgecumbe, in the case study area. It is the world's largest exporter of dairy products on the open market, and comprises a manufacturing infrastructure, research and product development facilities, and a world-wide network of subsidiary companies (Fonterra 2010). It is co-operatively owned by the farmers who supply milk to the company, but strongly influenced by global market trends and processes. Global trends such as the increasing power of retail firms in food chains have influenced the company to consolidate its own power and international advantage, through amalgamations and strategic alliances with large domestic or multinational companies (Jay 2007).

Fonterra is owned by its over 11,000 farmer-shareholders. The company's size gives it a competitive advantage, and shields dairy farmers, to some extent, from a true market. By hedging currency, for example, some of the risk to the individual farmer is removed through increased 'collective' adaptive capacity. As Chapter 5 will demonstrate however, at the farm level producers remain exposed-sensitive to varying degrees. This demonstrates the need to explore those conditions related to exposure- sensitivity and adaptive capacity at the farm-scale, rather than simply at the macro- or national and regional scale. Just as analysis conducted at a national scale can obscure vulnerabilities between communities and households within a region (O'Brien et al. 2006; Vincent 2007) so too can an inordinate focus on national or international bodies that influence vulnerability. By accounting for the differences between farms, and farming systems at this scale, the research will show how differences in at the farm-level, such as higher- or lower-input system, alter the nature of vulnerability.

The kiwifruit industry – which was largely unaffected by restructuring – sells its product through a grower-owned co-operative, Zespri. This single marketing desk was established in 1997 by the New Zealand Kiwifruit Marketing Board. The purpose behind the formation of Zespri brand was to help distinguish New Zealand fruit from kiwifruit grown overseas (most notably Italy and Chile), and position it as a high-priced consumer good (Beverland 2001). Zespri also is involved in the development of new varieties targeted at certain markets; for instance, Zespri Gold (HORT16A) was developed specifically for the Asian market, and emphasises sweetness, and 'lucky' yellow colouring (Beverland 2001). The marketing structure for kiwifruit is under domestic and international pressure to reform. It is the last single marketing desk in the world, and faces growing competition from another domestic company, Turners & Growers, seeking to

grow and sell its ENZA varietal of red kiwifruit in New Zealand (NZ Herald 24/11/2009).

Among the potential pathways of influence on New Zealand producers are European codes of “good” agricultural practice that must be adhered to in order for Zespri to sell to overseas supermarkets (Hayward & Le Heron 2002; Campbell 2005). In this way, producers are teleconnected to overseas legislation, which can dictate production practices here in New Zealand through auditing requirements (Campbell et al. 2006).

The meat industry is also heavily export oriented. Eighty-five percent of New Zealand's lamb production, 70% of the mutton and 80% of beef production is sent overseas (MIA 2011). New Zealand provided 46% of the international trade in sheepmeat in 2004, and 6% of the beef trade. One of the effects of deregulation was to spur amalgamation and consolidation in the meat processing sector (Smith & Montgomery 2004). Despite boosts in productivity through increased efficiencies, improved breeding and improved lambing percentages (MAF 2010), returns for meat however, have fallen steadily (Smith et al. 2007; Morris 2009). Farm-gate returns for dry stock farmers are not helped by marketing practices. In the absence of a single marketing desk, there are 22 meat processing companies, 57 meat slaughterhouses with export licences and a number of companies that process for the local market only, which are continually undercutting prices in competing for the lucrative overseas markets, making producers particularly vulnerable to market-related risks (Curtis & Reveley 2001).

3.4.2.3 Governance and legislation

Scholarship on the determinants of adaptive capacity has also begun to acknowledge the importance of including governance, regulations, legislation, and the role of formal and informal institutions as part of the analysis (Keskitalo & Kulyasova 2009; Young 2010). Local government, legislation and regulations governing agricultural production and formal and informal institutions in the eastern Bay of Plenty are all components of exposure-sensitivity and adaptive capacity identified by producers through the empirical work.

Farms investigated as part of this research fall within the administrative boundaries of the Bay of Plenty Regional Council (BoPRC), and the Whakatane District. BoPRC represents the local government authority through which development interventions and implementation of the Resource Management Act 1991 (RMA) are coordinated and implemented. The RMA is a planning instrument, not an operational code (Jackson & Dixon 2007). It is a framework for governing the planning and development of New Zealand and sets out who has what responsibilities in local and central government, and the rules for carrying out the planning process. The central purpose of the RMA is defined in terms of the principle of sustainability (MfE 2010).

The RMA recognises that government has an important role in environmental planning and defines a hierarchical, three-tier planning structure (*Table 3.8*). This hierarchy is based on the assumption that decisions should be made as close as possible to the appropriate level of community of interest where the effects and benefits accrue.

Central government

Overview role

Developing policies for managing resources

Performance and quality standards

Aspects of coastal management

Management of toxic wastes, explosives, and other hazardous substances

Regional councils(Environment Bay of Plenty)

Overview and coordination role: regional resource policy statements; regional plans (optional)

Water and soil management

Management of geothermal resources

Natural hazards mitigation and planning

Regional aspects of hazardous substances

Pollution management and air pollution control

Aspects of coastal management

Territorial councils (Whakatane District)

District plans

Control of land use and subdivision

Noise control

Control for natural hazards avoidance and mitigation

Local control of hazardous substances use

Table 3.8 Functions by levels of government.

Other formal and informal institutions of note include research centres and Crown Research Institutes (CRIs). HortResearch and AgResearch are involved in monitoring, analyzing and developing opportunities for the horticulture and agricultural industries respectively. This is done through new cultivars and varieties; identifying efficiencies in production; and research. DairyNZ is a research body, funded through a levy on milk solids as well as government investment. The National Institute for Water and Atmosphere (NIWA) is the CRI responsible for producing New Zealand's climate change scenarios. Government ministries with interests and programs in agriculture and or climate change, include Ministry of Agriculture and Forests (MAF) and Ministry for the Environment (MfE).

Farmers in New Zealand also have a highly organized and politicized farming union. Federated Farmers (FFNZ) is a national body with regional chapters, representing the interests of the rural sector in policy development, and lobbying all levels of government. The Federation advocates for farmers and the role of farming in the modern New Zealand economy (Federated Farmers 2010). The organization makes regular submissions to government with respect to policy. Policy is member driven. Members' views are canvassed by staff and elected representatives who formulate submissions that help local and central government decision making. The Federation's stated aim is to "add value to the business of farming for our members and encouraging sustainability through best practice" (Federated Farmers, accessed 14/04/11). The role of FFNZ in agriculture, policy, and culture has received limited attention in the literature (Bremer 1993; Liepins & Bradshaw 1999). Consistent with their neo-liberal philosophy (Liepins & Bradshaw 1999), the official position of the FFNZ on climate change is that it is a naturally occurring phenomenon; and that any proposals to tax agriculture with respect to emissions will adversely affect economic activity (Federated Farmers 2010). This official stance however, does not represent the heterogeneity of views within the farmers interviewed as part of this research, as per Chapter 4 on building the research network.

3.5 Conclusion

In order to assess farm-level vulnerability of producers in the Whakatane District, it is necessary to locate production within a broader context. As this chapter sought to demonstrate, exposure sensitivity and adaptive capacity are likely to be influenced by a range of stimuli and conditions external to the farm, including patterns of land use, soil type, and marketing systems. Current vulnerability is also likely to be influenced at the farm level by historical processes and conditions. While floods, for example, have been a significant exposure for lowland farmers, it is dynamic, and a function of changing land-use and drainage. Farmers are also teleconnected to world markets, economic and legislative pressures operating at scales beyond their immediate control (Adger et al. 2009; Eakin et al. 2009). Agricultural restructuring in the 1980s, for example, increased exposure to market risks by removing subsidies to farmers, along with a range of agricultural supports. Producers are now not only uniquely dependent on export markets but also likely sensitive to fluctuations in commodity prices, currency exchange rates, and input costs.

The chapter also showed that current systems of agricultural production in the study area, including drystock, dairying and kiwifruit production, were best understood as being a function of the opportunities associated with the unique climatic and biophysical conditions of the study area and historical trajectories and processes of land transformation and resource use. As outlined in the conceptual framework, the empirical research relies on insights from these producers in order to inform the analysis of farm-level vulnerability. This chapter has sought to contextualize the subsequent discussion by identifying elements external to the farm - social, economic and

biophysical - that may influence relevant exposure-sensitivities and adaptive strategies. The development of the network of participant farmers and growers, the methods of empirical data collection and analysis in order to document exposure-sensitivity and adaptive capacity is the subject of the following chapter.

CHAPTER FOUR: Methodology and Analysis

4.1 Introduction

Rather than believing that one must choose to align with one paradigm or another, I advocate a paradigm of choices. A paradigm of choices rejects methodological orthodoxy in favour of methodological appropriateness as the primary criterion for judging methodological quality. The issue then becomes whether one has made sensible decisions given the purpose of the inquiry and the questions being investigated (Patton 1990, 39; emphasis added).

In short, “the question shall determine the method.”

- Susan Elliott (1999, p.240)

Farmers work in a multi-dimensional risk management environment, one shaped and influenced not only by climatic conditions, but payout and commodity prices, indebtedness, legislative changes, interest rates, and changing market access (Hardaker et al. 2004; Bradshaw 2007; Sivakumar & Motha 2007; Kay et al. 2007). While climate is important, one of the aims of this research was to situate exposure-sensitivity to current and future climatic conditions within the broader context of other stimuli. Applying the context-sensitive framework developed in Chapter 2, the research sought to document relevant climatic and non-climatic stressors based on the experience of agricultural producers in Whakatane District, and the strategies employed to manage those risks in order to better understand their ability to respond to long-term climatic variability and change.

To obtain the empirical data, a bottom-up, mixed-methods and participatory based approach was used to develop a place-based case study. This was informed by a close reading of other vulnerability assessments across a range of fields including climate change research (Subak 2000; Vásquez-León et al. 2003; Sutherland et al. 2005; Næss et al. 2006; Few et al. 2007) and environmental risks and hazards (Cutter 1996; Oliver-Smith & Hoffman 1999; Smith et al. 2000; Wisner 2004; Pearce 2005), as well as ethnographic and participatory studies from applied climatology and agriculture (Roncoli 2006; Bryant et al. 2007; Bruges & Smith 2007). These were instructive in determining the choice and suitability of methods, and the potential challenges associated with participatory and practice-oriented research. The term participatory is used to refer to working with the knowledge of ‘ordinary’ people (Park 1999), actors (Keskitalo 2008) and producer-stakeholders (Belliveau et al. 2006), and is consistent with its use elsewhere (Battaglini et al. 2008; Ford et al. 2009; Pearce et al. 2009; Hovelsrud et al. 2010). It denotes the importance of participation by affected persons in the assessment process in order to accurately identify forces relevant to them (van Aalst et al. 2008).

As Elliott (1999) above argues, the appropriateness of any methodology is a function of the purpose of the inquiry and the questions being investigated. This chapter discusses the practical considerations and relevancy of the methodology and methods used in this research, as they pertain to the examination of farm-level vulnerability. It is organized as follows. Consistent with the conceptual framework, the following section reviews the practical and theoretical component of the participatory, ‘bottom-up’, assessment of farm-level conditions used in this research. A research strategy and time line is presented. As part of ensuring rigour (Baxter & Eyles 1997), a biography of the research is also discussed. Following this, the sampling procedure and methods

employed in the research, as they link to the conceptual framework and the research objectives are described. The challenges of fieldwork, temporal characteristics of data collection and sampling methods and procedures of data analysis are presented in the final sections of the chapter.

4.2 Methodology and Analysis

The ways in which adaptation can be assessed have been broadly classified by Tol et al. (1998) as ‘no adaptation’, ‘arbitrary adaptation’, ‘observed adaptation’ (analogues) and ‘modeled adaptation’ (optimization). Assessment of the impacts of climate change on various social and ecological systems in which no adaptation is assumed, are not uncommon in the literature, particularly in agriculture (Rosenzweig et al. 2001; Tubiello et al. 2007), health (Kovats et al. 2005; McMichael et al. 2006; Costello et al. 2009; Howden-Chapman et al. 2010), and impacts from extreme events (Diffenbaugh et al. 2005; Jentsch et al. 2007; Sillmann & Roeckner 2007; Smith et al. 2009). Where vulnerability is recognized in the analysis, the emphasis continues to be on ‘end-point’ approaches (Kelly & Adger 2000) or vulnerability as an outcome (O’Brien et al. 2007). These studies employ a scientific framing of vulnerability (O’Brien et al. 2007) and typically use downscaled Global Circulation Models (GCMs) to characterize impacts.

Vulnerability is the endpoint of analysis, a function of the residual negative impacts as moderated by any arbitrary adaptation (Kelly & Adger 2000). Where the potential for adaptation is recognized, it is modelled in terms of ‘perfect knowledge’ by actors. Much of the research on the impacts of climate change and adaptation continues to employ this ‘first generation’ vulnerability assessment (Füssel & Klein 2006) approach. It is most prevalent in studies related

to agriculture and climate change (Rosenzweig & Parry 1994; Parry et al. 2004; Parry et al. 2005), the so called “dumb farmer” approach (Easterling et al. 1992; Kaiser et al. 1993).

In agricultural research, even though advances have been made in understanding current and anticipated impacts of climate change (IPCC 2007; Rosenzweig et al. 2008), and potential adaptation options (Howden et al. 2007), most impact assessments continue to be derived from such modelling studies on extremely simplified and hypothetical farming systems, usually single crop simulation analyses (Asseng et al. 2004; Challinor et al. 2007; Tubiello et al. 2007; Tao et al. 2009). Analysts use GCMs to derive target temperature increases to describe the impacts on production (Parry et al. 2004; Parry et al. 2005; Seo 2006). Models determine what the characteristics of regional climate patterns might be in the future, and then the results are applied to an agricultural production model (Schneider et al. 2000), using the mechanisms through which climate shapes agricultural production patterns. For instance, water stress (drought or water excess) and thermal stress (heat or cold) might have large impacts on plant production by disrupting the phenology (foliation, flowering, life cycle, etc.), growth and yield (size, number and quality of fruits/grains) of plants and their spatial distribution (Ebi et al. 2009). The effects on animal production are similarly modeled, through examination of the disruption to feedstock production; and the distribution and propagation of emerging diseases that could impact plant and animal production (Gaughan et al. 2009; Junk et al. 2011).

While research increasingly recognizes that the severity of impacts will be related to the response of producers and other stakeholders, adaptive responses in modeled studies continue to be defined as absolutes (Schneider et al. 2000). The “dumb farmer” (Rosenberg 1986) assessment assumes no adaptation takes place (Easterling et al. 1992), while the “clairvoyant farmer” (Smit 1991) approach assumes actors have perfect advance knowledge of climatic conditions and instantly adopts ideal adaptive strategies arbitrarily (Kaiser et al. 1993; Schneider et al. 2000). Easterling et al. (1992) for example presume farmers’ adaptation responses for the MINK (Missouri, Iowa, Nebraska, Kansas) area in the United States. Using the EPIC (Erosion Productivity Impact Calculator) Model, they create a future baseline for crop productivity in the year 2030 that reflects changes in technological advances including crop-breeding improvements that lead to higher yields, more efficient chemical conversions, and earlier leaf development. Chettri et al. (2010) have also modelled the effects of climate variability and change on corn yields in the Southeast United States using a regional climate model nested within a global climate model (GCM) simulation, to demonstrate that even with no adaptation and “perfect adaptation”, higher concentrations of GHGs in the atmosphere will result in lower yields. In contrast, work done on the Canadian Prairies (Nagy 2001) has shown that assuming the widespread adoption of different crops (chickpeas and dry beans), that farmers may in fact be able to realize opportunities associated with changing climatic conditions.

Modelled end-point approaches do have their value. Models can demonstrate the potential significance of adaptation in moderating the impacts of climate change in agriculture, however they often neglect the complex dynamics that shape how climate change is experienced and responded to by human systems. Models also tend to over-emphasise future conditions and neglect current stresses. There is also a tendency in such approaches to assume *a priori* that climate is the most significant stressor faced by producers, and also which climate stimuli are important (Meinke et al. 2006; O'Brien et al. 2007; Gawith et al. 2009; Meinke et al. 2009; Wreford & Adger 2010). Ignoring adaptation however can also lead to a serious overestimation of the damage of climate change (Tol et al. 1998). Not only does this assumption lead to overestimations of damage, it also conveys the message that there are no actions available in the face of climate change and the only option is to mitigate emissions or suffer serious consequences (Wreford & Adger 2010).

Agricultural producers are neither dumb nor clairvoyant. Producers are constantly learning through experience with existing climatic variability (Roncoli 2006; Meinke et al. 2009), adjusting the timing of cropping patterns, the selection of cultivars, and other production practices. This “practical wisdom” (Schwartz & Sharpe 2006) regarding the management of climate variability is central to agricultural production, policy and practice and can provide a natural foundation from which adaptation to climate change can evolve (Howden et al. 2007) and insights obtained. Observed adaptation (Tol et al. 1998) to existing climatic conditions, including variability and extremes, has the potential to serve as an analogue for adaptation to future climate

change (Wreford & Adger 2010; McLeman & Ploeger 2011). Together with an understanding of vulnerability this can provide the basis for a complementary analytical framework to traditional, model-based assessments.

Observed adaptation uses examples (analogues) from other situations in order to predict adaptation in the current situation (Glantz 1996). These analogues may be spatial or temporal (Ford et al. 2010; Malone & Engle 2011). Spatial analogues use the experiences and actions in one location as examples or predictions of possible action in another similar location (Tol et al. 1998). Mendelsohn et al. (1994) use this method to estimate climate change impacts on US agriculture. Temporal analogues examine how adaptation has occurred historically. McLeman and Hunter (2010) use examples of large-scale historic migrations, including the Dust Bowl of the 1930s as analogues for identifying general causal, temporal, and spatial dimensions of climate related migration.

Contextual vulnerability is based on understanding the dynamic interactions between climatic variability and change and the social, institutional, economic and social structures in which it occurs (O'Brien et al. 2007). To examine vulnerability from this perspective, the emphasis is on empirically derived qualitative data. The use of qualitative data implies a greater emphasis on processes and meanings as opposed to the rigorous examination and measurement (if measured at all) of the usual metrics for documenting hazards: quantity, amount, frequency or magnitude (Tobin & Montz 1997; Hewitt 1997; Keller & DeVecchio 2011). In such research, the focus is on insight, discovery, and interpretation rather than hypothesis testing (Merriam 1988).

Vulnerability assessments conducted elsewhere have often been place-based case studies (cf. Ford et al. 2010; Cutter 1996; Malone & Engle 2011; Hadarits 2011).

Creswell (2007) identifies five methodological approaches for qualitative research: narrative research, phenomenology, grounded theory, ethnography, and case study. This study employed methods associated with a place-based case study methodology. A case study refers to in-depth analysis of a single example within its real-life context (Flyvbjerg 2006; Yin 2009). Place-based case studies have been widely used in climate change research because it is recognized that the drivers of vulnerability will vary between nations, regions, communities, and even within communities, on the basis of differential exposure to climate change effects and differential adaptive capacity (Cutter 1996; Mitchell et al. 1989; Wilbanks & Kates 1999; Turner et al. 2003; Cutter & Finch 2008; Malone & Engle 2011). Vulnerability is based in a locality but this locality is understood as being nested within levels (Turner et al. 2003; Schröter et al. 2005; Eakin & Luers 2006; Adger et al. 2009). In short, vulnerability is location-specific, manifesting and requiring adaptation at the local or local/regional scale (Næss et al. 2005).

While national-level analyses are useful, they hide vulnerabilities at the regional or local level, and can lead to questionable conclusions about resilience (Cutter & Finch 2008; O'Brien et al. 2007). The detailed documentation of vulnerability – conceptualized as exposure-sensitivities and adaptive capacity – at this local level, within the context of other, broader scale conditions, then becomes the basis for exploring potential adaptive responses to future climatic variability and change (Ford et al. 2010).

In other studies (Ziervogel et al. 2006; Barnett et al. 2007; Westerhoff & Smit 2008; Young et al. 2009; Ford, Berrang-Ford, et al. 2010) the empirical qualitative data has been derived from interviews, focus groups, participant observation and other social-science and participatory techniques. This helps to facilitate the reconstruction of situated and negotiated realities of individuals and their experiences of events and processes related to hazard events, and vulnerability (Masuda & Garvin 2006). Culture can be located in attitudes, beliefs, values, and social interactions that influence the articulation of various risks (Santos & Chess 2003), and is one of the most complex dimensions of global environmental change research (Proctor 1998; Adger et al. 2003). Through *thick information* (Geertz 1973), qualitative research can be complementary to traditional quantitative research on risks and hazards by providing experiential substantiation or offering new insight into possible new directions of theories, models, and frameworks (Easterberg 2002; Adger et al. 2003).

The emphasis in this research was not on generating a quantitative measure or ranking of vulnerability, though such studies have been done elsewhere (Schimmelpfennig & Yohe 1999; Alwang et al. 2001; Wilhelmi & Wilhite 2002; Yohe & Tol 2002; Hahn et al. 2009). These quantitative rankings are useful. Luers et al. (2003) developed a quantitative scheme to measure the vulnerability of wheat yields in the Yaqui Valley, Mexico. Their methodology is transferable to other cropping systems, enabling comparison across diverse locations and sectors (Schröter et al. 2005). In Australia, Nelson et al. (2010; 2010b) have developed and applied a similar approach to vulnerability to climate change, based on statistical indices. This research was concerned instead, with understanding the nature of farm-level vulnerability based on the experience of producer-stakeholders in the Whakatane District of the eastern Bay of Plenty.

Working “from the bottom-up”, the research sought to empirically identify (rather than assume *a priori*) the factors and processes that affect producer-stakeholders and characterize their vulnerability. Van Aalst et al. (2008) identify two significant ways in which working from the bottom-up can be distinguished from top-down approaches. Firstly, the assessment process involves local stakeholders. Secondly, instead of using global model scenarios far into the future, the assessment seeks to examine vulnerability to current climate variability and extremes, as well as the current adaptation strategies, policies and measures, based on actual experience at different scales. In this way, the first steps of the analysis are not theoretical and future oriented, but empirical and based on actual observation of current climate risks and how individuals within the system of interest or communities cope with them. On the basis of existing knowledge, the dimension of new risks (those with which there is no experience), can be introduced, and assessed in the context of current experience and knowledge. This overcomes some of the inherent uncertainty in model-based climate scenarios, and accounts for the capacity of actors to adapt to changing conditions, by grounding the analysis empirically in existing circumstance.

In keeping with the research questions and objectives, a mixed methods approach was used including participatory, in-depth interviewing; temporal analogues and analysis of secondary sources, including scenarios of future climate change and results of other, model- or experimental, climate change impact studies. The methodology used is broadly consistent with analytical and methodological frameworks of vulnerability from the literature (Kasperson & Kasperson 1996; Turner et al. 2003; Ford & Smit 2004; Keskitalo 2004; Füssel 2007), and with the documentation of vulnerability in other places (Adger 1999; Pearce et al. 2010; Faraco et al. 2010; Fekete 2009). The methodology also satisfies the criteria proposed by Schröter et al.

(2005) who suggest vulnerability assessments should (1) be derived on the basis of stakeholder participation, (2) be place-specific, (3) consider multiple interacting stresses, (4) take into account differential adaptive capacity and (5) be prospective as well as historical.

4.2.1 Vulnerability case study

The case study methodology was developed around two stages: (1) assessing current vulnerability, and (2) exploring the future vulnerability of actors: pastoral farmers and kiwifruit growers. The term ‘stakeholder’ is often used in the literature to define the main actors that are impacted by change in any given sector and area studied (Belliveau et al. 2006; Young et al. 2009; Keskitalo 2010). It is used here to describe individual pastoral farmers and kiwifruit growers in the eastern Bay of Plenty. Those involved in processing, distribution, and marketing are also stakeholders in the regional agricultural system however the focus in this study was on the experiences of producers at the farm-level.

Assessing current vulnerability involved:

- Identifying the risks or conditions (both climatic and non-climatic) to which were relevant to producers (exposure-sensitivities)
- Identifying and assessing the strategies employed to cope with and adapt to exposure-sensitivities (adaptive capacity)

Assessing ‘future vulnerability’ involved:

- Estimating future risks or exposure-sensitivities based on likely changes in previously identified conditions
- Assessing the capacity to adapt to future climatic conditions based on current adaptive capacity as well as the influence of likely drivers of future adaptive capacity, including socio-economic and institutional factors

While Chapter 3 located the unit of analysis – individual farms – within a broader social and ecological context, the exact nature of exposure-sensitivity and adaptive capacity were only identified after consultation with farmers and growers. Further insight into relevant conditions and past exposure was gained through subsequent reading and analysis of government reports, scientific literature, and published historical accounts. A schematic of the vulnerability assessment is shown in *Figure 4.1* (overleaf).

Current exposures are conditions or risks that stakeholders have dealt with in the past or are currently exposed-sensitive to. In other studies, assessment of current exposure-sensitivity has been done using techniques of ethnographic in-community fieldwork, such as participant observation, questionnaires and semi-structured, as well as drawing on insights from local and regional decision makers and resource managers (Ford et al. 2006; Næss et al. 2006; Eakin & Wehbe 2008; Rasmussen et al. 2010; Hadarits 2011). In this study, both physical and non-physical stresses as well as the characteristics of farms (soil type, location, etc.) contributing to problematic conditions, were identified, as per the conceptual framework (*Figure 2.3*).

Assessing current *adaptive capacity* involved identifying the ways in which the actors deal with, and have dealt with exposures. It required the identification of the broader conditions that facilitate or constrain adaptive strategies. The conceptual framework accounts for this by seeking to identify conditions beyond the scale of the unit of analysis (i.e. the individual farm), as many of the determinants of, and barriers to adaptive capacity are institutionalized at a broader level and beyond the perceived or real control of stakeholders (Adger et al. 2005; Neudoerffer & Waltner-Toews 2007; Keskitalo & Kulyasova 2009b; Wandel & Marchildon 2010). Barriers can

be considered conditions or factors that make adaptation more difficult, such as limited access to capital, information or technology, as opposed to limits to adaptation which render it ineffective and “largely insurmountable” (Adger et al. 2007, p.733).

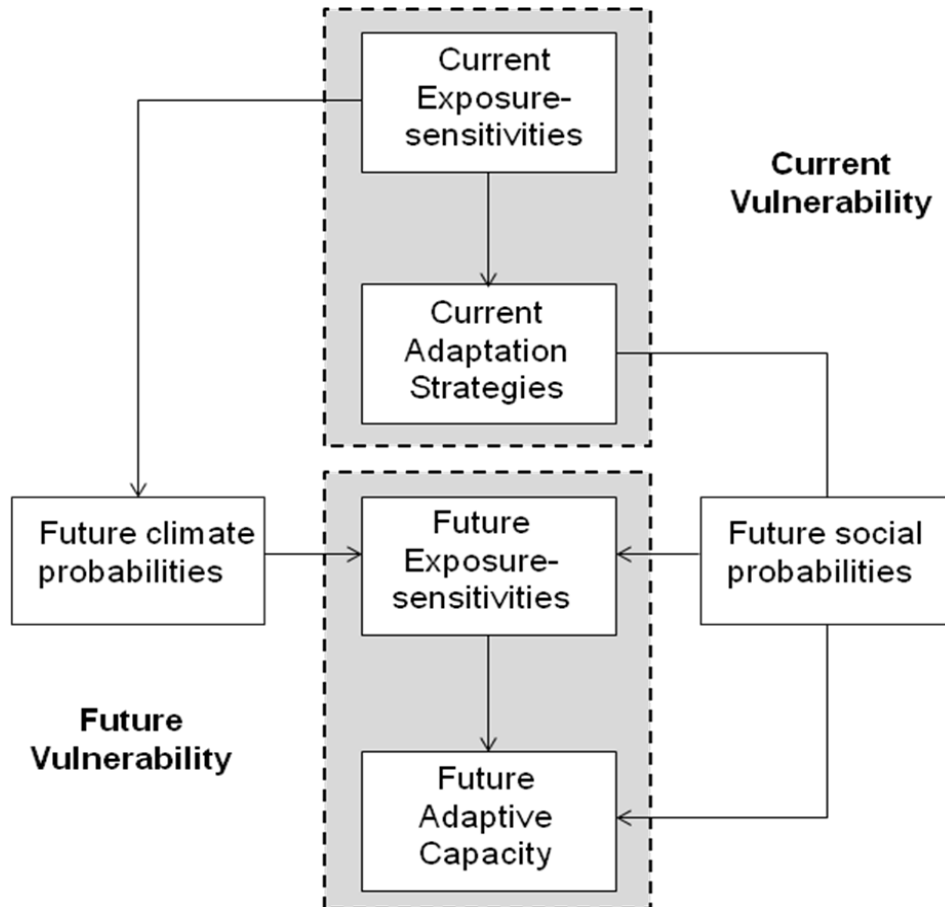


Figure 4.1 Two-step analytical framework used to structure the empirical assessment of vulnerability in the eastern Bay of Plenty (After: Smit and Wandel 2006; Sydneysmith et al. 2010)

The empirical application of the conceptual framework developed in Chapter 2 then was informed by this methodology. Together, this approach is flexible enough to allow for the presence of multiple risks and multiple sources of capacity including political, cultural, economic, institutional, and technological factors (de Chazal et al. 2008; Tarleton & Ramsay 2008; Wilbanks & Kates 2010; McCarthy & Martello 2010). The assessment is both historical and prospective (Schröter et al. 2005) and recognizes that vulnerability changes over time, as different exposure-sensitivities, adaptive strategies and varying degrees of adaptive capacity interact. What is vulnerable in one period (or in one way) may not necessarily be vulnerable in the next (or in the same way), and some exposure-sensitivities (e.g. those produced by “creeping hazards” (Glantz 1988; Wisner 2004)) develop slowly over time. Furthermore, sources of exposure-sensitivities and adaptive capacities operate at various scales from the individual to the national to the global (Adger et al. 2005; Schröter et al. 2005; Wilhelmi & Hayden 2010). As shown in the conceptual framework, vulnerability is ‘teleconnected’ and nested (Adger et al. 2009; Eakin et al. 2009). Exposure-sensitivity and adaptive capacity at the farm-level are linked through markets, management systems, and legislative and economic processes to often distant places (Eakin & Wehbe 2008; Hausermann & Eakin 2008). Vulnerability is also dynamic. As exposure-sensitivities are reduced in one part of the system, they may be enlarged elsewhere (Cash & Moser 2000; Luers 2005; Adger 2006; Garschagen et al. 2011).

By documenting current exposure and capacity in detail, it is possible to estimate future vulnerability to changing conditions. It is likely that the future climatic conditions will be experienced and responded to in similar ways as they are today, with many of the same constraints and facilitating factors (Glantz 1996; Adger 2003; Næss et al. 2005; Pelling et al.

2008). In this framework then, *future exposures* relate to conditions that are anticipated to adversely affect producers or provide opportunities related to changed climatic conditions (Wandel et al. 2007; Howden et al. 2007). Likely future climate can be derived from model-based scenarios along with a range of related environmental conditions (such as soil moisture levels) that might have been identified as relevant. These provide a valuable resource for assessing future exposure. Information from stakeholders regarding their own understanding and awareness of future exposures is also included in the analysis.

The assessment of *future adaptive capacity* is conducted in a similar manner. Based on the review of existing farm management practices, how might producers be able to effectively cope with estimated future exposures? More broadly, consideration is given to the degree to which actors have adaptive capacity in terms of the scope, resilience, resources and potential to deal with expected future exposures. Future adaptive capacity is also likely to be influenced by non-climatic conditions, which will continue to exert an influence on the range of adaptations that are possible. In analyzing future adaptive capacity, it must be recognized that while adaptations to climatic conditions are common in the agricultural sector, they are often undertaken in response to more than climatic conditions alone. Adaptive decisions rather, will likely continue to be made as part of a strategy of integrated management at the farm level (Smit & Skinner 2002; Bradshaw 2007; Rodriguez et al. 2011). Adaptation to climate change may in fact be a secondary consideration, but farmers' actions may have the unintended effect of reducing or increasing their vulnerability to climate change anyway (Bryant et al. 2000). Non-climatic farm-level stimuli may amplify or exacerbate climate-related risks, or they may dampen, counteract, or overwhelm the climatic effects (Smit & Skinner 2002).

In soliciting the opinions, and experiences of farmers in the eastern Bay of Plenty, and analyzing and collating that information, the goal is that the findings of this research will be of more than simply academic value. Case studies and assessments of vulnerability conducted elsewhere have often had an applied focus. They may be used to inform policy, build awareness, or enhance resilience within the system of interest (Næss et al. 2005; Sutherland et al. 2005; Pouliotte et al. 2009; Pearce et al. 2010), and contribute to the development of ‘actionable’ information (Vogel et al. 2007). This orientation is closely related to the grounding of this methodology in participatory methods, and also the origin of vulnerability assessment in hazards and development research which was often directed at harm reduction or livelihood enhancement. The results of this study will be shared as a report in suitable language and format, to networks and contacts established in the study area; provided to regional council; and prepared as manuscripts to be submitted for publication in academic journals. The goal is that research will have practical application for participants, and inform future policy and proposed adaptation measures in the eastern Bay of Plenty with insights from the those most likely to be affected. It also seeks to demonstrate the urgent need for, and benefits to be gained from greater engagement with stakeholders in the adaptation process, particularly in New Zealand. This supports the important work begun in this regard by Kenny (Kenny 2006) and Kenny and Fisher (2003), and is consistent with the model of ‘adaptation science’ for agriculture proposed by Meinke et al. (2009).

4.3 Research Strategy

Several methods were used in the development of the place-based case study including semi-structured interviews, temporal analogues, and analysis of secondary sources. The choice of methods was based on a close reading of the literature and a review of methods used elsewhere (Sutherland et al. 2005; Westerhoff & Smit 2008; Keskitalo & Kulyasova 2009a; Few & Tran 2010).

Two phases of fieldwork in 2007 and 2008 were the foundations on which the overall PhD project was based (*Table 4.1*). In order to increase the likelihood of participation, field seasons were timed to correspond with the seasonal nature of agricultural production. Interviews were arranged during the “quiet” parts of the dairying and horticultural seasons respectively, after the milking season had ended, and during those months in which horticultural producers were not occupied with pruning or harvesting kiwifruit.

Project stage	Time	Purpose and activities
Project planning	October 2006 – June 2007	Review of literature Establish research links Proposal submission
Fieldwork preparation	August 2007 – December 2007	Scoping visit to study area Contacts established within community through gatekeepers at Environment Bay of Plenty, Federated Farmers and local farmers Pilot interview questions Participate in overseas workshops and conferences on climate change adaptation, and prepare for fieldwork and data collection phases
Fieldwork phase one	January 2008 – May 2008	Network of interviewees developed through purposive snowball sampling Semi-structured interviews conducted with lowland dairy farmers in the Eastern Bay of Plenty Interview strategy refined
Fieldwork phase two	August 2008 – January 2009	Follow-up with lowland dairy farmers Network within the horticultural and dry-stock farms in the Eastern Bay begun through purposive snowball sampling Interviews conducted with horticulturalists and dry-stock farmers
Write up	June 2010 – September 2011	Transcription of interview data Coding and analysis of transcripts using NVivo 9 Further development of research skills and write up PhD dissertation submitted Findings communicated to stakeholders, community and institutions

Table 4.1 Research strategy and time line used in the preparation of the PhD thesis.

Research progressed swiftly at first, in a flexible, iterative and exploratory manner, with return visits to the South Island, Canada and participation in overseas conferences. Conferences and workshops provided time for reflection, introductions to new scholarly networks, and literature in the field. It also allowed for the preliminary development of the conceptual framework and the publication of early results (Cradock-Henry 2008). Following the final field season, there was an

extended absence from the research project during which time I returned to Canada to lecture in physical geography and resource management. This allowed me an opportunity to reflect on the fieldwork, establish needed distance between data collection and analysis, and begin to conceptualize my theoretical framework. I returned June 2010 to full-time study with new motivation, fresh perspective, and a renewed commitment to its completion.

4.4 Research Methods

The vulnerability assessment which forms the basis of the study had two main stages of analysis: assessing current vulnerability and projecting future vulnerability. The research employed a combination of qualitative techniques in order to document the environmental and socio-economic exposure-sensitivities and adaptive responses, and the decision-making context. As such this method can be considered a ‘temporal analogue’ (Glantz 1988; Glantz 1996; Tol et al. 1998), involving the documentation of current risks and adaptive responses as a means of understanding the potential range of future responses, empirically grounding the analysis of vulnerability to changing conditions (Young et al. 2009; Ford et al. 2010; Sydneysmith et al. 2010; Malone & Engle 2011).

The research strategy and methods used to address these, and the overall objectives of the research are summarised in *Table 4.2*.

	Objective	Methods
Objective one	Document current exposure-sensitivities of agricultural producer stakeholders in the Eastern Bay of Plenty within the broader context of agricultural decision-making.	Analysis of relevant literature to develop conceptual framework for study Develop a semi-structured interview format to be administered across a range of agricultural producers representing a diverse range of farm types and geographical location, throughout the Eastern Bay of Plenty
Objective two	Identify adaptive strategies for managing current exposure-sensitivities	Semi-structured interviews with range of producers in which producers were asked to about current exposure-sensitivities (climatic and non-climatic risks) and adaptive capacity.
Objective three	Assess the vulnerability of agricultural systems to climate change	Assess future vulnerability on the basis of current exposure-sensitivity and adaptive capacity; scenarios of changes in climatic conditions; insights from stakeholders regarding their views on climate change, potential risks and opportunities
Objective four	Contribute to ongoing development of policy discussion on mainstreaming adaptation and return results of research to stakeholders	Complete analysis and write-up of PhD study, copies of which will be made available to participants, along with a summary report highlighting the results of the research, to be distributed through local contacts and research networks to interested parties; public presentation of the results of study.

Table 4.2 Research methods as they relate to the stated objectives of the PhD thesis.

For the duration of the fieldwork I was resident in the community of Whakatane. Residency achieved several goals related to data collection. The first was practical: living in the community was necessary in order to conduct the interviews. Second, as per Lincoln and Guba (1985) a period of prolonged engagement can enable the researcher to build trust and rapport with the respondents, learn the ‘culture’ of the relevant group(s) and enhance the overall *trustworthiness* (the degree to which findings are credible, have integrity, and are worthy of attention) of the research. Living in the community, I developed a network of stakeholder-participants,

familiarized myself with the larger community and built a sense of commitment to the success of the region and the research. It is anticipated that this will help ensure the legitimacy of the findings, create a greater sense of ownership and promote uptake and consideration of the findings (Hedger et al. 2000; Turner et al. 2003). The expectation is also that through the goodwill and trust that was established in the farming community, that some of the perceived barriers within rural sectors around climate change (Fulton 2008) might be overcome. As Stone and Meinke (2006) note in their study on weather forecasts for the agricultural sector, participatory approaches provide farmers with ownership of the process, which often results in much more widespread adoption of the outcome. Finally, because exposure-sensitivities and determinants of adaptive capacity were not presumed in advance, the active engagement with, and participation of stakeholders was vital. This required the establishment of a network of participant-stakeholders in the community, something that was only feasible with a period of extended residence within the Bay of Plenty area. The theoretical and conceptual orientation of the study then, deemed it methodologically appropriate (Elliott 1999) to have extended periods of community-based fieldwork.

Farmers and kiwifruit growers were invited to participate in a semi-structured interview in which they would be solicited for information in order to empirically document the range of exposure-sensitivities and adaptive capacities employed in the regional farming system. The following section discusses the sampling procedure, development of the network of participant-stakeholders and interviewing formalities and techniques.

4.4.1 Engaging participants, sampling and interviewing

The research network was prior to and concurrent with the fieldwork. After meeting at a hydrology conference, Dr. David Wratt, Chief Scientist Climate Change at NIWA, suggested I contact Dr. Gavin Kenny of Earthwise Consulting in Hastings, New Zealand. Kenny, who had consulted for BoPRC and the kiwifruit industry, provided the names of a dairy farmer and two BoPRC staff. This formed the basis of the initial interviews. John Douglas, a land-manager with BoPRC, introduced me to two pastoral farmers, and a kiwifruit grower. The first dairy farmer I interviewed assisted with the piloting of the interview questions and provided me with the names of four additional lowland dairy farmers.

Following Bernard (2005) and Bradshaw and Stratford (2005), purposeful and “typical case” snowball sampling methods were used in order to obtain an illustrative sample of size and spatial distribution of farms and orchards in the area. Care was given to ensure that a diverse selection of farmers, in different locations, were identified and engaged. No incentives were used to engage participants; I relied on goodwill and interest in the subject. All initial contacts were made by telephone. In cases where an individual was busy, a message was left, or a repeat phone call was made several weeks later to follow up. As shown in *Table 4.3* (refer also to *Figure 3.1*), farms were sampled over a wide geographic area, to ensure a diversity of farms with differing soil, climate, topographic and other bio-physical characteristics.

Farm Type	Location	Number of farms
Dairy farm	Rangaitaki	
	Plains	18
	Opotiki	9
	Galatea Valley	8
	Waimana Valley	6
		<hr/> 41
Drystock	Opotiki	6
	Waimana Valley	4
	Rotorua	2
		<hr/> 12
Kiwifruit orchard	Rangaitaki	11
	Plains	
	Opotiki	10
	Waimana Valley	1
	Te Puke	2
		<hr/> 24

Table 4.3 Approximate geographic distribution of farms ($n = 77$) represented in study

There is a great deal of scepticism in the agricultural community in New Zealand regarding climate change, supported in large part by FFNZ. Part of the problem has been ascribed to a conflation of mitigation and adaptation (Reisinger et al. 2011), and opposition to a carbon or emissions tax (Fallow & Beston 2006). Local and national governments can also initiate policy which either facilitates or limits adaptation (Kelly & Adger 2000; Næss et al. 2006; Keskitalo & Kulyasova 2009b). In order to identify as accurately as possible, those conditions and factors to which producers were exposed-sensitive and that affected their ability to adapt to existing and anticipated changes in climatic conditions, it was necessary to work around what might potentially have been barriers to the insights and experiences of stakeholder-participants. It was vital that participants felt comfortable in identifying local government policies or legislation that

constrained the flexibility of their adaptive strategies. Many in the farming community hold strong opinions about the RMA, for example.

This is supported by research from overseas in which perceptions of climate change have been identified as a barrier to communication and consideration of likely adaptation needs (Harrington & Lu 2002). Working in northern Canadian communities dependent on forestry, Davidson et al. (2003) provide a summary of characteristics that make them particularly vulnerable to climate related impacts. Several of their points are true for rural communities in general. They note, for example, that community adaptability is often constrained by political change, such as the trend towards regional amalgamation, in which local government loses control of resources for dealing with challenges of all kinds. Or, as in the case of New Zealand, responsibility for adaptation is shifted to local government without a concomitant commitment of resources, technology, or skills for the identification of necessary adaptation strategies (Greenaway & Carswell 2009). Davidson et al. (2003) also point to risk perception as another factor that may compromise the ability of resource-based communities to adapt to climate change. They suggest that rural residents may not acknowledge climate change is a serious problem because they associate the topic with ‘environmentalism’ and take a position counter to those they think of as an urban-based radical opposition. Denial of climate-related problems is not conducive to implementing strategies and tools that may help individuals adapt to altered conditions, and nor is it conducive to networking with stakeholders in a rural environment, characterized by a high-degree of antagonism towards what is often interpreted as ‘meddling’ by the urban majority in the rural sector.

In light of these considerations, the study was therefore deliberately introduced as an independent doctoral research project, not affiliated in any way with BoPRC or FFNZ. The research project was introduced to stakeholders as a study “exploring agricultural risks and opportunities in the eastern Bay of Plenty”. Concern about climatic risks or climate change was not mentioned specifically at first. The letter of introduction provided to stakeholder-participants is included in *Appendix A*. By presenting the research as an independent study intended to support agricultural decision making and inform policy through a ‘bottom-up’ approach, I had a great deal of success building a network of those willing to participate in the research. Questions regarding climatic variability and change were part of the interview, so individuals did have an opportunity to share their views, however, it did not preclude participation unnecessarily.

Interviews were semi-structured and conducted over coffee at the home or a small meal in Whakatane. Questions were developed in advance based on a close reading of previous work on agricultural risks and vulnerability (Smit & Skinner 2002; Vásquez-León et al. 2003; Ziervogel et al. 2006). An advantage of the semi-structured format was that it provided the flexibility to develop questions, pursue comments, and develop ideas as the conversation progressed (Dunn 2005). Working with different farming systems, the generic nature of the interview format also allowed me to pursue lines of inquiry specific to particular farms, farmers, or management systems. I quickly learned the terminology associated with different types of production, and was able to communicate clearly on a number of different aspects of farming in the area, including pruning practices and the relative advantages of high- and low-input dairying. This further established the legitimacy of the research, and myself as a scientist-researcher and has led to several offers of future employment.

The study sought to identify the presence of multiple climatic and non-climatic stressors to which producers are exposed-sensitive, as well as establish the context within in which production occurs. Questions therefore were designed to solicit input on a range of topics related to agricultural risk, and not just climate alone. Interviewees were asked first about the general features of the farm or orchard (size, location, soil types, length of time in operation). Producers then responded to a series of questions regarding their experiences over the last ten years, and prospects for the future, including their characterization of past good or bad years, and the farm management practices used in response. In several instances, farm owner-operators had grown up in the area or had grown up on the same property and taken over the business. In these cases, longer time periods were discussed. Conditions identified in good years were considered opportunities and those identified in bad years as risks (Belliveau et al. 2006; Wandel et al. 2007; Reid et al. 2007).

Consistent with the methodology, and in an effort to minimize bias, producers were asked about all possible conditions that affected them, and all management strategies – not simply those related to weather. The interview guide did not prompt interviewees to discuss the climate, climate variability or change until the very end, when producers were asked specifically about their views on climate change. The purpose was to develop an understanding of producers' exposure to, and adaptive capacity for, managing multiple climatic and non-climatic risks. It also provided a sense of where climate risks and climate change fit into producers' multi-risk decision-making environment.

I established a good rapport with all of the stakeholder-participants. A total of eighty-people were contacted, only three of whom declined; two for logistical reasons and one because they felt they had nothing significant to say on the subject. Non-response is unlikely to have exerted a significant impact on the research findings as few problems were experienced with finding willing participants (Fowler 2002). Interviewees readily suggested other farmers that might be willing to participate. The research project also received local media attention, including an interview on local radio and a short article in the Whakatane Beacon, the community's newspaper.

All participants were asked for permission to use a digital recording device during the interview. The advantage of using the recorder was that it enabled a more conversational and flexible interview style, as well as providing an important record (Dunn 2005). Following the interview, a brief summary was immediately written up. If the interview was conducted at the farm, I was often invited on a farm walk. This provided an opportunity to observe and further document aspects of relevant exposure-sensitivity and adaptive capacity, such as soil type, and on-farm drainage and flood pumps. My genuine interest in farm operations also further contributed to the legitimacy of the research within the farming community, and myself as scientist-researcher.

Interviews were held with local dairy farmers between January and May. Dairy farming in New Zealand is seasonal, and so too is farmers' workload. As much as possible, the interviews then were conducted prior to calving, which is the busiest time of the year. Kiwifruit interviews were conducted in a similar manner, and consideration given to the seasonal nature of orchard management when seeking to schedule interviews. There are a small number of dry-stock farms

in the area, and interviews were conducted at their convenience. As noted earlier, interviewees were contacted through chain-sampling (Bernard 2005; Bradshaw & Stratford 2005).

Important criteria for determining the rigour of qualitative research based on interviewing is triangulation (Baxter & Eyles 1997). Based on convergence, triangulation suggests that when multiple sources provide similar findings their credibility is considerably strengthened (Knafl & Breitmeyer 1989; Krefting 1990). In hindsight, it was probably not necessary to complete a total of 77 interviews, though the large sample size has produced a rich data source, which captures more nuance and detail than a smaller population would have. The extensive data also acts as source triangulation and therefore helps establish the rigour of the empirical data.

While the use of questionnaires can often unduly limit the amount and type of information obtained (Valentine 1997), there were also limitations to the methods used in this study. The semi-structured interview format did achieve the goals associated with data collection as it relates to the research objectives and questions, and can therefore be considered methodologically appropriate (Elliott 1999). The aim of the research was not to develop metrics or indicators of vulnerability for quantitative comparison across individuals and farms, but rather to draw qualitative insights into the role of social, economic, and environmental factors and their interrelations. However, as the analysis and write-up progressed, it became apparent that the addition of a standardized questionnaire accompanying the interview, might have allowed for a closer contextual analysis within and across farm units. Data on costs associated with management system, fertilizer inputs, or age of farmer, for example, might have yielded additional insights not captured in the interview process.

Audio recordings were transcribed verbatim over a period of three-months (June – August 2010), yielding some 350 pages of transcript. Copies of individual transcripts were emailed to participants with an invitation to add additional comment or clarification if needed. Transcription allowed me to reacquaint myself with data over a period of several months. Interviews were formatted and loaded into a qualitative data analysis software package (NVivo 9) for analysis. The software was used mainly as an organizational tool, given the volume of transcription. Data was coded, and analysed according to the relevant themes as per the conceptual framework.

4.5 Reflexivity and the research experience

The challenges associated with fieldwork, were outweighed by the positive experience of learning about farming systems “from the ground up”, the genuine rapport that was established within the agricultural community and the personal satisfaction derived from my investment in the research. The following section reflects on, and acknowledges these challenges and the subjective nature of research, based on a qualitative interpretation and exploration of vulnerability.

4.5.1 Reflections on fieldwork

Much has been written on the fieldwork experience (Ladurie 1979; Orlove & Guillet 1985; Gupta & Ferguson 1997; Gerber & Chuan 2000) and while it is impossible to escape the power relations that shape the research process, both during fieldwork and in the process of representing ‘others’ attempts must be made to understand and take account of these

complexities in practice by examining the positionality of the researcher and reflecting on the research process.

The fieldwork required for this study was a new experience. Previous Master's research involved extended periods of fieldwork in a remote high-mountain environment in Northern Pakistan (Cradock-Henry 2001); however this was a much different experience, and had its own unique challenges. Building a network of participants required living in the community, and there were difficulties at first with access, and mobility. Interviews were initially conducted in town, but it soon became apparent that having interviews at the farm or orchard would be easier for participants and also provide an opportunity to observe farming and horticultural production more closely.

Developing the network of research stakeholder-participants was emotionally demanding. Interviews called for a level of personal engagement, both with the interviewee and the subject matter. Data collection was tiring, but yielded invaluable insights into farming practices that only came about through this type of intensive engagement. Owing to the high cost, travel to and from the field site was limited. This added to the challenge of working in relative isolation, without a strong support structure, until I met people in the community. I returned to Christchurch only occasionally and was without a strong network of colleagues or the security that comes from being part connected academically and socially. The intensity of fieldwork, and continued residency in the community however, enabled me to build a strong and diverse network of participants, across a range of farm sites, and develop a good understanding of farming practices. A greater awareness of local issues, unrelated to farming, including economic development and

the social and cultural context was also only made possible through the prolonged engagement that came from living in the community.

4.5.2 Ethics

Research was conducted in an ethical manner, seeking appropriate permissions, and respecting respondents' rights and opinions. Before all interviews, I asked participants were asked for permission to use a digital recorder. Participants were assured that no actual names would be used in the thesis and that they would receive a copy of their transcript and a digital copy of the final dissertation if they wanted. Current contact information was exchanged at the end of the interview. During all interactions I sought to maintain an open, non-judgemental approach to encourage participants to express themselves fully and respect their rights to express their own opinions (Mullings 1999; Dunn 2005).

4.5.3 Seasonality and research strategies

While no single extreme event can be directly correlated to climate change, it should be noted that perceptions surrounding the relative importance of exposure-sensitivities may be influenced by or reflective of, a particular season or climatic event (Vedwan & Rhoades 2001; Meze-Hausken 2004; Thomas et al. 2007; Battaglini et al. 2008). Research elsewhere has shown that pronounced interannual variability or extremes can influence producers' perceptions of rainfall change for example (Meze-Hausken 2004; Deressa et al. 2011). The conceptual framework accounts for this, by recognizing that vulnerability is dynamic; exposure-sensitivity and adaptive capacity vary temporally and spatially (Adger 2006; Turner et al. 2003; Füssel 2007; Wilbanks & Kates 2010).

It should therefore be noted the research findings may have been influenced by seasonality and by the characteristics of the specific years in which fieldwork was conducted. Eastern New Zealand experienced severe drought conditions between 2007 and 2008, necessitating government assistance for affected rural populations (MAF 2009). Producers may have been more aware therefore, of climatic conditions, risks and potential impacts of climate change. Another major drought affected the area in the time between data collection and write up (MAF 2010) and severe flooding affected in Whakatane, June 2010.

4.5.4 Topic

Respondents were comfortable talking about exposure-sensitivities as they affected livelihood and farm income. Potentially sensitive topics, such as loss or damage to property; financial security including income, and debt-servicing; family relationships and the allocation and division of farm assets, were treated with respect. One of the aims of the research was to identify relevant non-climatic exposure-sensitivities, and financial issues were often mentioned. Specific details regarding monthly income required, mortgages and debt servicing were often volunteered; suggesting participants were comfortable with the stated goals of the project, the information sought, and me as the researcher. Questions regarding the impacts of flood or drought and income, were tactfully presented only after a degree of rapport had been built up with the respondent (Fowler 2002; Dunn 2005).

Central to the research was the identification of relevant exposure-sensitivities by actors themselves, rather than *a priori* assumption. On the subject of climate change, I remained neutral and gave my opinion regarding the scientific basis for it, only when asked. This was to ensure the validity of the results, and not bias the interview and as noted earlier, to ensure as wide a range of participation as possible. Interviewees' own questions regarding the legitimacy of climate change science and climate scenarios were not challenged directly. If asked, I provided further assessment of the validity of climate change science. I often remarked on the inherent sensitivity of agriculture to climatic variation and extremes and therefore pragmatically suggested that enhancing the current adaptive capacity of farming and reducing vulnerability to existing variation now, was beneficial, regardless of the drivers, degree, or direction of anticipated climate change.

4.5.5 Women in agriculture

All but one of the interviews was conducted exclusively with men. There was little opportunity to interview women as part of this research. The role of women in owning and working on farms has greatly increased over the years and one of the shortcomings of the sampling method is that it did not account for this. The most recent data (1991) shows that 25% of the full-time workers in agriculture are women (cf. Smith & Montgomery 2004). This is only 1% up on the 1981 total, but contrasts dramatically with only 8% in the 1960s. Of the current 25%, 51% are business owners (farmers) and 35% wage or salary earners (the remainder describe themselves as 'relatives assisting' on the farm. The inclusion of part-time workers boosts the total percentage of women in agricultural employment to 33% (Rivers et al. 1997).

Research in the field of natural hazards and an emerging body of work in the climate change literature has shown that women's experiences of risks and hazards, their perceptions, and vulnerability is often negotiated along gendered lines (Cutter & Finch 2008). There has been some work on women's roles in the farming sector in New Zealand (Teather 1996; Teather 1998; Wilson 1994; Rivers et al. 1997) and internationally, there is literature in the field of sustainable livelihoods on women's contributions in agriculture (Liepins 1995; Trauger 2004; Ransom & Bain 2011). In addition to sampling method, the fact that men were interviewed may reflect both the division of labour on farms in the area and levels of pluriactivity. Most of the farms visited were 'family farms' and even if the farm was run as a joint-company, day-to-day farm operations were a 'male occupation'. A number of interviewees indicated that the wife or partner held outside employment, or was involved with other responsibilities. This is supported by Smith and Montgomery (2004) who suggest more and more women on farms in New Zealand also engage in off-farm work, to support the household. Pluriactivity is discussed in more detail in Chapter 6, on adaptive strategies.

There is work being done elsewhere on exploring women's vulnerability to climate change (Nelson et al. 2002; Shrestha et al. 2008; Patt et al. 2009; Terry 2009), and this has particular relevance in more traditional agrarian societies where women are employed directly, or as providing for their families, in agriculture and are thus exposed differentially to climatic events, pesticide use and remain often excluded from exchanges and commodification of agricultural goods and services (Trauger et al. 2009; Lyon et al. 2010; Ransom & Bain 2011; Rao 2011). An important avenue for future research may be to address the different perceptions, and experiences of climatic variability at a household level, between men and women in New Zealand. It was

clear, from comments made during the course of the research, that women's experiences of the 2004 flood event, for example, may have been more stressful in different ways than those of their partners.

4.6 Data analysis

Interviews were transcribed verbatim by the researcher. Transcription was an important first step in the analysis, providing an opportunity to re-acquaint myself with the data. Placing "distance" between the experience of fieldwork and write-up brought new perspectives and fresh insight to bear on the study. Interview data was coded and analysed based on widely used methods outlined in Corbin and Strauss (2008).

Findings from multiple interviews were analysed using the principles of latent content analysis (Dunn 2005). Interview data was scanned to identify common or recurring themes or processes related to the central components of vulnerability, exposure-sensitivity and adaptive capacity. Identification of themes and connections in interview transcripts was facilitated by the underlying structure to the questions asked (Kitchin & Tate 2000). Data were coded and analysed based on these themes using Nvivo 9. The conceptual framework and reading of the literature and previous case studies on vulnerability provided guidance to this process and assisted organization of data.

Transcription and repeated readings of transcripts ensured a high-degree of familiarity with the data. Text was highlighted first using markers, and notes made in order to develop themes of exposure-sensitivity and adaptive capacity. Exposure-sensitivities were then classified as climatic

or non-climatic, and organized according to relevant variables (e.g. *Climatic*: precipitation, temperature, variability, etc.). Factors that increased production or yield, boosted productivity, or reduced the sensitivity of the farm system to a range of exposures are identified as opportunities; and those factors which reduced productivity, or increased the overall vulnerability of the farm (for example by reduced adaptive capacity to respond to financial crisis) – as risks.

To develop an understanding of an agricultural system's adaptive capacity it is helpful to identify the types and forms of adaptation that are possible, who implements these actions, and under what conditions (Wandel & Smit 2000; Smit & Skinner 2002; Meinke et al. 2006; Reid et al. 2007). Farmers have different levels of control or influence over particular adaptations, with some available for implementation at the decision of a single operator, others being shaped by multiple stakeholders in farming, government and elsewhere. Adaptations can also be distinguished based on their timing, whether adaptations are taken in anticipation of a potential risk, during the realization of the risk or in reaction to it (Wandel & Smit 2000).

Transcripts were analysed and adaptive strategies were identified and classified. Adaptations were classified according to timing (Wandel & Smit 2000), duration (Risbey et al. 1999), and level of farmer control (Smit & Skinner 2002). Adaptations were further classified according to the source or nature of the exposure to which they were a response (climatic or non-climatic) with illustrative quotations retained to characterize the described exposure, adaptive response or risk management strategy.

4.7 Conclusion

This research adopted a mixed methods approach to address the original research objectives. Consistent with techniques used widely in vulnerability assessment, rural appraisal, and community risk assessment (van Aalst et al. 2008) the research utilized secondary sources, and semi-structured interviews, and temporal analogues, to assess farm-level vulnerability. The research included a period of extended fieldwork in the regional community of Whakatane, New Zealand. An opportunity to reflect on the research, gain teaching experience, and consider the results of the data collection between data collection and final write-up, brought new perspectives to bear. Transcription and repeated readings of data sources, interview notes and reading of secondary sources all represented additional influences on the process of coding that increased its complexity but ultimately produced a holistic and grounded analysis (Kitchin & Tate 2000; Cope 2005).

The theoretical and conceptual framework established in Chapter 2 and the discussion of the research area in Chapter 3 guided the adoption and use of the case study methodology. Fieldwork focussed on documenting current and historical exposure-sensitivities and adaptive responses to these risks as well as exploring vulnerability to future climate change and the resilience of farming systems. The findings generated through use of this methodology constitute the remainder of the thesis.

The research builds upon existing vulnerability scholarship, by providing an additional case study that can be used to track changes in vulnerability. It provides a baseline for further work on addressing resilience in human-use and agricultural systems in New Zealand (Kenny 2011), and provides a template for additional place-based agricultural case-studies. It contributes to the existing literature on impacts of climate change in New Zealand (Stroombergen et al. 2006; Wratt et al. 2006; Tait et al. 2008), and fills a conceptual, methodological and spatial gap in the literature with respect to climate change and agriculture in New Zealand by providing the first contextual vulnerability analysis incorporating an assessment of dynamic vulnerability within the context of multiple stressors.

CHAPTER FIVE: Farm-level exposure to multiple stressors

5.1 Introduction

When you think about it, risk covers all aspects of farming really doesn't it? There are risks involved in every single thing right down to grass species that we plant, cows that we milk – everything.

- Dairy farmer, Rangitaiki Plains, New Zealand

Farmers work in a multi-dimensional risk management environment, one shaped and influenced not only by climatic conditions, but payout and commodity prices, legislative changes, interest rates, and changing market access (Hardaker et al. 2004; Bradshaw 2007; Kay et al. 2007).

Furthermore, as the dairy farmer cited above notes, risk is inherent in farming, and covers nearly all aspects of agricultural production to varying degrees. While climate *is* important, one of the aims of this research was to situate exposure-sensitivity to climatic concerns within the broader context of other, multiple exposures and examine the interactive effect of those stimuli.

By empirically applying the conceptual and analytical framework developed in Chapter 2, the research sought to document and analyze relevant climatic and non-climatic stressors based on the experience of producer-stakeholders in Whakatane District. It was argued that through the development of a temporal analogue (Glantz 1988; Tol et al. 1998; Wreford & Adger 2010), the examination of current exposure-sensitivity and adaptive capacity can provide insights into future vulnerability (Meinke et al. 2009). The ways in which producers are vulnerable to future climate-related exposures are likely to be facilitated and constrained by similar, if not the same, factors as they are now (Glantz 1996; Adger 2003; Næss et al. 2005; Prno et al. 2011; Malone & Engle 2011).

This chapter identifies and examines those conditions to which farmers and growers in the eastern Bay of Plenty are exposed-sensitive. Chapter 6 identifies the range of tactical, short-term, and strategic, long-term adaptive strategies employed by farmers to manage risks and Chapter 7, future farm-level vulnerability to climate change based on the results of the empirical work and scenarios and trends of conditions likely to influence exposure-sensitivity and adaptive capacity (Figure 5.1).

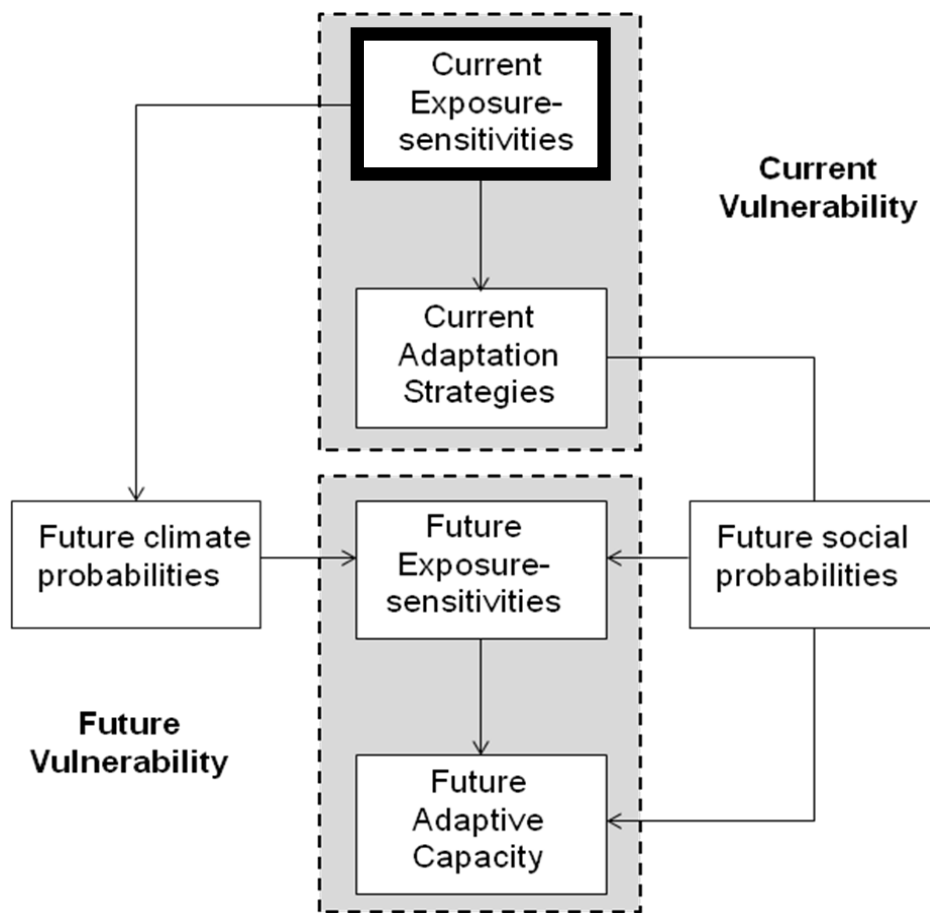


Figure 5.1 Chapter 5 (highlighted) within the analytical framework used to structure the thesis and empirical assessment of vulnerability in the eastern Bay of Plenty

The following discussion presents the results of the empirical work as it relates to farm-level vulnerability. Researchers have identified a number of risks relevant to agricultural production including climatic risks, technological risks, market risks, production risks, risk of personal injury and financial risk (Harwood et al. 1999; Hardaker et al. 2004; Kay et al. 2007). This chapter argues that producers in the study area are most sensitive to climatic conditions that affect production and yield, and in turn, farm income or orchard gate returns. The climatic conditions to which producers are sensitive vary from farm-to-farm, and between the types of commodity produced. It is also argued that producers are sensitive to a much broader range of climatic variables than average temperature and precipitation (the most widely modeled climatic conditions in typical scenario-based studies), but also climatic variability and extremes. The non-climatic stimuli to which producers are exposed-sensitive, such as rising input costs and poor returns, influence vulnerability independently, but can also increase sensitivity to climatic stimuli. Stressors function synergistically to influence producers' overall vulnerability. The chapter also demonstrates the influence of the characteristics and capacities of individual farm types, as a means of understanding some of this variation. It begins with an overview of relevant sources of exposure-sensitivity, then discusses the drivers and varied forms they take and the ways in which they influence production and other aspects of farming in the study area.

5.2 Farm-level exposure-sensitivity

The conceptual framework introduced in Chapter 2 (see also *Figure 2.3*), describes exposure-sensitivity as susceptibility to an external stressor. It defines the degree to which a farm experiences stress, indicative of both the nature of the unit of exposure (i.e., characteristics of the farm and farmer, such as location, type, and awareness, represented in the model by land, labour and capital) and the nature of the stress. It reflects the interaction of the characteristics of the system and the range of climatic and non-climatic conditions to which the system is sensitive. Elsewhere these have been referred to as external stimuli, stressors or hazards (Smit & Wandel 2006; Rasmussen et al. 2010; Hufschmidt 2011). Exposure-sensitivity has its origins, in broad terms, in climatic, biophysical, institutional and socio-economic conditions operating at a range of temporal and spatial scales. Elements of exposure sensitivity interact, such that the effect of a single stressor is rarely felt in isolation. This has been demonstrated empirically in work from regional and community-level vulnerability analysis. Westerhoff and Smit (2008), working in Ghana for example, have shown food insecurity to be a function not only of climatic conditions, but also environmental degradation, charcoal production and the overexploitation of fish and forest resources. Pearce et al. (2010) in a study in Canada's northern region, similarly show how increased travel risk, changes in travel routes and quality and availability of wildlife interact to influence community-level exposure-sensitivity.

While the literature on farm management and agricultural systems has long appreciated that farmers must manage exposure to multiple risks (Hardaker et al. 2004; Kay et al. 2007), climatic and non-climatic stressors are rarely examined together, and even more infrequent are empirical studies in light of potential climatic variability and change (Roncoli 2006; Meinke et al. 2009; Wreford & Adger 2010). This chapter provides empirical evidence from the study area of multiple-stressors and the dynamic nature of farm-level exposure-sensitivity in order to better understand current and future vulnerability.

Figure 5.2 (overleaf) presents the range of stressors to which producers are exposed sensitive. It shows the exposure-sensitivity component of the conceptual framework for examining farm-level vulnerability presented in Chapter 2. The model is not an attempt to show all possible components of exposure-sensitivity, rather only those pertinent to the discussion which follows, as identified by producers in the study area. Individual farms are exposed to a range of climatic and non-climatic stimuli. These stimuli originate with climatic conditions, including interannual variability; biophysical, institutional and socio-economic forces operating at a range of temporal and spatial scales. Climatic stimuli, for example, are driven by global processes of atmospheric circulation, over multiple decades. These in turn are influenced by regional topography and ultimately experienced at the farm level as micro-scale climatic conditions and weather, over much smaller spatial scales, including farm or orchard, and shorter time periods. Selected farm-level stimuli and related drivers are shown in *Table 5.1*. Stressors are shown in the model as rarely being felt or experienced in isolation. Exposure-sensitivity is a function of the interaction between stimuli creating multiple exposures.

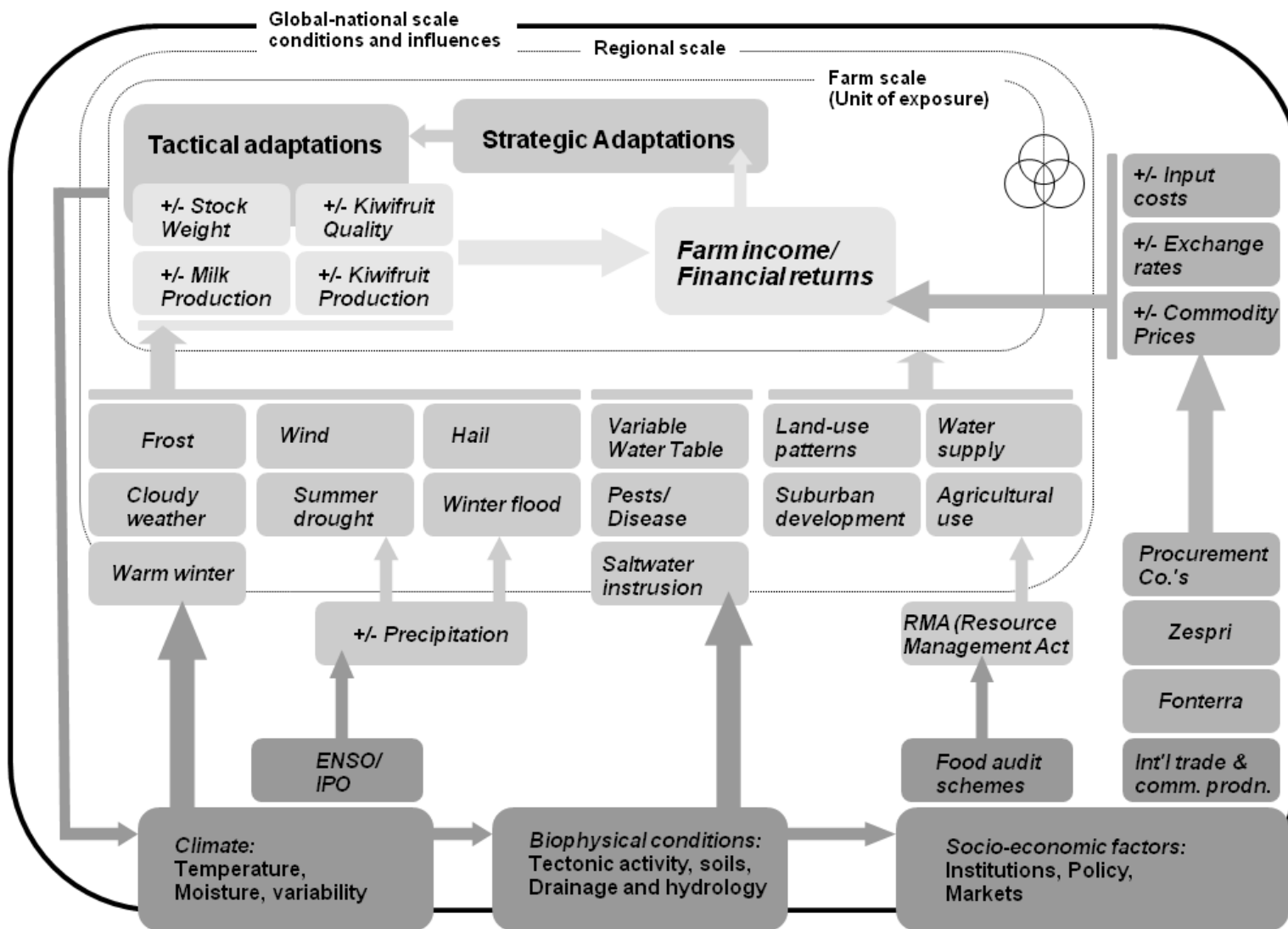


Figure 5.2 Interactive effects of multiple climatic and non-climatic stressors influencing farm-level vulnerability

Producers are exposed-sensitive at the farm-level in varying degrees. The capacity of individual farmers, their awareness, financial resources, and those characteristics of the farm or orchard, such as soil type and location, influence exposure-sensitivity at the farm level (Reid et al. 2007; Wall et al. 2007; Tarleton & Ramsay 2008). Feedback mechanisms and stressors are not static, but dynamic and change with time. The greatest effects of exposure are on production and yield, which in turn are linked to farm income and returns. Farm income is also shown as being a function of commodity price, input costs, and currency valuation.

Drivers of exposure-sensitivity	Macro level conditions	Micro (farm-level) stimuli
Climate	ENSO/IPO	Δ Precipitation, frost, wind, hail
Biophysical conditions	Drainage and hydrology, regional soil types	Saltwater intrusion, disease, pests, variable water table
Market and financial	Marketing networks, currency exchange rates, commodity prices, food audit requirements	Δ Input costs, payout, orchard gate returns, compliance costs
Other socio-economic conditions	Government legislation	RMA and consents, ‘rural change’

Table 5.1 Conditions influencing farm-level exposure-sensitivity and selected examples (Source: Research findings)

Climatic and biophysical conditions were cited most frequently by producers as having the greatest influence on operations. While temperature and precipitation were significant, it was climatic extremes – floods and droughts – which were identified as being most problematic for pastoral farmers. Other weather-related phenomena to which producers are vulnerable include climatic variability, and for horticultural producers, wind, hail and frost events. Pests, disease and weeds were also identified as risks. Biophysical conditions such as water availability and soil type can influence the sensitivity of the farm or orchard to climatic conditions. Market and financial stimuli including exchange rates, commodity prices,

changing input costs and overseas markets also influence the overall vulnerability of the farm operation; and often operate in conjunction with climatic events to affect farm income. Other sources of exposure identified by producer-stakeholders included government policy and regulations, and social change in rural Eastern Bay of Plenty, driven in part by shifting demographics and market forces.

The graphic representation of the exposure-sensitivity component of vulnerability is presented to help guide the following discussion. The model is an attempt to identify the key variables operating in this particular location; to codify the broad range of climatic and non-climatic stressors to which producers are exposed sensitive. The diagrammatic representation of factors, while showing some of the interactions between key variables, is not meant as an exhaustive, fixed representation of how they operate collectively, nor is it meant as a predictive tool. It does however demonstrate the complexity that often fails to be captured by linear, scenario-based assessments. The analysis of conditions/stressors at the farm level to which producers are exposed-sensitive begins with climatic conditions.

5.3 Climatic conditions

A good year is when everything goes right. A bad year, there's only got to be one factor not right, if it's severe enough, and normally, your single biggest influence is weather. No doubt about. If you can get a perfect year weather wise, everything else can go off, and you'll still be alright.

- Dairy farmer, Rangaitaki Plains, Eastern Bay of Plenty

Agriculture is inherently dependent on weather and climate (Salinger 2005; Howden et al. 2007) as well as localized biophysical conditions such as soil moisture capacity and fertility (Kandlikar & Risbey 2000; Tittonell et al. 2005; Kay et al. 2007) which affect production. Without prompting, growers and farmers most frequently identified climatic conditions (which were usually referred to as 'weather') as being the greatest source of exposure for operations in the Eastern Bay of Plenty. "Weather. We pretty much rely on the weather", said one dairy farmer. Regardless of farm type, size, location, or commodity produced, climatic conditions were seen as being integral to the long- and short-term success of their business. The main climatic exposures identified by producers were: combinations of temperature and precipitation; and current climatic variability and extremes, including drought and flood. For horticultural producers, hail, frost and high winds were also problematic. Examples of climate-related stimuli and farm-level impacts are shown in *Table 5.2* (overleaf).

Climate-related stimulus	Farm-level impacts	
	Dairy and drystock	Kiwifruit
Good weather (warm, timely precipitation)	Improved pasture growth and production	Improves yield
Excessive precipitation	Pugging	Wet feet, affects vine roots
Drought conditions	Pasture growth slowed, halted	
Cold, wet spring	Animal reproduction Delayed grass growth in spring	
Insufficient heat during growing season (GDDs)		Poorly developed fruit
High summer temperatures	Adverse effects on animal health (diet, reproduction, heat stress)	Contributes to taste/size/sweetness profile
Cloudy weather		Slows fruit development/growth
Flood conditions	Animal reproduction and mortality Halts/slow production Damage to farm infrastructure	Standing water can rot vine roots
Frost	Pasture slow to start growing in spring Knocks back unwanted C4 grasses Lambing mortality	Affects bud growth
Hail		Damages fruit and vine
Strong winds		Marks/scuffs fruit

Table 5.2 Climatic conditions and related effects on producers in the eastern Bay of Plenty
(Source: Research findings)

5.3.1 Temperature and Precipitation

The most frequently referred to climatic conditions were combinations of temperature and precipitation, both of which have their most significant effects on yield (*Table 5.3*). Of the pastoral farmers surveyed, 80% identified one, the other, or both of these as a source of risk and/or opportunity. For dairy and drystock farmers reliant on grass growth, warm temperatures with adequate precipitation are critical. In response to the question “What makes a good season?” typical responses from pastoral (drystock and dairy) farmers were: “Lots of rain and sunshine. It’s the climate that grows grass”, “A good season would be regular rain”. For these producers reliant on pasture, sufficient rainfall and warm temperatures are the basis of production, whether milk or meat (Verkerk 2003; Morris 2009).

Farms are able to capitalize on the opportunity in different ways. Drystock farms, given their size, typically rely exclusively on the grass that is able to be grown on the farm. While some dairy farms have moved away from all-grass system in an effort to boost production (Basset-Mens et al. 2009) or have invested in irrigation to overcome the limitations of weather and soil (Barkle et al. 2000), the grass that can be grown on the farm, at a relatively low cost, remains the cheapest source of feed, and has long been recognized as an advantage to New Zealand producers (Clark et al. 2007). One farmer summed it up as “My philosophy is every blade of grass that I’ve got on the farm goes into the vat to a certain extent”. Farms that are reliant on grass growth, must still match demand with available pasture cover, one of the risks of an all-grass system (Verkerk 2003; Clark et al. 2007; Morris 2009).

Type of condition	Initial effects	Positive (+) or negative (-)
Warm weather, timely precipitation	Yield	+
Excessive precipitation	Yield	-
Drought conditions	Yield	-
Cold, wet spring	Yield	-
Insufficient heat during growing season (GDDs)	Yield	-
High summer temperatures	Yield	+/-
Wet autumn	Yield	-
Cloudy weather	Yield	-
Climatic variability (seasonal, interannual, interdecadal)	Yield	+/-
Flood conditions	Yield	-
Frost	Yield	-
Hail	Yield	-
Strong winds	Yield	-

Table 5.3 Effects of climatic conditions on eastern Bay of Plenty farms and orchards (Source: Research findings)

Producers in all sectors identified a greater sensitivity to changes in precipitation, than to changes in temperature. A decrease or increase in precipitation is associated with a range of exposures including drought, poor grass growth, limited productivity, and certain pests; while excess precipitation can create problems with landslips on steeper terrain, floods, increase in disease and pests, and pugging (trampling by animals of the waterlogged pasture) all of which have an adverse effect on production. Timing of precipitation was also described as important as amount and availability. Heavy rains can reduce soil fertility (Troeh & Thompson 2005) and contribute to flooding at any time of the year; cold temperatures at the wrong time can affect mating, which results in lower milk production the following year (Pennington et al. 1985) as cows are less likely to come into calf. Rain during calving time can also result in mastitis, requiring the farmer to cull sick animals (Washburn et al. 2002). Pugging damage by cows in wet winters is an important limitation for dairying. As noted in Chapter 3, much of the Rangitaiki Plains is reclaimed swampland and during heavy winter rains the loam soils can quickly become waterlogged. Grazing trials conducted in Victoria, Australia, for example, showed medium–heavy pugging in winter reduced pasture yield in the following spring by 40–42% and pasture utilisation by 34–40% (Nie et al. 2001); while a New Zealand study showed that a single cattle treading event on winter-wet soils reduced daily pasture growth rates in spring from 18 kg of dry-matter (DM) per hectare to 11 kg DM/ha (Pande et al. 2000).

Extremes of cold and heat represent both a risk and opportunity for producers, depending on the type of commodity produced. Where invasive, temperate C4 grasses such as *paspalum* and *kikuyu* were problematic, cold winter temperatures were beneficial, slowing or halting their spread as certain *paspalum* species are killed by winter frosts (Rumball 1991; Radhakrishnan et al. 2006; Crush & Rowarth 2007). Where these grasses were less problematic, cold temperatures can be a negative influence, delaying spring growth. As one producer stated: “The cold just restricts your grass growth, winter obviously – if you get a cold winter, then it really knocks the grass back, frost after frost after frost. And you just have to wait for the warmer weather to get going again”.

Cold temperatures were also described as beneficial by kiwifruit growers. Cold winter temperatures and a minimum number of chilling hours are required to set the fruit and produce adequate bud burst in the spring (Sale & Lyford 1990; Ferguson & Seal 2008), improving yields. High summer temperatures were cited as having negative effects on animal health, including cow stress, heat stress, diet, reproduction and sunburn. High temperatures have also been shown to affect milk production in dairy herds (West 2003). For those producers in pastoral systems that have invested in irrigation, high summer temperatures represent an opportunity. Farmers are able to sustain grass growth with the additional moisture and continue milking, while other, non-irrigated farms may be forced to end the season early during periods of high temperatures and low soil-moisture.

For pastoral farmers, temperature and precipitation are among the most important climatic conditions to which they are exposed-sensitive. While pastoral farms are reliant on those conditions which promote grass growth, it is rare for pasture to be wiped out entirely. During drought, farmers are able to purchase supplemental feed or irrigate in order to maintain production. Kiwifruit growers on the other hand, are sensitive to a much broader range of climatic stimuli. This greater sensitivity is closely related to production cycle: unlike dairy and drystock farmers, an orchard's entire production can be wiped out by a single climatic event. A hail storm in 2007 left at least one grower on the Rangitaiki without a crop and a freak hail storm in Opotiki, in May 2009, affected 350 orchards, and 660 canopy hectares, destroying over NZ\$10 million worth of fruit (Irvine 2009). Furthermore, overall financial returns, for producers, are based not only on yield but quality as well. Fruit size, shape, sweetness, and dry matter content, all of which are dependent on climatic conditions during the growing season (Pailly et al. 1990; Pailly et al. 1995; Ferguson & Seal 2008), contribute to overall financial returns. As one grower said:

A bad year is still climate dependent; even a bad year you're still...you still want to have those hot temperatures if you can, to get that dry matter – because that's what the customer wants is a sweet tasting fruit. They don't want sour tasting, and that sweetness only comes with drier, warmer temperatures.

Cloudy days, high humidity, too much/too little rain, frosts, hail and wind also affect horticultural production (Sale & Lyford 1990; Woodward 2007) and thus orchard income. For growers located on the Rangitaiki Plains a combination of winter rains and cold temperatures are the most problematic. Heavy winter rain results in lower soil temperatures, and delayed warming in the spring; cool temperatures inhibit pollination, and because the amount of pollen determines

the size of the fruit (Gonzalez et al. 1998), growers end up with lots of small fruit, for which there is little financial return after expenses.

5.3.2 Flood and drought

In addition to combinations of temperature and precipitation, producers also described floods and droughts (extremes of both temperature and precipitation) as being serious climate-related exposures to which they were sensitive. There is history of damaging floods in the area, dating from the time of the first permanent human settlement in region (refer to *Table 3.5*). Drought conditions, as discussed in Chapter 3, are typically related to ENSO/IPO (Rolland 2002; Griffiths et al. 2003; Fowler & Adams 2004; Ummenhofer & England 2007). Exposure-sensitivity to both these risks varies, and is closely correlated to location and soil type. Dairy farms are most affected by floods, as they tend to be located on flatter country, while drought impacts both types of pastoral farm.

The most severe impacts of flooding are due to production losses, impacts on animal health, and physical damage to farm infrastructure. Other farmers mentioned the emotional and psychological toll a destructive flood event could take, not only on individuals but the community at large, as well as the financial losses associated with decreased production and rebuilding farm capacity. Floods in the eastern valleys are typically more destructive: the rivers originate in areas of higher relief, and carry large amounts of suspended sediment (refer to *Figure 3.2*). Floodwaters on the Waimana River rise rapidly and conditions in the upper catchments – where there has been widespread commercial forestry – result in higher suspended sediment loads as well as woody debris which can damage farm infrastructure. Recovery can

also be delayed, as flood deposits choke grass growth. One farmer described a metre of sediment being deposited on the pasture, which took six months to dry out, resulting in significant production losses. When the Rangitaiki River floods it inundates the adjacent Plains. Floods are higher volume, but largely sediment-free owing to the dam upstream. Pasture usually remains unaffected, once the water has been drained. Flood waters do last longer – often a week or more – ponding behind stop banks, and in the absence of natural drainage, must be pumped off.

Floods have their most significant impact on production. The most severe floods in the area in recent years (1998, 2004 and 2010) have occurred during calving and resulted in dramatic losses for some farmers. According to the Insurance Council of New Zealand, between 2004 and 2010, floods in the Eastern Bay of Plenty cost over \$30 million (ICNZ 2011). One farmer, at Ruatoki on the Whaktane River, experienced two floods during the 2004 season, losing 35% of production (65,000 kg of milk solids), in addition to losing fences, pasture and raceways.

Describing his own losses, another farmer stated:

The 2004 flood affected us dramatically, really, I was doing – we were averaging 75,000 kilos of solids over the last three years, and the flood year we did fifty I think. It was a huge drop and we were back to sixty-six last year, and if I can get back to seventy... which we thought we were going to do this year, but the dry hit us.

Production losses can be further compounded by rising input costs as feed supply is affected. The carry on effects, in terms of re-grassing pastures, replacing damaged fences and races take an additional financial toll and the effects of a damaging flood often extend beyond a single season. Cows that have been stressed or gone through periods of reduced feed consumption may be less likely to come into calf the following season (Pennington et al. 1985); farms can lose animals

and need to replace stock; pastures need to re-seeded, and nutrient levels and soil fertility restored. In some cases, fences, cow sheds and raceways must also be rebuilt.

While flood events are one extreme, they do not affect all farms in the area. They are typically localized, and many farms are located away from the floodplain or are on well-drained soils. Farmers were unanimous however, that worse than a flood, was a drought. One farmer stated: “I’d rather have a flood than a drought. And I don’t want an earthquake. That’s a disaster. We’ve experienced them all”. For horticultural producers, a decrease in precipitation and higher summer temperatures were not as serious. Some growers mentioned a decrease in the size of the fruit, but that was offset by greater sweetness resulting from the higher summer temperatures. Moreover, many horticulturalists had overhead frost protection, which is used in the winter to cover the kiwifruit buds in a protective layer of ice. In the summer, frost protection doubles as irrigation, and so growers were better adapted to the summer dry. For pastoral farmers, drought conditions slow or halt grass growth; producers are also vulnerable to much higher input costs as competition for supplemental feed becomes more intense and the carry on effect of a prolonged dry spell can be much longer, further delaying recovery. “The one thing about a flood,” said a dairy farmer, “is that it can be up to there today and gone tomorrow, but a drought might last for two months. And you’re going to recover from the flood, generally the recovery is not too bad, from the average flood, but a drought can take a bit longer.”

Over half of the pastoral farmers surveyed, described drought as a serious exposure for production on their farms. This was most prevalent for non-irrigated farms, and farms on well-drained pumice and ash-derived soils, such as those in Galatea. Farmers had all experienced dry conditions before, though the dry periods characteristic of the 2007/2008 and 2008/2009 seasons, for many, were described as “exceptional”, “not normal” and “unusual” in its severity and duration.

Normally it starts getting dry after Christmas and you might have three months of fairly hot and dry, but then it will rain in April, and as long as all your lambs are gone, it doesn't really matter, you get by, because you're not – your numbers of priority stock are low, so yeah, we think we've got the thing set up to cope with that scenario fairly well, but when you double that dry period – never had that before, it was exceptional, the drought covered the whole country.

The same farmer noted that in ‘normal’ drought conditions, it might be regional and so farmers are able to send out for grazing elsewhere, as part of a typical adaptive strategy. However, when the drought covers the whole country and no one has any grass, the ‘usual’ response is severely constrained.

For dairy farmers, the most significant impact of drought was on milk production. Farmers described being unable either to source supplementary feed or afford the higher cost, and so simply dried animals off, incurring significant losses. In one reported instance, drying off five weeks early was a difference of over one-hundred thousand dollars. Another dairy farmer affected by the 2008 drought said “on a normal hard year to normal good year, might be more like 60,000 kilos down from 70,000 kilos. But last year we had fifty-two. So that was pretty extreme”. Drought also has effects on animal health. During exceptionally hot temperatures,

cows simply stop eating, which can result in weight loss, and lead to problems the following season with fertility (West 2003).

The sensitivity of producers to dry – or wet – conditions is also a function of soil type. Farms located on pumice or ash; dry out very quickly – in some cases less than a week. Peaty soils, which are more prevalent on the Rangitaiki Plains, can hold on to moisture for longer, providing a buffer for protracted grass growth (Pullar 1985; Rijske & Guinto 2010). A number of producers commented on an apparent trend towards more frequent and severe dry spells, and expressed concern with being able to handle severe droughts. Producers also noted that a drought was a source of exposure that was felt not only as a climatic or financial risk. As one farmer said, “It’s a lot of stress, walking the farm, wondering if another blade of grass is ever going to grow again.”

5.3.3 Climatic variability and extremes

Seasonal to interannual climate fluctuations strongly affect the success of agriculture. Wratt and Matthews (1992) estimated year-to-year climatic variability is responsible for about NZ\$600m in losses in New Zealand’s agricultural production. Using a structured VAR business cycle model, Buckle et al. (2007) have shown there is a demonstrated statistical relationship between soil moisture and GDP and exports in New Zealand. The dynamic reactions shown by the authors clearly imply that adverse climatic conditions will generate a recession. A rise in the number of days of soil moisture deficit results in an immediate and significant fall in domestic output which is sustained for nearly two years (Buckle et al. 2007, p.1007). Long-term climate change is likely to alter agricultural productivity in the eastern Bay of Plenty. In addition to climatic variability,

unseasonal frost, hail and wind events are problematic for kiwifruit growers. Studies have drawn on local observations and experience of climatic conditions, particularly extremes, in order to derive insights into the effects of existing (and future) climatic variability on a system of interest (Tarleton & Ramsay 2008; Bunce et al. 2009; Wandel et al. 2009; Wreford & Adger 2010).

When queried, producers in the study area did describe observed changes in weather in the short term (< 10 years) as a source of risk. This short-term climatic variation is most likely linked to the ENSO/IPO which has a significant influence on inter-decadal climate in the area (Griffiths et al. 2003). As one orchardist noted:

Oh yeah, absolutely, I'm sure we're in a different cycle to what we were eight to ten years ago, we're longer, or more variable type springs, and up until Christmas until just after, we're quite variable, and then it evens out, right through until the end of May.

Climatic variability, independent of climate change then, represents another source of risk and/or opportunity for producer-stakeholders. Decisions regarding calving dates, planting, harvesting, spraying, and other management decisions are often based on experience with a long-term mean. Producers described the challenge of a “lack of predictability” or “increased variability” in weather patterns, which made planning more difficult and making strategic forecasting more difficult, and which may ultimately require adjustments in the timing of management decisions. This is not always a negative however. One dairy farmer mentioned the possibility of moving to a split-calving, to take advantage of a more variable climate, and other producers noted being able to diversify production, by planting earlier crops or shifting from dairy to horticulture, or adjusting the timing of operations.

In addition to current climate variability, horticultural producers are exposed-sensitive to frost, wind and hail events that affect production. Unseasonal frosts affect kiwifruit yield, while wind and hail affect yield but can also affect fruit quality, lowering financial returns. Fruit and vines are particularly vulnerable to frosts in the spring – when shoots and flower buds are exposed – and the fall, just prior to harvesting. A late frost affects the vines in the spring, when shoots and flower buds are exposed; and early frosts in the autumn, near harvesting (Ferguson 1991; Woodward 2007; Ferguson & Seal 2008). Both have a significant effect on yield and can in many cases, wipe out an entire year’s production and growing costs (Sale & Lyford 1990; Ferguson & Seal 2008). “There aren’t many industries”, as one grower noted, “where your whole year is riding on a single event.” One grower who described his orchard as being ‘touched’ by a late frost said: “Oh that year I lost, instead of getting say twenty-thousand trays, I only got one-thousand trays. Everything was gone.” Frost related losses in the Bay of Plenty vary from year-to-year. Hail is also a significant climatic exposure for growers. Hail events, though infrequent, cause significant damage to vines, shredding leaves and marking fruit, and as with frost, require significant investment to return the orchard to full production. As one grower notes:

Frost is potentially the most catastrophic, you can lose your whole crop, everything; whereas hail you lose percentages. The other thing with frost is you’ve still got a lot of work to do to get your vines back into shape for the following year, so don’t save any money by losing your crop, you can’t save any money by saying “Oh we’ll just leave it until next year”, you’ve got to work on your orchard just as hard. So your frost and hail the worst.

A hailstorm in Opotiki in May 2009, affected 350 orchards covering 660 hectares of vines (Irvine 2009). About 2.2 million trays of Green Kiwifruit and 150,000 trays of Gold Kiwifruit were lost (Campbell 2009). High winds – most common at the equinox, through October and November – are also a risk for kiwifruit growers. Winds can cause vines to ‘whip’ one another, and if sufficiently strong can pull vines from the supporting structures. If there is fruit on the vine, wind causes them to rub together producing ‘proximity marks’ where two fruit knock together (McAneney & Judd 1987). These are particularly problematic for growers. Fruit may appear unblemished but under inspection at the packhouse, will be disposed of. Thus producers have borne the cost of production, and harvesting, but end up with no financial return.

5.4 Biophysical constraints and conditions

In addition to direct risks, climatic conditions also represent an indirect source of risk for farmers and growers. Climatic conditions in the study area have been favourable for the spread of tropical non-native grasses, and severe livestock diseases such as facial eczema. Two biotic pests – scale and leafroller – affect only horticultural production, and are currently managed effectively with oils and chemical sprays. Producers did express concern that if the use of pesticides is controlled, that this would present a greater challenge to production. Other biophysical and environmental conditions are risks and opportunities related to the farms’ location including soil type, and a variable water table and tectonic activity, as shown overleaf in *Table 5.4*.

Type of condition	Initial effects	Positive (+) or negative (-)
Livestock disease	Livestock, Income	-
Pest infestation	Yield	-
Invasive grass species	Yield	-
Variable water table	Yield	-
Salt-water intrusion	Yield	-
Tectonic/volcanic activity	Infrastructure, Yield	-

Table 5.4 Effects of biophysical conditions on eastern Bay of Plenty producers
(Source: Research findings)

5.4.1 Pests, weeds, disease

For pastoral farmers, the greatest exposure is from an increase in the incidence of biotic pests and invasive species such as such as *paspalum*, *johnsongrass* (*sorghum halepense*) and *kikuyu*. These non-native and non-commercial grass species have low nutritional value (Prestidge & Potter 1990; Crush & Rowarth 2007), reduce overall production and yield (Clark et al. 2001); and result in additional cost for producers trying to effectively manage or eradicate these pests. *Kikuyu*, a tropical grass (Radhakrishnan et al. 2006), is increasingly prevalent in inland eastern Bay of Plenty, where it has spread after being introduced to Northland where it flourished in the dry temperatures (Ballinger 1962; Askew 1965). Several farmers expressed concern that with the trend towards warmer and drier conditions and milder winters in the region, that it would be an ever increasing source of risk to pastoral production in the region.

Facial eczema is also a serious climate-related exposure. The disease, which affects sheep and cattle, occurs during the late summer and autumn, and flourishes under warm, humid conditions, producing severe toxic effects in the liver of the animals. Loss of production and animal mortality are common. The Bay of Plenty is known for its problems with eczema (Davenport 1958; Anderson 1985), and with the intensification of farming, and greater number of stock per hectare potentially more exposed to outbreaks.

5.4.2 Other biophysical constraints and conditions

Other non-climatic, environmental exposures include fluctuations in the water table, salt water intrusion, seismic and tectonic activity. Furthermore, the degree to which producer-stakeholders experience climatic risks is related to the biophysical conditions and constraints of the individual farm. On the Rangitaiki Plains, the variable water table presents the greatest challenge for horticultural producers. Kiwifruit vines do not tolerate what is referred to as “wet feet” - when the roots of plant are immersed in groundwater for several days at a time. Variation in the water table also leaves the plants ‘starving’ for water, when it drops. One grower characterized the problem in the following terms:

The water table here will vary – from ½ metre after a lot of rain, down to about 2.4 meters over the summer (2008). What happens with your water table is your roots kiwifruit roots do not like wet feet. So after 2 or 3 days they start to die off. So you get a high water table, comes right up, knocks all those roots out at that level, and then your water table goes down and you’ve got this gap between your water table and your root system. That’s a problem. If we had a constant water table it we’d be alright, they’d grow just above that water all the time. They’re either drowning or starving.

In response to this limitation, wherever possible, growers have tried to site orchards on relict dunes or well drained soils where the water table exhibits less variation.

Saltwater intrusion also affects producers located on the Rangitaiki Plains, where extensive pumping of the groundwater for irrigation has drawn saltwater in to contaminate some bores. At least two orchards on the Plains have been removed owing to problems with salinization, and one dairy farm abandoned. As more and more farms rely on irrigation for pasture growth, this may become more pervasive, as research from other coastal areas has shown (Narayan et al. 2003). Seismic and tectonic activity is also a risk to agricultural production. Fonterra's Edgecumbe processing plant which was severely damaged in the 1987 earthquake, stopbanks and levees, as well as farm-infrastructure, and operations would all be affected by any further tectonic movement. The earthquake remains one of the most costly, in dollar adjusted terms, events in the area surpassing that of the 2004 and 2010 floods (ICNZ 2011).

Soil type was identified across a range of farming types as being an important factor at the interface between larger, macro-level forces and the scale of the farm, effectively increasing or reducing the sensitivity of producers to climatic risks and production. Throughout the Plains and surrounding area, there is widespread variation in soils (Pullar 1985; Rijkse & Guinto 2010) and many farms have a diversity of soil types. This diversity can be an opportunity. As one producer noted, soils that are drier in the summer can be advantageous during a wet winter.

They're all silt loam really, bit more volcanic here and across the top is sand ridges which are from the sea, years ago, an old sand dune. It's good and bad – burns off a bit if it gets dry, but it means in the winter, we've got about a ¼ of the farm that up on the high; in the winter time people would give you heaps of money to have a bit of dry stuff, that's how it works. No such thing as ideal soil.

The quote above also reflects the fact that the soil moisture ability of the soil to retain moisture is as important a consideration as drainage. The balance between moisture retention and drainage can be problematic in an area where rainfall patterns tend towards periods of heavy, intense rainfall, or drought conditions. Both the heavier and lighter soils, broadly speaking, have their advantages and disadvantages. Those soils with higher moisture holding capacity – loam and peat – retain water during dry spells, and provide adequate pasture growth, if irrigation is not available. Heavier soils however, are also prone to pugging. Lighter soils, while less prone to pugging, dry out quickly during periods of prolonged hotter and drier conditions, and some of the volcanic soils become hot enough to “cook” the grass.

5.4.3 Summary

Climatic and other biophysical constraints were identified by producer-stakeholders as having the greatest influence on production, though this was most often expressed in terms of farm income or orchard-gate returns. Farmers are exposed and sensitive in varying degrees, to changes in mean climatic conditions, but more so to extremes of both temperature and precipitation. For horticultural producers, unseasonal frosts, high winds, and hail pose the greatest weather-related risks. Producers also identified challenges associated with current climatic variability. Indirectly, the short-term trend towards warmer conditions was associated with changes in the incidence of invasive temperate grasses, and higher humidity in autumn and spring, with more frequent outbreaks of facial eczema, affecting sheep and dairy cows. Sensitivity to climatic and biophysical risks is most affected by local conditions on the farm. Farms on lighter soils reported more problems with drought, and pasture growth,

while farms on heavier soils were more prone to flooding and pugging, but commented on their ability to grow grass longer during dry spells.

It is important to note however, that rarely are climatic conditions experienced in isolation from other, non-climatic risks. A farm might be exposed-sensitive to drought, but depending on the severity and extent, downward pressure might be put on commodity prices, at the same time as input costs rise due to growing demand, demonstrating the interactive and synergistic effects of multiple stressors. Furthermore, climatic conditions themselves are influenced and shaped in conjunction with other non-climatic or biophysical stimuli. Producers identified market, financial and other socio-economic risks as having a similar bearing on influencing the difference between a good and bad year. This is the subject of the following section.

5.5 Market and financial forces

Probably the real risks have been those financial ones.

- Dairy farmer, Whakatane, Eastern Bay of Plenty

Farmers and growers also identified a range of market and financial exposures as having significant impacts on farm operations. While climatic conditions affect yield and production and through that, farm income, market forces also have a direct influence on the farm as a set of distinct, non-climatic stimuli. These also operate in conjunction with climatic conditions. As shown later in the chapter, it is this interactive and iterative effect of multiple stressors together that is often overlooked in attempts at modelling the impacts of climate change. Changing market and economic conditions are a constant influence on all farms, but they are not felt equally from one operation to the next. For some producers, market risks were cited as being more significant than climatic exposures, due to high-debt loads or a management system that left them more exposed to rising input costs. For others, climatic conditions and market forces worked in concert, exerting a dynamic influence on operations. The most frequently referred to market-related stimuli were returns on production and rising input costs. Related exposures include marketing risks, access to export markets, increasing competition from lower-cost producers, rising land prices and labour market conditions. The greatest effect of market conditions was on farm income or orchard gate returns as shown in *Table 5.5*.

Type of condition	Initial effects	Positive (+) or negative (-)
Commodity prices (direction of effect depends on direction of prices)	Income	+/-
Changes in input costs (e.g. feed, fertilizer)	Income	+/-
Value of NZ currency (direction of effect depends on whether production is for export; origin of inputs)	Income	+/-
Overseas markets	Income	+/-
Marketing	Income	+/-
Availability of affordable farmland	Income	+/-
Rising land prices	Income when leaving farming	+
Competition from overseas producers	Yield	-

Table 5.5 Effects of market and economic forces on eastern Bay of Plenty producers
(Source: Research findings)

5.5.1 Commodity prices and exchange rates

For producers, the most frequently identified source of risk related to market and economic forces, were financial returns on production. Variable returns were an exposure of great concern to the majority of producers surveyed. All producers are particularly sensitive to price fluctuations because their commodities are sold in a world market where prices are in constant flux; hence their income is variable and uncertain from year to year. The commodities produced by eastern Bay of Plenty farmers are sold in a competitive and increasingly international commodity market, where prices continually fluctuate based on global supply and demand. Prices for agricultural goods have typically depreciated over the long term in inflation-adjusted terms (Verkerk 2003; Morris 2009). Producers are thus “price takers”, and the price they receive is set by the world market, not individual producers. The largest drivers of financial returns for farmers and growers are commodity prices and exchange rates.

Dairy farmers most often cited payout – which includes the price paid to farmer shareholders for milk supplied to Fonterra on a cents per kilogram of milk solids (kgMS) basis, as well as distributable profits and dividends – as making the difference between a good and bad year. As one farmer stated: “Payout. Payout’s always the biggest – that’s a good year or a bad year, and close behind that is climate. The climate, it doesn’t matter what else you do, if you have a bad year financially, it’s hard to do well. Those are the two big things.” Similar comments were made by drystock farmers. When asked what made the difference between a good or bad year, this drystock farmer said: “The market is the biggest influence. You can recover from the weather. But yeah, the biggest – the price of lamb per kilo – well, wool is so pathetic it’s not even worth talking about – but those are the bigger influences than climate, in a normal year.”

Producers are also exposed-sensitive to returns to different degrees, relative one to another, as shown in *Table 5.6* (overleaf). Horticultural producers identified climatic risks as the source of greatest exposure, followed by market forces. “Orchard gate returns” were cited as source of exposure but it was, for the majority of orchardists, second to climate. “Good payout is better, especially on a high-producing year, but you’ve got to remember we’re a primary industry. There are a lot of limiting factors other than the price of a tray of fruit: frost, drought, and we can mitigate some of that, but there are also things that are out of your control like pollination, and the wind”, said one grower. Despite identifying payout as the most significant driver between a good and bad year, dairy farmers are less vulnerable to this market risk than horticultural producers or drystock farmers. Dairy farmers are paid on the year’s production and have relatively high capacity to adapt to low returns or poor climatic conditions through supplemental feed, which maintains production.

Market exposure	Production system	Degree of exposure-sensitivity	Conditions
Payout/returns	Dairy	Low	Payout based on year's production; able to supplement feed to continue milking during adverse climatic conditions
	Drystock	High	Fewer options for supplementing with feed in event of adverse climatic conditions; more exposed to price fluctuations than dairy farmers
	Kiwifruit	High	Growers paid on basis of production/yield, as well as for quality (sweetness, taste, size, dry matter), thus also more exposed to climatic conditions that effect quality

Table 5.6 Differences in exposure-sensitivity to payout/financial returns (Source: Research findings)

The disparity in the relative importance placed on financial returns by dairy farmers and drystock farmers, as opposed to horticulturalists, can largely be explained by differences production over a season and marketing structures. Even in the worst drought, dairy farmers will be able to import feed and continue milking, whereas orchardists are producing a single crop in a growing season. As one dairy farmer – who also owns a kiwifruit block – noted: “Dairying’s a little bit more shorter spans, you get drought, fuck it up for eight-weeks; kiwifruit you get one bad thing and that’s your whole season”. Secondly, dairy farmers are paid for production on the entire year, which provides a steady cash flow and shields producers from short-term fluctuations associated with market forces. Similarly, drystock farmers have some flexibility in the timing of their responses to market forces. They are able to drop stock numbers in order to boost short-term cash flow in response to favourable market conditions, or adverse weather. “Sheep and beef side, your restrictions are basically the dollar and the payout. Whatever the dollar’s sitting at, is what the works are going on. The weather does have an influence, but you can sell unfinished stock early

if you read the markets reasonably well, or the weather, you can bail out”, said this drystock farmer. Horticulturalists, again, are reliant on the production of a single export crop, favourable markets, and ideal weather conditions.

Another factor that may influence the emphasis on payout among dairy farmers is the high levels of debt in the industry, and the percentage of income required to service interest payments. New Zealand dairy farmers are very highly indebted, making them vulnerable to interest rate increases, a drop in land prices, and fluctuations in payout. Over the past 10 years, the debt carried by the average New Zealand dairy farm has increased four-fold (Fox 2011). The average production farmer now owes NZ\$2.8 million, up from NZ\$700,000 in 2000 (DairyNZ 2010). Payout has risen; however, farm working expenses have also increased through inflation and input costs (Rennie 2009; Rutherford 2011).

As will be shown later in the chapter, producers also noted that it was often not *either* the weather *or* payout that made a good year or a bad year, rather that it was the combination of the two. Bad years for example, were described by dairy farmers as ones with low payout and weather conditions that reduced milk production. What saved many dairy farmers during the years covered by this research (2007-2008; 2008-2009), was that while production dropped dramatically due to drought, milk prices were high and exchange rates were favourable. As this farmer stated:

What’s made a good year? The payout. If we’d had a low payout and no cows and no grass, yeah, it’d be a shocker of a year, but it’s just lucky we’ve had a shocker of a year as far as the cows and grass go, extremely good payout year. Imagine if the payout was still down at five dollars! We would have struggled, there’s no doubt. We would have been struggling just to make interest payments.

The influence of the New Zealand dollar, not only as it affected commodity prices, but also imported input costs, was the other significant related exposure for horticulturalists. One grower described two years in which orchard gate returns had been almost negative:

The costs are higher than your income, and that's because of the high dollar. Zespri are saying well we're selling the fruit in Europe and Japan for a higher price than we were the year before, but your returns are way down because the dollar is up to eighty cents you see.

The influence of currency valuations extends to farm inputs, many of which are imported from overseas. It is this rise in input costs that producer-stakeholders described as being the second most significant market and financial force that affected production, and in turn, the sensitivity of the farm system to other exposures.

5.5.2 Input costs

In addition to payout and the influence of the dollar, producers also described the significance of rising input costs on farm operations. Farm inputs can include labour, fertilizer, fuel, stock, seed, and materials. Additional inputs may also be related to the type of farm, the farm-management system, and the scale of the operation. There is tremendous variation as well in the scale of inputs; horticulture, for example, is more labour intensive than dairy farming (Ferguson & Seal 2008). Input costs were cited as an exposure by producers from all three commodity sectors surveyed, though each were affected in different ways, indicative of their sensitivity (*Table 5.7*). For dairy farmers, the degree of exposure was correlated strongly with management (feeding) system, while horticultural and drystock producers were more uniformly exposed to cost increases. Producers also described how input costs interacted dynamically with other market forces. All agricultural input costs increased, for example, as payout to dairy farmers increased.

Market exposure	Production system	Degree of exposure-sensitivity	Conditions
Rising input costs	Dairy – High Input	High	Farmers reliant on supplemental feed or high inputs of fertilizer more exposed-sensitive to cost increases
	Dairy – Low input	Low	Low-input, all grass systems reliant on fewer inputs, but more sensitive to climatic conditions as they effect pasture production
	Drystock	Low	Drystock farms cut back on inputs in response to higher prices
	Kiwifruit	High	Fixed labour, fertilizer, spray and energy inputs regardless of production/yield

Table 5.7 Differences in exposure-sensitivity to input costs (Source: Research findings)

Within the dairy industry, the biggest determinant of sensitivity to rising input costs was feed management system. A distinction is often made between all-grass (pasture-based), low-input systems, and high-input systems, which by definition, source as much 55% of animal feed from outside the farm (Basset-Mens et al. 2009; DairyNZ 2010). Typical imported feeds include maize (Stockdale 1995) and increasingly common is palm kernel expeller (PKE), a by-product from the production of palm oil (Dias et al. 2008). Intensification (MacLeod & Moller 2006), and several drought years has resulted in an increase in the amount of supplemental feed being used by New Zealand dairy farmers (MAF 2010). Between 2004 and 2008, imports of PKE rose from 42,700 tonnes to over 1,000,000 tonnes to the end of 2008 (MAF 2009). With widespread droughts in recent years, prices have risen dramatically. During the 2008-2009 seasons, PKE rose from approximately \$200 a tonne to \$415 a tonne (MAF 2010). The higher input costs, required to keep cows lactating, resulted in significantly lower margins.

Producers utilizing a low-input or all-grass system are not totally sheltered from rising input costs. The dependence on grass growth requires the soils are ‘adequately resourced’ as some farmers put it, through the application of fertilizer, nutrients and moisture through irrigation, to maintain production. Producers are also exposed to any increases in electricity costs. During drought, grass-based farmers also more sensitive to the drier weather conditions and in many cases either dried off early (i.e. stopped milking), or purchased supplemental feed to see them through. If they purchased supplement, then they were just as exposed to the rise in feed costs as others. The immediate significance of rising input costs were described by one dairy farmer in the following terms:

A year ago nitrogen was \$450, now it’s \$1240 a tonne – it’s a huge increase in cost. Your diesel cost, well there’s another thing, that’s another big cost increase too. Electricity, when we first put irrigation in five years ago, it was costing me around \$1500 a month if we were running, last year on average I was paying between \$2700 and \$3200 a month to run that irrigation. It used to cost us about 6 cents a kilo, dry matter, to grow the grass out there on the back, on the sand hills, it’s now gone up to between 11 and 14 cents a kilo of dry matter, or thereabouts. Not just the cost of electricity, but the cost of urea to try and encourage that grass growth too.

Forward planning can reduce exposure; however there is no guarantee that the returns will be there the following year. Grass silage and maize might be planted when input costs (seed, fertilizer, diesel) costs are high, but utilized when payout is lower, eliminating the margin. Drystock farmers were exposed to similar cost increases, including urea, and fertilizer, both of which had gone up in price substantially, driven in part by burgeoning demand from overseas and dwindling supply (Cordell et al. 2009; Huang & Service 2009; Vaccari 2009). Horticultural producers are also exposed to rising input costs and are more sensitive to price increases because

they are on a more rigid production system. Growers are required to maintain a regular spraying regimen, for example, so they have less flexibility in adjusting to cost increases. No matter what the orchard produces, the required inputs are constant, even if input costs rise or returns drop. Another major input cost for growers that has risen in recent years is labour. Kiwifruit is a highly labour intensive industry and changes in production practices in recent years have also boosted labour requirements. The rising minimum wage has forced producers to raise staff wages in order to maintain the margin between the minimum and the often 'low' wages provided in the industry or recruit seasonal labourers and less experienced workers from overseas.

The two major economic forces described above, while they represent exposures that affect the farm directly, their importance extend beyond that, influencing producers' vulnerability to climatic conditions as well. First, variable market prices have ability to enhance or dampen the effect of climatic conditions. Producers characterized really bad years as ones with low yield and low prices. Thus farmers may be in a position where they are 'double exposed' to risks and are 'double losers' (O'Brien & Leichenko 2000). High prices on the other hand, can compensate for climate-induced yield losses, resulting in more average income years. One farmer described it as follows:

You know the payout's gone up 40 cents, but we dried off 5 weeks early and the increased payout will cover half the income that our farm has lost by drying off early. Not only have lost income from the drought, but some of our costs have doubled and tripled. It used to be grazing a cow, we used to pay \$14 to \$18 would be top money, it's \$40 now – if you can get it! And bales - \$65 a bale, that went up to \$240 a bale, because the supply was tight, and people just cranked the price up.

Secondly, economic conditions also affect farmers' adaptive capacity (Brooks 2003; Smit & Wandel 2006; Engle 2011). Shrinking profit margins due to high input costs and low prices limit an operations' ability to withstand repeated years of crop losses without financial debt or stress, it limits their ability to purchase crop insurance or risk-reducing technologies, and prompts farmers to reduce their inputs and input costs such as fertilizers and sprays, which in turn increases their vulnerability. As one farmer noted:

With the fertilizer prices going high, I've cut back to maintenance, so didn't put on a lot of urea and that sort of thing, which consequently meant I grew less grass and then we had a harder winter and so I've been slower coming out of this winter; normally I'd have a lot of cattle ready to be sold now, finished, but we're only just starting to bring them in off some of the harder country to finish them, which – at the end of the day will be a big loss financially.

5.5.3 Markets

In addition to commodity prices, currency exchange rates and rising input costs, producers also described several other market and financial exposures that had an adverse effect on farm operations. These exposures affected only certain producers, and the degree to which they did so, varied from farm-to-farm. Horticultural and drystock producers both described access to overseas markets as a source of exposure. Unlike dairy producers in New Zealand, who, through Fonterra, have a significant international market share for their product (Verkerk 2003; Gray & Le Heron 2010), drystock farmers and kiwifruit orchardists are dependent almost exclusively on export markets and also face increasing competition for access *to* those markets. As a drystock farmer noted: "There's thirty wholesalers trying to sell New Zealand meat into Britain. So if you're a supermarket you just play them off, and you'll find one that, because of shortage of money, or oversupply or whatever, has just got to dump the stuff". Horticultural producers also

described the challenge of maintaining access to export markets; though they do not face the internal competition and price-undercutting that sheep and beef producers must contend with. In this regard, the single marketing desk, Zespri, described in Chapter 3, reduces at least one market exposure for kiwifruit growers: internal competition.

Increasing production of kiwifruit by overseas growers was also mentioned. New Zealand fruit still commands a premium in the marketplace because growers here produce a high-grade fruit, and Zespri has been successful in developing brand awareness (Beverland 2001). “It is so important for kiwifruit to retain their New Zealand'ness”, said one grower, “we only actually make any money in Japan, and in selected Asian markets; the rest of the world we sell kiwifruit to get rid of the volume; that's probably one of our biggest threats is competition, but fortunately we seem to be able produce a higher grade fruit than others so we do, on a world market get a premium for, and if we were to lose that premium it would be disastrous”. Increased competition from lower cost producers – in horticulture and the dairy industry as well – represents another source of risk identified by producers.

It should also be noted that the policy and legislative environment, and processes of rural change, are perceived by producers to influence, moderate, and exacerbate exposure to climatic and market risks. Much of this is associated with regulatory frameworks; reduced competitiveness through increased compliance costs; and local, national and conditions set by foreign markets which influence the market, business, and overall decision-making environment within which farms operate. Restrictions on production under the Resource Management Act (RMA), nutrient-management and fertilizer restrictions, the proposed Emissions Trading Scheme (ETS) and taxes

on production and foreign policies, influence the production environment. Farmers and growers described the impacts of the RMA in terms of increasing the amount of ‘red tape’ and bureaucracy, rising compliance costs and restrictions on farming activity. Kiwifruit growers, for example, need to comply with the environmental, health and safety conditions outlined in EurepGAP (since renamed ‘GLOBALGAP’, a European standard for ‘Good Agricultural Practices’) in order to sell their fruit in that market. International trade agreements and the absence of agricultural subsidies have further opened up commodity markets and caused increased volatility in commodity prices, shown earlier to be a significant exposure for New Zealand producers.

While not a source of direct risk, producers also cited the growing number of ‘lifestyle’ blocks in the Eastern Bay of Plenty, a growing disconnect between urban and rural areas, and overcoming some of the negative perceptions and attitudes regarding farming as problematic. Some of these processes and pressures associated with rural change have resulted in changes in farm management practices and have the potential to increase exposure-sensitivity to climatic stimuli. The flexibility of producers to take advantage of favourable climatic conditions, for example, is reduced through the need to notify neighbours. As one grower said, “Up until probably 3 years ago, we had no one around our orchards. Just in the last 3 years we’ve had subdivisions, and we’ve got subdivisions all around us now. Like we’re the biggest farm up here, everyone else is lifestyle blocks – and that puts a lot of pressure on; like I have to ring about fifteen people now before I can spray”. Another kiwifruit grower on the Plains was cited after complaints from neighbours about the “visual impact” a mobile frost protection fan was having on the

environment. In order to obtain resource consent to operate the fan, approval was needed from sixteen properties in a one-kilometre radius.

Finally, while the majority of risks identified by producers are forces that are external to the farm, the way in which they are experienced may be influenced by factors relating to the farm itself. Farmers described how relationships with family members or business partners, the health and well being of family members and unexpected crises like flood have important influences on operations. Many farmers noted that their children's interest in becoming part of the business was a key factor in decisions to increase farm size or expand operations. For those nearing retirement and without children wanting to take over the business, there is little incentive to invest in long-term risk management strategies, such as strategic adaptations to anticipated climate change.

5.6 Multiple stressors and the dynamics of exposure-sensitivity

Although dairy, drystock and kiwifruit orchards are located in the same region (with most drystock farms located on steeper country, unsuited to dairying), the risks that were of concern to each group differed, as data in *Figure 5.3* show. When asked about the conditions that made the difference between a 'good year' and a 'bad year', over the past ten years, nearly all of the horticulturalists surveyed identified at least one weather condition. This response indicates that climate risks feature prominently in growers' decision-making environment, as weather is a manifestation of climate. Kiwifruit growers also identified a range of market and financial risks that contributed to a good or bad year. The relative

importance, or attention paid to weather related stimuli is likely a function of the greater sensitivity of horticultural production to climatic conditions, and the more limited range adaptations available. While a dairy farmer might be able to source supplemental feed during a drought in order to maintain milk production, there is little recourse for an orchardist who loses half the crop to hail.

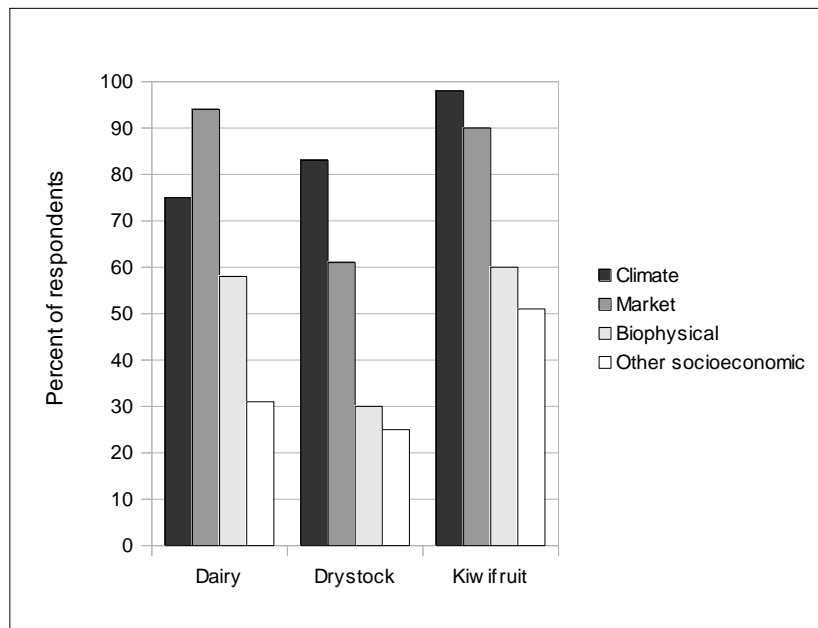


Figure 5.3 Risks that characterize bad years, as identified by producers (Source: Research findings)

More importantly however, as it is clear from the earlier discussion and from the data presented above that climate and weather are not the only risks that concern producers. Producers also identified risks associated with pest and disease outbreaks, changing government policies, interest rates, failures in technology, and risks associated with larger market forces access to lucrative markets, competition from other regions and rising input costs. Over one-third of producers surveyed across the different farm types also described other socio-economic risks associated with processes of rural change, such as the expansion

of lifestyle blocks in areas where agriculture was the primary land-use; management and labour market pressures and government policy and legislation, at a range of levels, of which they were conscious of as posing a risk to the viability of their operations.

Producers' identification of these non-climatic risks demonstrates that farmers work within a multi-risk environment. Furthermore, it is the presence and interaction of these various risks that influences producers' exposures, sensitivities, and responses. The climate and the market are two types of risk that are intimately related. Dairy farmers cited a number of climatic conditions to which they were exposed-sensitive, particularly as it affected grass growth. Seasonal variability in pasture growth may result in short lactation length, e.g. in the instance of autumn drought, cows are dried off early; or excessive wet conditions during winter and spring which lead to pasture damage following grazing and also pugging which can reduce subsequent pasture growth rates by up to 40% (Betteridge et al. 2002). The result is variability in milk production and profitability along with loss of body condition score and consequential cow fertility issues such as prolonged postpartum anoestrus (Verkerk 2003). Given the limited availability of low cost supplements that can give economic returns, farmers must then bring in extra feed – at a higher cost – in order to boost cow conditions. Producers described 'pulling the pin' on the season, and cutting their financial losses, in order to ensure they were set up for the following year's production. One dairy farmer stated that "It's going to be a long, hard recovery. The ripple-on effect is that if they are still very thin, your mating's downs, or you're going to have a spread out mating the following year". Successive droughts in recent years also affect producers' vulnerability to fluctuations in commodity prices or other climatic extremes.

This last drought is the only one that's ever carried over the following year. We ended up the past 15 months we've been struggling for feed. We've had other droughts before but you bounce back the next season. She's been a long hard grind for this farm. That's why this year is not normal at all.

Climatic conditions and market risks are linked in other ways too for pastoral farmers. Drystock farmers in the study area described drought as a serious production risk, however climatic conditions also affect markets. Drought is closely correlated to the prices drystock farmers receive for their commodity, meaning that not only are they exposed to production losses, but are also exposed to falling prices. During drought, procurement companies know that farmers will be desperate to relieve pressure on remaining feed by dropping stock, and so reduce the prices they pay to farmers. As one farmer said:

Usually when you have a drought, you'll get screwed both ways because the meat companies don't have to pay as much; and you know that can happen because some of the country is dry, not necessarily us. Just because we've got feed here doesn't mean the price won't go down, and then your livestock performance can be not quite up to scratch.

Another producer described the impact of drought on production and commodity price for lambs, as follows. When asked what made a good year, he replied:

Weather. Especially now with the extremes we seem to be having, weather's the biggest challenge of all and of course the weather always goes opposite to what the values are doing; as soon as it gets dry, the values drop, right when you're forced to sell things and vice-versa – when you've got heaps of grass things are worth heaps and you don't want to sell them!

Abundant grass growth then can actually be a negative, driving the returns down as the market is flooded. Unlike dairy and kiwifruit, nearly thirty firms market New Zealand beef and lamb, and so “You can have really good weather – but if everyone has good weather

often that means the schedule will be lower and so dollar wise you might not be a lot better off” said one farmer.

Kiwifruit growers are also affected by interannual variability as well as frosts, wind, and hail. These directly influence production and yield, and income, but producers are affected in other ways too. Growers are paid for fruit not only the basis of yield or production, but are able to earn premiums for sweetness, dry matter, storage time, shape and size (Pailly et al. 1995; Ferguson & Seal 2008), all of which are influenced by climatic conditions. For example, cloudy days and low summer temperatures that kiwifruit growers repeatedly cited as problematic, do not damage the vine or reduce yield, but they affect the vine’s ability to mature the fruit fully and hence influence sweetness, or quality, of the product (Woodward 2007). A reduction in quality, in turn, reduces a grower’s orchard gate return. Thus, in both cases, producers are not vulnerable to the climatic or biophysical stress itself – heavy rains and pugging, or cloudy days and low-summer temperatures - but rather to the expression of the climate or biophysical stress as a market risk.

Furthermore, this emphasis on quality is in part a result of the larger process of trade liberalization, and globalization. As Beverland (1998) and Campbell et al. (1997) have shown with respect to the kiwifruit industry, the Zespri brand was developed in response to poor returns and the inability of New Zealand producers to earn price premiums for superior quality. While the program has been effective in differentiating New Zealand kiwifruit from that grown by other, lower-cost producers, it has also changed the degree to which growers are exposed-sensitive to climatic variability and change. Producers now have a greater incentive to produce a high quality product in order to compete with other kiwifruit growing regions such as Chile,

which has a lower cost of production. It also increases sensitivity of producers to those climatic conditions that affect fruit quality (sweetness, taste, sugar content, storage time and size). This expands upon the double exposure concept in that not only can global economic forces exacerbate or dampen existing vulnerabilities (O'Brien & Leichenko 2000; Leichenko & Karen O'Brien 2008), but these forces may also influence the way in which communities – or agricultural systems – are vulnerable to climate change. As growing conditions become potentially more problematic in the future, the emphasis on quality will be another challenge for growers to overcome, demonstrating also the need to consider the role of non-climatic forces in future vulnerability.

Globalization and changes in the processing of dairy products can also be viewed in light of the double-exposure framework. In 1971 there were 107 processing facilities for dairy products in New Zealand, including six in the Bay of Plenty (Willis 2003). That has been reduced to three, with the majority of processing capacity at the main Fonterra Edgecumbe factory (Willis 2003). The changes and concentration of regional production increases the exposure-sensitivity of those remaining facilities to either drops in production due to changes in drought frequency, leading to greater inefficiencies as well as exposing infrastructure to a significant non-climatic risk: seismic activity. Similarly, the economic downturn reveals the vulnerability of producers to market risks, and the links between orchard gate returns and global economic forces. As one grower stated:

We've still got to sell our fruit in Europe, Japan, Japan's a bit dead they reckon, nobody's got any money to buy our fruit, which is another big concern with all this credit business – whether people will be able to afford our luxury fruit, that's the way it will affect us. Our fruit, New Zealand fruit, is a step up from everyone else's and for people to buy it, they've got to be able to afford to buy it, and if they've not got the money, they're not going to buy the premium product, they're going to buy the cheaper stuff from Italy or Chile.

The interconnectedness of the multiple risks and the dynamic nature of vulnerability are also apparent when adaptations occur within the system. Dairy farmers are paid for milk solids (per kg). Research suggests that New Zealand is reaching the limit in terms of per cow production. The actual return to dairy farmers in inflation adjusted terms has remained relatively constant and so efficiencies have to be found in the system in order to improve profitability (Clark et al. 2001; Verkerk 2003). Increased protein intake, through supplementation is one way to boost production, and supplementation was also cited by a number of dairy farmers as a way to reduce their exposure to climatic variability and extremes by decreasing their reliance on pasture growth. By adopting a high-input system, farmers reduce their exposure-sensitivity to some climatic risks, however, dramatically increase their exposure to fluctuations in input costs, illustrating the dynamic nature of exposure-sensitivity, and ultimately the vulnerability of certain farming systems. The risks of a high-input system relative to a low-input one, are not unknown to producers, who identified increased exposure to price increases, “sticky downward” prices and supply problems as concerns. As one dairy farmer commented: “To me the risk factor behind brought in feed is horrendous. Sure, weather is our biggest risk, but there’s nothing much we can do about that. But if you are high input you’re very exposed to what prices do, if you’re even able to get the feed in the first place”.

As shown earlier in the chapter, prices for supplemental feed have been rising dramatically in recent years. Within a single season, a tonne of palm kernel landed on the farm, more than doubled in price (MAF 2010). Furthermore, these input costs are “sticky downwards”; rising quickly in response to external conditions such as a high-payout to dairy farmers, but falling slowly – if at all. “Think about the long-term effects of this drought”, said one farmer, “right,

grazing for instance is going to go up by at least fifty-percent, and it's not going to go back to normal next year, is it? Palm kernel has gone from \$230 to \$450. You know, they give you a good payout, and everyone puts their costs up and then when the payout drops, those costs stay high and you're stuck with them. All that's happened is payout has gone up, but everything else has gone up too". Finally, high-input dairy producers found themselves exposed on the supply side. During the drought, not only did feed prices rise dramatically, but feed was difficult to come by. Some farmers reported paying two-hundred dollars a bale (up from sixty-dollars), for "the dregs of the chest – if you can find it, because that constant supply has been a bit wayward this year". Others described maize growers running out of silage: "My neighbour he's really upset. One of the major growers of maize around here ran out, just didn't get a good enough crop, so basically told him he couldn't have any. So that's his whole winter feed suddenly not arriving".

While a shift from a low-input, or all-grass system to a high-input system may enhance an individual dairy farmer's production (though there is research to suggest, that margins are lower than on all grass) and reduce exposure to climatic risks, it simultaneously increases exposure-sensitivity to rises in input costs. A shift in management system requires a feed-pad, a dedicated tractor, and often an additional labour unit as well as the ongoing cost of PKE or maize silage. This example suggests that climate is a fundamental driver to which producers are vulnerable and to which they adapt. This adaptation, changing from a low to high-input system for example, changes the nature of the system to make it better adapted to the climatic conditions but more vulnerable to the market stresses to which it was previously less sensitive (*Figure 5.4*).

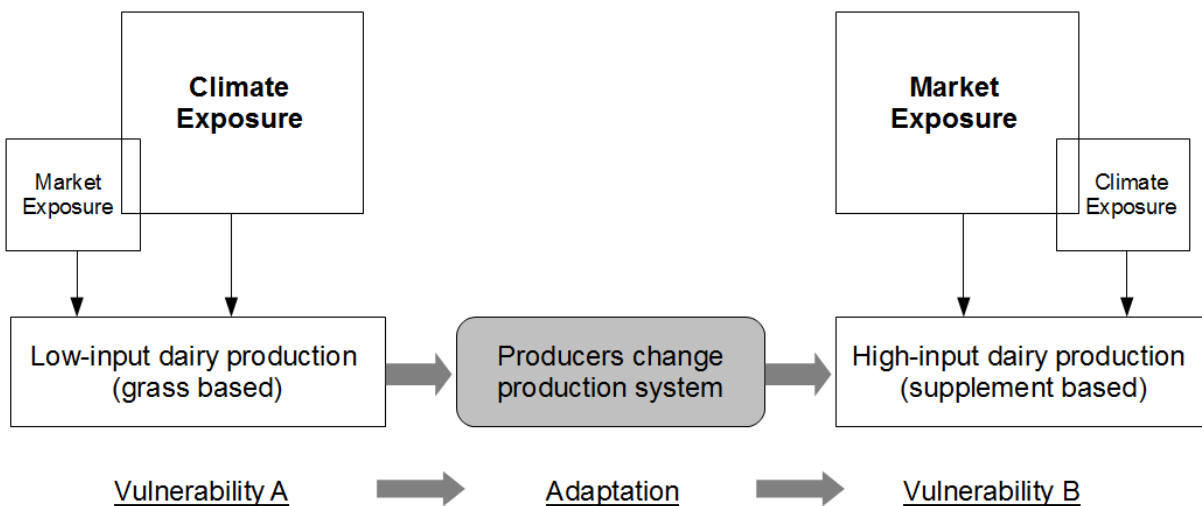


Figure 5.4 Dynamic nature of exposure. The relative sensitivity of the system to each type of risk exposure is represented by the size of the box, illustrating that following an adaptation, the nature of the system, and hence its sensitivity, is changed. Reduced exposure to climate by ensuring adequate feed supply, results in increased exposure to market forces (rising input costs), moderated by any increases in production.

At the same time, secondary adaptations to moderate the increased sensitivity to climatic stresses may enhance market risks. Anecdotally, some dairy farmers stated that milk produced from cows that are fed a highly-supplemented diet, may be of lower quality with higher cell counts and water content; and one study has concluded milk from cows fed a diet high in PKE contains elevated levels of harmful trans-fatty acids (Benatar et al. 2011). Hence dairy farmers are now more sensitive to market conditions as well as to conditions that effect quality, and hence farm income as well, as payout is determined, among other things, by milk fat content (Verkerk 2003).

Unseasonal climatic events have significant effects of producers, particularly horticulturalists. Frost, hail and strong winds, adversely affect production – in some instances the entire crop can be lost in a single event – and requires significant re-investment, to bring the orchard back into full production. Orchardists are not only then exposed in terms of lost income, losing a year of production, but also the investment needed to restore the orchard. Many growers and producer-stakeholders in other sectors commented on the particular vulnerability of orchardists to climatic events. Furthermore, sensitivity to extremes is also associated with the type of kiwifruit grown. As was demonstrated with respect to the dairy industry, exposure-sensitivity is dynamic with respect to adaptive responses. Some kiwifruit growers have changed varieties, planting or replacing Hayward, with Zespri Gold kiwifruit (Zespri Hort 16A). This can be seen as an opportunistic adaptive response to the potential for higher yields and production per canopy hectare, as well as the higher price paid per tray of fruit. Producers therefore are taking advantage of market and production/yield opportunities. In so doing however, they become more exposed-sensitive to climatic conditions. Gold kiwifruit flower one month earlier, and are therefore more exposed to the risk of a late or unseasonal frost; and are also more scuffing and marking, due to high-winds. So although the fruit fetches a higher premium and production per hectare is higher, and with the attendant higher risk, comes the potential for higher returns, so too does sensitivity to climatic conditions. The synergistic and dynamic effects of multiple risks are not limited to climate and market, but also government policy and legislation and processes of rural change.

As shown in the conceptual framework (*Figure 2.3*), exposure-sensitivity at the farm level can be influenced by conditions, and stimuli originating at multiple temporal and spatial scales, linked to local impacts through various pathways. “Teleconnections” are most often used to in climatology to describe “any transmission of a coherent effect beyond the location where the forcing occurred” (Chase et al. 2005, p.2849). For example, one of the teleconnections associated with ENSO are drier than average conditions in eastern New Zealand (Mullan 1998; Fowler & Adams 2004). The term “teleconnection” is not explanatory in and of itself, but rather signifies the existence of a correlation in events, and highlights the need to explore the connecting mechanisms and drivers in order to anticipate outcomes (Eakin et al. 2009). It has been argued that vulnerability, in an increasingly globalized world, is teleconnected to and nested within different spatial and temporal scales (Young et al. 2006; Adger et al. 2009). Distant places are now linked through environmental change process feedbacks, economic market linkages, and flows of resources, people, and information (Adger et al. 2009). Eakin et al. (2009) for example have examined the effects of changing patterns of coffee production in Mexico and Vietnam on growers’ vulnerability. Their research showed that household vulnerability in distant places was driven by, and linked to market and institutional forces as well as climatic conditions. Changes in political structure and land-tenure in Vietnam during the 1990s resulted in rapid expansion in coffee bean cultivation, and subsequent oversupply, depressing prices. Price declines, coupled with the privatization of Mexico’s industry resulted in stagnation and a dramatic increase in out-migration from coffee growing states such as Veracruz (Hausermann & Eakin 2008; Eakin et al. 2009). Improved household livelihood in Vietnam as production grew, continued to exert downward pressure on global prices, decreasing the livelihood security of Mexican farmers. Nepstad et al. (2006) have also demonstrated the global economic “teleconnections” between

fears of mad-cow disease in Europe and increasing meat consumption by the Chinese middle class with the growth of soybean production, cattle herds and associated deforestation in the Brazilian Amazon.

The growing integration of New Zealand agricultural production with key overseas markets was also noted by producers as a source of exposure. Under audit schemes, consumer demands borne out of concerns over food safety, the environment and welfare are theoretically poised to influence agricultural production systems (Campbell & Le Heron 2007). This emerging teleconnection is altering the terms of production in New Zealand and elsewhere (Campbell et al. 2006; Rosin 2008; Henson & Humphrey 2010), by overseas consumers. The growing power of European supermarket chains for example, and food governance bodies with audit authority, represented by EurepGAP (EU=European; RE=Retailer; P=Produce; and GAP=Good Agricultural Practice, since renamed GLOBALGAP to account for its wider acceptance among global retailers (Rosin 2008)), as evidenced by widespread consumer demand. Suppliers of New Zealand produce (Hayward & Le Heron 2002; Campbell 2005) and some meat products (Haggerty et al. 2009) need to meet these production protocols to provide goods to European markets. While many GLOBALGAP requirements are put in place to assure consumers that their food is safe to eat (e.g., negligible chemical residues), there are also other items in it that address environmentally beneficial practices (e.g., reducing fertiliser and chemical inputs) to achieve the food safety goal.

A number of kiwifruit growers did mention audit schemes. Growers were largely critical of the scheme, suggesting that because it is first and foremost, the product of European retailers, there is a lack of understanding of the local context and complexities of orchard management. Audits also require growers provide a great deal of detailed information which requires an ‘excessive’ amount of time dedicated to office work. It is unclear at this point, whether or not such restrictions will make adaptation to future climate change more or less difficult, or whether producers are likely to be more exposed-sensitive to future climatic variability and change. However, as the following chapter will show, overseas dictates on production do have the potential to constrain the flexibility of horticultural producers adaptive responses to existing climatic variability and is likely to be an important component of future vulnerability.

5.7 Conclusion

A good year? Climate, payout, and the dollar. They say if we ever got three of those things all coinciding, we'd never have to work again.

- Dairy farmer, Rangitaiki Plains, Eastern Bay of Plenty

As this chapter has sought to demonstrate, it is clear that farms and farmers in the Eastern Bay of Plenty are exposed and sensitive to a range of climatic and non-climatic forces that do not act in isolation of each other. Climatic conditions were consistently cited as an important factor affecting farm success each year, not only because of direct effects on crop yields, but also indirect effects on pest outbreaks and livestock stress, and the resulting impact on farm income. However, even with the best growing conditions, overall income in a year is also influenced by commodity prices and input costs, which in turn reflect processes and policies occurring at a broader international scale. These findings indicate that climatic stresses are

often expressed in economic terms by farmers, which are simultaneously influenced by non-climatic forces. These external forces present risks to the farm itself, but in turn influence the degree and way in which producers are vulnerable to climatic stresses. The chapter also demonstrated the synergistic effect of multiple stimuli, including the interaction between climatic and non-climatic risks. It was shown that exposure is dynamic, and that adaptations or strategies to minimize exposure-sensitivity in one part of the farm-system, can have the effect of increasing exposure elsewhere. These considerations demonstrate the importance of, and need to, consider the role and influence of not only climatic conditions, when examining the likely impacts of future climate change, but also non-climatic stressors, and the ways in which those might interact.

Producers are not helpless, or unaware. In response to the broad range of stimuli discussed, they have developed short- and long-term strategies to manage these risks. Through the exploration and analysis of adaptive strategies and the conditions that influence those responses, it is possible to gain insights as well, into the potential capacity to adapt to climate change. The following chapter details these adaptive responses of producers to the range of exposure-sensitivities, in order to better understand their vulnerability to climatic variability and change.

CHAPTER SIX: Adaptation to climate and other stressors

6.1 Introduction

Basically I got into kiwifruit to spread my risk, for income, but it opened up a whole new door of risks for losses I hadn't struck before. It took me a while to get my head around the fact that I'm minimizing my risk by spreading my income stream, but I also increased my risk, exposed myself in areas I never dreamed I would have.

- Dairy farmer and orchardist, Rangitaiki Plains, eastern Bay of Plenty

The previous chapter argued that farmers and growers operate within a multi-risk, multi-opportunity environment; that they are exposed-sensitive to a broad range of complex and interacting stressors that have their origins in conditions operating at multiple scales beyond the farm gate. These are experienced by individual farmers as effects on yield or production, and in turn farm income. It was shown that stresses are dynamic; adjustments in the system can increase or reduce exposure-sensitivity to other risks, as was demonstrated with respect to low- and high-input dairy production systems. Furthermore, it was argued that stressors interact. Climate and market risks for example mutually reinforce exposure-sensitivity during drought: pastoral farmers are exposed to declining grass growth and production, as well as higher supplemental feed costs or a drop in the meat schedule. The effect is to raise input costs in the face of declining production; or a decline in returns for drystock when farmers are most vulnerable. Climatic risks are not therefore experienced in isolation.

While the majority of producers identified climatic conditions as important, they also identified a broad range of non-climatic stressors including market risks, biophysical conditions that influenced production and government legislation and policy as well as processes of rural change. Taken together, the chapter suggested that as a component of understanding current and future vulnerability to climatic variability and change, one must account for a broad range of interacting stressors, and not only climatic conditions. Vulnerability however does not consist simply of exposure and sensitivity to climatic and non-climatic stressors (Turner et al. 2003; Ford & Smit 2004; Adger 2006). As shown in Chapter 2, an important component of assessing vulnerability is the capacity for adaptation (Füssel & Klein 2006).

This chapter argues that in response to climatic and non-climatic stressors, and to take advantage of opportunities associated with localized biophysical conditions, agricultural producers in the eastern Bay of Plenty have adopted/developed a range of adaptive responses to minimize exposure and increase production. By analyzing the types and forms of adaptation that are possible, who implements these actions, and under what conditions, the chapter suggests that it is possible to develop an understanding of the adaptive capacity of the regional agricultural system (Reid et al. 2007; Meinke et al. 2009; Rodriguez et al. 2011). By identifying the broad drivers of adaptive capacity furthermore, an assessment of future vulnerability to climatic variability and change can be developed (Glantz 1996; Adger 2003; Næss et al. 2005; Milly et al. 2008). This is particularly true for agriculture, as producers respond to climatic conditions on an ongoing basis (Roncoli 2006; Meinke et al. 2009). For farmers to successfully adapt to climate change, relevant experiential information needs to be available (Schwartz & Sharpe 2006), so that likely options

can be evaluated, and various impacts considered. The ways in which producers currently adapt, then serves to inform the assessment of future vulnerability in Chapter 7.

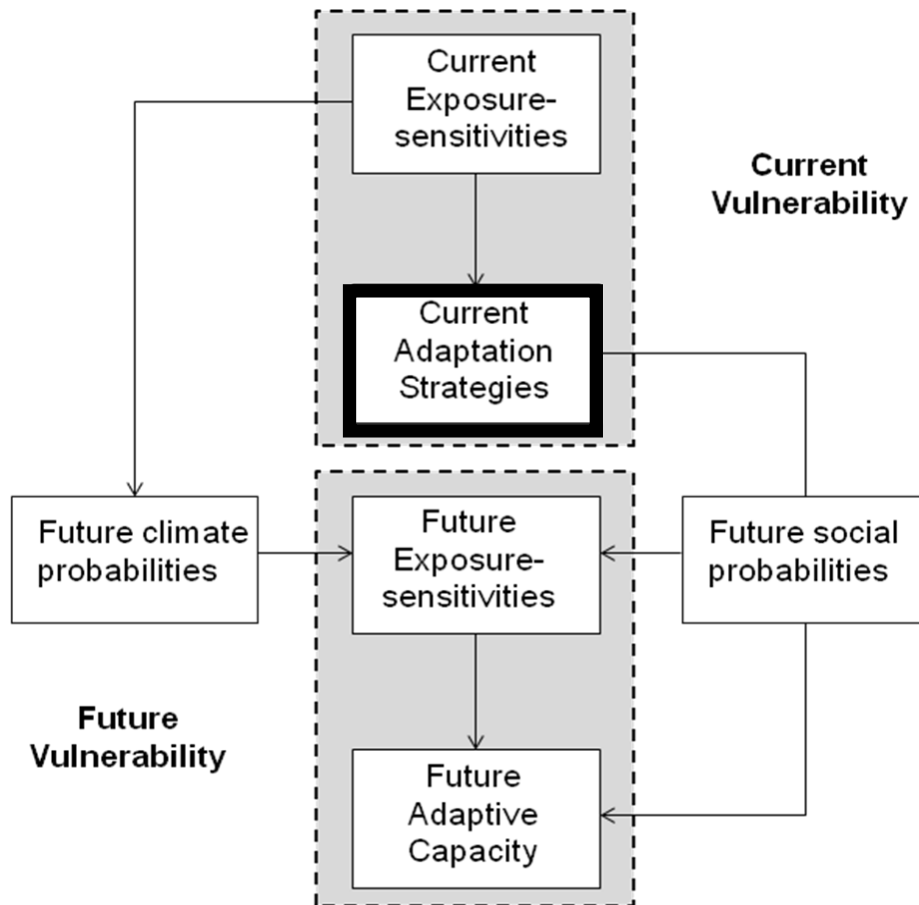


Figure 6.1 Chapter 6 (highlighted) within the analytical framework used to structure the thesis and empirical assessment of vulnerability in the eastern Bay of Plenty.

The chapter begins by briefly reviewing the concept of adaptive capacity. Adaptive strategies within agriculture are theorized, and the results of the empirical work discussed. Adaptive strategies identified by farmers and growers in the eastern Bay of Plenty are classified based on timing, duration, level of control and intent (Bryant et al. 2000; Smit & Skinner 2002; Smit & Wandel 2006). Through the empirical work, producers identified the greatest range of adaptive

responses to climatic conditions. These range from short-term, tactical and reactive responses to adverse growing conditions within a season to longer-term strategies for overcoming the limitations of climate. Producers not only identified adaptations to climatic conditions, but also describe adaptive responses to market and economic forces and opportunistic adaptive responses to take advantage of higher payout or returns. Complicating many adaptations is the fact that an adaptive response to one stress may alter exposure elsewhere, as illustrated by the quote from the kiwifruit grower at the beginning of the chapter. In this way, adaptive capacity is also understood to be dynamic, changing as elements of the farm-system change.

6.2 Theorizing adaptation in agriculture

Humans have a long history of both adapting to their environments, and adapting their natural surroundings to better suit their needs (Orlove 2005). While there are potential insights afforded by these historical antecedents of change (Diamond 2006; Leroy 2010), the contemporary discourse of climate change adaptation is still an emerging field, with a growing emphasis on the vulnerability and adaptive capacity of various socio-ecological systems (Allison & Hobbs 2004; Walker et al. 2004; Armitage 2005; Keskitalo & Kulyasova 2009). In the most general terms, adaptive capacity describes the ability to adapt (Engle 2011). Adaptive capacity has become a much discussed topic in the climate change literature, much of it focussed on the use of the term ‘adaptation’ (Simonet 2010). The following section briefly reviews adaptation as the basis for a discussion of adaptive strategies and capacity.

6.2.1 Adaptation

Despite widespread use in the climate change literature, there remain a number of different definitions and applications of adaptation as a concept (Schipper 2006; Ford 2007; Simonet 2010). Smit and Wandel (2006) link the origin of adaptation to evolutionary theory, and understanding the ways in which organisms have adapted to their environments over long periods of time, of which climate has long been recognized as being of crucial importance. ‘Adaptation’ has also been used in anthropology including works that characterizes societal or cultural adaptations to past climate variability (Diamond 1999; Orlove 2005; Brooks 2006; Leroy 2010). In anthropology, adaptation is most often used to describe the ways in which humans and societies successfully (or otherwise) adjust to adverse conditions. Faced with adversity, adaptation takes place or societies collapse (Diamond 2006). Given that the full effects of climate change have yet to occur, most of the documented adaptive strategies are reactive in nature (Tompkins & Adger 2005), responses to existing climatic variability (Salinger 2005). Adaptation is complicated (Barnett & O’Neill 2010). It is scale dependent (Adger 2001), temporally and spatially. Adaptation also has cultural, social and political dimensions (Turner et al. 1990; Wilbanks & Kates 1999; Adger et al. 2005; Vincent 2007; Westerhoff et al. 2011), making it difficult to predict whether or not adaptive responses will be viable. ‘Maladaptation’, or adaptation that does not moderate harm but instead exacerbates it (Rappaport 1977), therefore can occur.

In the climate change literature, adaptation is used to describe “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects” (Parry et al. 2007). Adaptation can be reactionary or anticipatory (Fankhauser et al. 1999; Smit et al. 2000). Successful adaptation is not inevitable (Engle 2011), but is dependent on, or a function of, a system’s adaptive capacity (Füssel & Klein 2006). Adaptive capacity can be characterized as a property of any given system, describing the ability to manage current or anticipated stresses or exposure, by utilizing available resources. It is this that influences the ultimate potential for implementing sustainable adaptation to climate change (Wall & Smit 2005; Wilbanks 2007). Adaptive capacity is contextual, varying between systems, and it is not equally distributed (Adger et al. 2007). Therefore, it is important to identify what enhances adaptive capacity and what functions as barriers to, or limits adaptation (Adger et al. 2009; Moser & Ekstrom 2010).

Given that responses to climate change are difficult to predict, proxy indicators of adaptive capacity have been proposed in the literature. Drivers or determinants of adaptive capacity include economic resources, technology, information and skills, infrastructure, institutions, and equity, as described in the widely referenced Third Assessment Report of the IPCC (Smit & Pilifosova 2001). Other studies have identified proxies based on empirical work. Brooks et al. (2005) for example, derived a set of national-scale indices of adaptive capacity based on mortality from climate-related disasters. The authors describe eleven key indicators of adaptive capacity, such as literacy rates, sanitation, government effectiveness and life expectancy (Brooks et al. 2005). Adaptive capacity can also be influenced by the ability of a community to act collectively (Adger 2003). In agricultural systems, social capital – which might range from sharing equipment between neighbouring farms, or freely distributing innovative management

techniques – then, is likely to be an important component of future adaptation. There is greater attention being paid to the role of institutions in enhancing adaptive capacity, both conceptually and theoretically (Yohe & 2002; Brooks et al. 2005; Eakin & Lemos 2006; Brown et al. 2010; Gupta et al. 2010; Dovers & Hezri 2010), as well as empirically (Ivey et al. 2004; Haddad 2005; Badjeck et al. 2009; Keskitalo et al. 2010; Engle & Lemos 2010; Wandel & Marchildon 2010). While most definitions of adaptive capacity focus on social determinants, Williamson et al. (2010) show that features of economies can also enhance adaptive capacity. Economic diversity and market efficiency or failure, for example, can enhance the short- and long-term capacity of economies to respond to climate change. Adaptive capacity in the framework presented in Chapter 2 (*Figure 2.3*), shows it to be a broad function of institutions, social and human capital, technology, awareness, and resources.

6.2.2 Adaptive capacity

Adaptive capacity is central to the theoretical and conceptual vulnerability-based framework used in this research. Adaptive capacity represents the system's ability to prepare for and adjust to the stress, mainly to lessen the negative impacts and take advantage of the opportunities (Smit & Pilifosova 2001; Adger et al. 2007). Adaptive capacity affects vulnerability through adjustments in the degree to which the system is exposed-sensitive (Yohe & Tol 2002; Adger et al. 2007). As shown in the conceptual framework (*Figure 2.3*) adaptive capacity is central to reducing vulnerability. It is a function of human activity, and influences both the social and biophysical characteristics of a system (Eakin & Luers 2006). It is important to note also, that adaptive capacity is also understood to be a component of resilience, and has the potential to link the different frameworks (Zhou et al. 2009; Adger & Brown 2009; Nelson et al. 2010; Engle

2011). In the resilience literature, adaptive capacity is used to describe the capacity of actors in a socio-ecological system to affect resilience by enhancing interaction between human and biophysical components of the system (Walker et al. 2004; Walker et al. 2006). The greater the adaptive capacity of a system, the more resilient it is to stress. The term is also used in reference to the ability of a system to transform or change state, following a disturbance. The more adaptable the system is, the more successful the transition to a new state is likely to be following a disturbance (Robards et al. 2011).

6.2.3 Adaptation in agriculture

The history of agriculture reflects a series of adaptations to a wide range of factors both including climatic condition, but also institutional, social and political environments (Diamond 1999; Brooks 2006; Orlove 2005; Perkins & Jamison 2008). Environmental conditions related to soil, water, terrain, and climate provide constraints and opportunities for agricultural production; however technological developments lead to modifications in the structure and processes of farming operations. Likewise, market factors related to input costs and prices paid have a dramatic effect on what commodities are produced and where production takes place. The availability of irrigation at a low-cost, for instance, has led to dramatic changes in land-use in areas where agriculture would not otherwise be possible (Davis 1999; Cai et al. 2003). Adaptation is therefore an important component of any assessment of vulnerability and subsequent policy response to climate change in agriculture (Mizina et al. 1999; Reilly & Schimmelpfennig 1999; Burton & Lim 2005; Howden et al. 2007). Without adaptation, climate change may create considerable problems related to agricultural production and agricultural economies and communities in many areas; but with adaptation, vulnerability can be reduced and

opportunities realized (Nordhaus 1991; Rosenzweig & Parry 1994; Smit et al. 1996; Wheaton & Maciver 1999; Smit & Skinner 2002; Howden et al. 2007).

Agricultural producers have the potential to adapt to climate change through a wide range of actions and measures (Brklacich et al. 1997; Smit & Skinner 2002; Wall et al. 2007; Mertz et al. 2008; Reilly 2011). There also exist numerous characteristics by which these adaptations can be distinguished (Carter et al. 1994; Smithers & Smit 1997; Risbey et al. 1999; Bryant et al. 2000; Wandel & Smit 2000; Smit & Skinner 2002; Meinke et al. 2009). Smit and Skinner (2002) for example distinguish adaptations in agriculture on the basis of intent and purposefulness, timing and duration; scale and responsibility; and form. Intent and purposefulness are used to differentiate between those adaptive responses that are either spontaneous or autonomous as part of on-going management from those that are consciously and specifically planned in light of a climate-related risks (Carter et al. 1994; Bryant et al. 2000; Smit et al. 2000; Smit & Skinner 2002). The development of drought resistant cultivars or advances in biotechnology for example, might be consciously planned adaptations and involved government agencies as well as agribusiness. Adaptations adopted by individual producers can be autonomous, planned or some combination of the two. A producer opting to gradually shift varieties grown on an orchard, for example, to take advantage of climatic conditions might be considered spontaneous and autonomous, but would also be consciously undertaken (Smit & Skinner 2002).

Given differences in characteristic temporal and spatial scales, and the different contexts in which different individuals and institutions are required to make decisions regarding adaptation, adaptations have also been usefully distinguished based on timing and duration (Risbey et al. 1999). Responses differentiated on the basis of timing are described as being anticipatory (proactive), concurrent (during), or reactive (responsive). While this differentiation is logical in principle, in the real-world context of agricultural production the distinction can be more ambiguous. For example, a producer who has experienced several droughts in as many years, and expects similar or increased drought frequency in the future, may adjust farm production practices or financial management to reduce exposure to drought-related risks. In this case, the adaptive strategies adopted are both reactive and anticipatory.

Duration of adaptation distinguishes responses according to the time frame over which they occur, such as tactical (shorter-term) versus strategic (longer-term) (Smit et al. 1996). Tactical decisions are made by individuals on a local scale based on weather (and other short-term) signals and might include adjustments made within a season, that involve dealing with a climatic condition, such as drought, in the short term. Tactical adaptations might include selling of livestock, purchasing feed on the spot market, or obtaining a line of credit or restructuring financing. Strategic decisions are made by individuals and institutions on local to regional scales based on market, climate, and other signals over a number of years (Risbey et al. 1999). Strategic adaptations refer to structural changes in the farm operation or changes in enterprises or management that would apply for a subsequent season, or a longer term. Strategic adaptations might include changes in land use, farm activities, crop type or insurance. Structural decisions

are made by institutions on a scale of states and are based on climate, economic, and other environmental signals received over multiple decades (Risbey et al. 1999).

Adaptations can also be distinguished according to the scale at which they occur and the agent responsible for their development and employment (Smit & Pilifosova 2001). In agriculture, adaptations occur at a variety of spatial scales, including plant, plot, field, farm, region and nation (Smithers & Smit 1997). At the same time, responsibility can be differentiated among the various actors that undertake or facilitate adaptations in agriculture including individual producers (farmers), agri-business (private industries), and governments (public agencies) (Smit et al. 2000). However, most discussions of adaptation do not distinguish the roles of different decision-makers. For example, the development of genetically modified crops as a response to changed climatic conditions is a commonly referred to potential adaptation to climate change (Howden et al. 2007; Schmidhuber & Tubiello 2007; Brown & Funk 2008). Such an adaptation would likely involve government agencies which would invest in and encourage research, agri-business that might also develop and market new crop varieties, and producers who themselves would adopt and grow new crops. Any realistic assessment of adaptation options needs to systematically consider the roles of the various stakeholders.

Adaptations in agriculture can also be classified on the basis of form. Adaptation in agriculture occurs via a variety of processes and can take many different forms at any given scale or with respect to any given stakeholder. Distinctions among adaptations based on form have been suggested by Burton et al. (1993), Carter et al. (1994) and Smithers and Smit (1997). These studies consider adaptations according to their administrative, financial, institutional, legal,

managerial, organizational, political, practical, structural, and technological characteristics. For example, Bryant et al. (2000) identify forms of adaptation at the farm-level, including modification of resource management, purchasing crop insurance, and diversification. They also identify different forms of policy level adaptations including aid for research and development, incentive strategies and infrastructure measures. Smit and Skinner (2002) offer one such classification, in which agricultural adaptation options are grouped according to four main categories: technological developments, government programs and insurance, farm production practices, and farm financial management. Their typology is based on the scale at which adaptations are undertaken and the stakeholder involved. The first two are principally the responsibility of public agencies and agri-business, and adaptations included in these categories might be thought of as system-wide or macro-scale. Farm production practices and farm financial management involve farm-level decision-making by producers.

Another framework for classifying adaptive strategies in agriculture is proposed by Wandel and Smit (2000). Drawing on elements of risk management, they propose a multi-scalar typology which accounts for the varying temporal scales in which adaptations are undertaken as well as the level of farmer control. In the case of climatic variability, production risk (e.g., maintaining milk production during a dry season) has its source at farm scale (the weather the farm experiences that year), but financial risk emanates from the wider environment (e.g., nation-wide yield reductions resulting in higher, end product prices). The types of actions designed to deal with these risks differ by the degree of control. Differentiation is between those the individual farmer has control over (e.g., crop choice), and those that require the farmer to participate in larger co-operative, industry, or institutionally-sponsored schemes (e.g., crop insurance).

Temporal scale is a consideration in agricultural risk as well. Actions can be taken pre-risk (e.g., before the crop is planted), during risk exposure (e.g., during the growing season), and post-risk (e.g., after crop failure or a low-yield harvest). Most farm-level risk management strategies will incorporate actions that apply to various degrees of farmer control and temporal scales, and to both production and financial risk (Wandel & Smit 2000).

Based on the above review then, given an ongoing process of adaptation, a set of basic questions arises with respect to adaptation and adaptive capacity: *What?* What are the types and forms of adaptation that are possible?; *Who?* Who is it that is doing the adapting?; *How?* Under what conditions is it that producers are adapting? i.e., what are the key ‘environmental’ changes that have driven change in the operating conditions for agriculture? (Risbey et al. 1999). The following analysis therefore seeks to identify the types and forms of adaptation that are possible; who implements these actions; and under what conditions. It takes adaptation to refer to “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects” (Parry et al. 2007). Adaptations thus include activities which represent changes in some attribute of the agricultural system (the agriculture sector or farms within it) directly related to reducing vulnerability to the exposures identified in the previous chapter.

6.3 Adaptive responses to climatic risks in agriculture

To develop an understanding of an agricultural system's adaptive capacity, it is useful to identify the types and forms of adaptation that are possible; who implements these actions; and under what conditions. As shown in the previous chapter, producers are exposed-sensitive to a broad range of climatic and non-climatic stimuli that have their greatest effects on production and yield, and farm income. Producers identified a range of adaptive strategies used to mitigate exposure-sensitivity to stressors. Responses can be differentiated on the basis of timing (anticipatory or reactive) and duration (tactical or strategic) (Risbey et al. 1999) as well as the level of farmer control (Wandel & Smit 2000; Smit & Skinner 2002). Producers identified the greatest range of adaptive responses to climatic conditions. These range from short-term tactical responses to adverse growing conditions or exposure from a single flood event, to longer-term strategies for overcoming the limitations of the climate through irrigation. Adaptive capacity is also a function of several determinants, including the availability of financial resources, technology, and government policies.

For pastoral farmers, climatic variability and extremes of temperature were identified as the weather-related exposures to which they were most exposed-sensitive. Horticultural producers manage their exposure to frost, wind and hail as well as climatic conditions that effect fruit production and quality. Producers also cope with and respond to, those exposures related to biotic pests a range of biophysical conditions which can exacerbate vulnerability (*Table 6.1*). Adaptive capacity is also dynamic (Meza & Silva 2009), as shown in Chapter 5.

Climatic exposures	Impact on farm/orchard	Farm-/Orchard-level adaptations
Good weather (hot sunny with timely rain)	Improved pasture growth, reduced feed costs	Stockpile hay/silage
Excessive precipitation	Pugging	Stand cows off on feed pad
Cloudy days	Reduced temperatures in orchard, effects fruit quality	Reflectors placed under vines to raise Ts
High temperatures	Animal health	
Frost	Delays spring growth Effects kiwifruit vine flowering	Apply HiCane/Thermomaxx Heat orchard through burning hay bales Heat transfer via helicopter Overhead frost protection
Wind	Marks fruit, lowering returns paid based on quality	Shelterbelts
Hail	Damages vines, scores fruit and significant losses	Hail cannons, enclose vines
Drought	Turn on irrigation Purchase supplemental feed Shift to a longer round (pasture management) Dry off milking cows early Drop to once-a-day milking Plant fast growing fodder crop (e.g. Turnips) Monitor grass growth Switch to drought-tolerant grass species (e.g. sorghum)	Lower stocking rate Have % of animals ready for market Split milking/calving; earlier lambing Diversify income streams Shift to a longer round (pasture management)

	Purchase runoff	
	Shift from grass-based system to high-input system	
	Improve soil quality	
	Plant trees for fodder	
	Lease farm to someone else	
Flood	Shift animals off the farm	Covered yards
	Turn on flood pumps	
	Clear drains	
	Sell farm (eliminate exposure)	
	Recontour land	
	Improve drainage	
	Install/upgrade flood pumps	
	Purchase non-flood prone land to stand animals off	
	Feed pad	
	Covered yards	
	Stand-off pad	

Table 6.1 Selected examples of climatic and biophysical conditions effecting eastern Bay of Plenty pastoral farms and orchards, and related adaptive strategies (Source: Research findings)

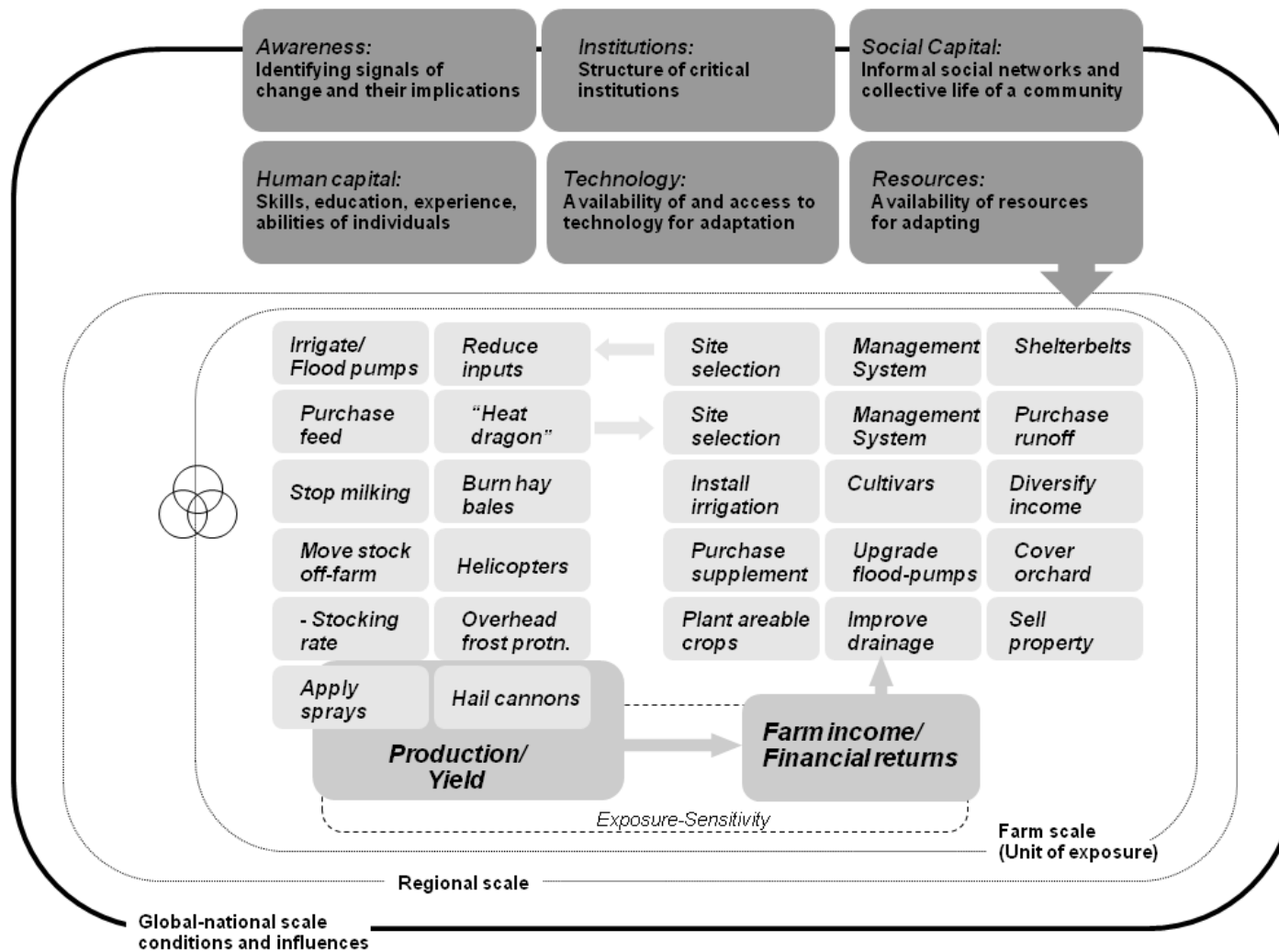


Figure 6.2 Adaptive capacity as a component of vulnerability. Adaptive capacity includes adaptive strategies used by farmers and growers to reduce exposure-sensitivity to climatic and non-climatic stimuli. As with exposure-sensitivity, adaptive capacity is influenced by a number of forces operating at a range of scales beyond the farm gate. Adaptive capacity is shown to be influenced by information, social and human capital, technology, resources and awareness.

6.3.1 Adapting to climatic variability and extremes of temperature and precipitation

How do you manage a dry year? Self-preservation. It's been eighteen months of total grief, of trying to find grass, go and chop trees down, fence off bits. It's just a matter of hunt for feed. It's just a matter of farming.

- Dairy farmer, Galatea, Eastern Bay of Plenty, New Zealand

Extremes of temperature and precipitation were shown to be the most significant source of climate-related risk for pastoral farmers, as farmers reliant on pasture or grass growth for production were exposed-sensitive – in varying degrees – on the ability of the farm to produce grass for feed. Low-input systems, reliant on grass growth, were most exposed to climatic conditions, shifting to a high-input system with supplemental feed, however, exposed producers rises in input costs and changes in supply. A shift to high input also does not totally eliminate climatic risk as dairy cows cannot subsist on supplemental feed alone (Verkerk 2003). In this way, drought can also be experienced at the farm level as a financial or market-related risk. Kiwifruit growers also identified drought as a source of risk but are less exposed-sensitive than other producers. Many growers have overhead frost protection which doubles as irrigation in the summer months. Floods also pose a risk to lowland dairy farmers, and to a lesser extent, horticultural producers in the eastern Bay of Plenty.

Evidence from other farming regions has shown that a range of farm-level responses to drought are utilized by agricultural producers. Conditions vary, temporally, and spatially. Bradshaw et al. (2004) showed that in response to drought conditions, Canadian Prairie farmers deliberately diversified farm-enterprise and production. McLeman and colleagues (McLeman et al. 2007;

McLeman & Hunter 2010; McLeman & Ploeger 2011) have also studied responses to drought, using it as a temporal analogue. Through their investigation of the Dustbowl of the American mid-west in the 1930s, they show how farmers have adapted to drought conditions in the past, and on that basis suggest possible entry points for developing adaptation strategies for current and future, analogous situations that may arise as a result of climate change (McLeman et al. 2007).

Pastoral farmers in the eastern Bay of Plenty have developed a range of short- and long-term strategies for coping with soil moisture deficits. Supply and demand provides the basis for most adaptive strategies for responding to drought on pastoral farms in the study area. While they are not mutually exclusive, adaptations to drought can be broadly classified as those which either seek to ensure an adequate food supply or those which involve reducing demand to better match available supply (*Table 6.2*). For instance, farmers might opt to purchase supplemental feed in order to keep milking; or if they are unable to source sufficient feed, might instead reduce the number of stock on the farm so that the remaining animals are well-fed, instead of having all stock struggle.

Ensure adequate supply of feed	<ul style="list-style-type: none"> Purchase supplemental feed (spot market) Purchase supplemental feed (6-12 month forward contract) Stored supplements Install irrigation system Switch on irrigation Plant fast growing fodder crop (e.g. Turnips) Switch to drought-tolerant grass species (e.g. sorghum) Shift from grass-based system to high-input system Install feed pad Purchase runoff Plant trees for fodder Site selection Choice of cultivar
Match feed supply with demand	<ul style="list-style-type: none"> Dry off milking cows early Shift to a longer round (pasture management) Drop to once-a-day milking Drop stock numbers Have % of animals ready for market Deferred grazing Calve earlier Run lower stocking rates Split milking/calving; earlier lambing
Other strategies	<ul style="list-style-type: none"> Monitor grass growth Improve soil quality Monitor soil nutrient levels Lease farm to someone else Diversify income streams

Table 6.2 Adaptations to manage drought risk in pastoral farming systems in the eastern Bay of Plenty (Source: Research findings)

Dairy farmers in the eastern Bay of Plenty most frequently cited purchasing supplemental feed as a response to drought conditions, to make up for shortfalls of grass. When pasture growth is limited, farmers on low-input or all-grass systems must bring in supplemental feed; while high-input farms will adjust the ratio of pasture to supplemental feed so that stock get a greater percentage of their diet from imported foodstuffs. This can be a short-term, tactical response, with farmers purchasing feed as needed; or as part of a longer-term strategy, involving forward contracts or changes in farm production practices. By installing a feed pad or meal feeder

system, producers have more control over feed supply, reducing exposure-sensitivity to climatic variability and extremes as they pertain to grass growth. As this dairy farmer stated:

One of the reasons people went to feed pads, was because they can control their feed through the year – used to be shitloads of grass in October, November, dry out in the summer, alright in the autumn, fuck all in the winter. So you get this up and down through the season, so alright, let’s feed them all year and we can control the situation and growing grass becomes a secondary thing.

There are limitations to this strategy however. Purchasing supplemental feed is constrained both by farm income – only if the payout was good, were producers able to make a margin – and the availability of feed. In “normal” drought years, this response has been adequate. Recent droughts in 2008, 2009 and 2010 have been far more extensive however, covering large portions of, if not the entire North Island (MAF 2010), rendering “normal” adaptive strategies insufficient. As this farmer noted:

If it was just up in Galatea, yeah, I probably would’ve milked, but it was all over New Zealand. Everyone was having the same problems, so it wasn’t as if you could just truck them off somewhere, realistically, or buy in something. Like normally when we get dry here, we can still buy in feed from down the Bay, but because everyone’s having the same problem, just pull the pin and figure it out next year.

For low-input producers, this problem is compounded by access. Most of the feed that was available to farmers in the last drought was absorbed by producers on high-input systems that already had forward contracts for feed purchase. As recent droughts have been more widespread, some farmers described problems with finding feed on short notice.

The problem we've had this year is that people like us, that didn't have things in place if you like, didn't have their risk management for something like this, we couldn't source feed once it [the drought] came, because it was so widespread. The whole country was short of feed, and we just couldn't get it. Whereas some of the people that were on farms that dried every year, and had decided to manage it with feed pads, they got that feed organized before and it comes. They've been able to manage a lot better.

Secondly, supplemental feed as an adaptive strategy is based on having a margin between the cost of production and the price paid for milk solids. With recent prices for supplements going much higher than anticipated, there is often little or no margin in continuing to buy in expensive feed simply in order to keep milking. In many cases, producers opt to simply "pull the pin" on the season. By not milking farmers are able to preserve cow health and condition, which better prepares them for the following season when they might make up the shortfall in production.

Exposure-sensitivity to drought and the limitations of existing strategies has prompted some to look at longer-term, strategic anticipatory responses, including irrigation. A number of farms in the area are irrigated and during drought simply turn it on; others are now considering irrigating as a long-term response to the risk of drought occurring with greater frequency and/or severity. Irrigation reduces exposure-sensitivity to dry periods but has other advantages as well. Exposure-sensitivity to climatic conditions is reduced by ensuring sufficient grass growth during dry periods (overcoming the limitations of climatic conditions), and in turn enables continued or increased production (overcoming market and financial risks). Increased production improves cash flow and permits expansion, or investment into the farm can enhance adaptive capacity. Prior to installing irrigation, this farm near Kawerau on a combination of sand and ash, struggled to produce sufficient quantities of grass. As the farmer notes:

The irrigation has given us the ability to grow – the ability to service whatever you want to borrow, and with irrigation we've had a much greater cash flow, going from a hundred odd cows to where we are. We had irrigation, increased cash-flow and so could take on more debt. On an average year here without irrigation, you do seven-hundred kilos a hectare. And some years you might do five, and some years you might do nine, and now we sit at eleven-hundred, it was four-hundred over seven-hundred, so greater than fifty-percent. And it's had the effect of stabilizing your income, and creating more income.

There are limitations to irrigation as a response to climatic extremes, including capital costs, as well as questions surrounding long-term sustainability. "Irrigation means a lot more work, an extra labour unit, housing, a new cow shed, heap more cows – it was a whole lot of capital costs beyond irrigation", said one farmer. In addition, irrigation comes with ongoing operating and maintenance costs. Energy resources on a low-input farm have been shown to be half that of a nitrogen-fertilized system, and one-third those of a high input system (Monaghan et al. 2008; Basset-Mens et al. 2009). Furthermore, there are concerns about the long-term viability of irrigation as a sustainable adaptive strategy. Water resources on in the eastern Bay of Plenty are not well understood (White 2005) and it is unclear whether or not increasing demand for irrigation will be sustainable in the long-term. In this way, irrigation may actually be considered a maladaptation (Barnett & O'Neill 2010; Holman & Trawick 2011).

Irrigation as an adaptive strategy to climatic conditions, also demonstrates the close interrelationship between climate, market forces and adaptive capacity. The range of potential adaptive strategies producers' might adopt is strongly influenced by farm income (which in turn is influenced by climatic conditions, markets, and other stimuli) or an individuals' access to capital (Smit & Skinner 2002). As this dairy farmer noted, market forces can be a barrier to

adaptation, limiting producers' capacity to respond. When asked what had stopped them from installing irrigation, one farmer replied simply: "Payout. Up until this year of seven-dollars, pay back on an irrigation system was about 20 years. You were doing it for nothing for all those years and that's what kept me away from doing it". Horticultural producers also described irrigation both as a tactical, reactive adaptation – if they had irrigation installed, in response to dry conditions, it was simply a matter of "flicking the switch"; and also as a long-term, anticipatory adaptive response, and an investment in future-proofing the orchard.

Other adaptive strategies used by pastoral farmers to ensure adequate feed supply, included planting fodder crops. In response to two dry years in a row, one farmer reported planting a fast-growing crop of turnips each season; others used trees as an emergency food source. Farmers had also changed cultivars in response to recent droughts, in one instance re-grassing affected portions of the farm with a hardier rye-grass that might better withstand drought conditions in the future. "It's not the best growing grass, but it's probably one of the toughest. We chose it based all on what we could grow on those dry areas". The neighbouring farm, similarly exposed to dry conditions, had experimented with sorghum, which was an effective strategy for drought. The grass, which originated in South Africa, grew quickly, and survived the dry summer conditions better than rye grass.

We got three grazings and about 40 bales of silage off it. We're going to put it in again. If they [cows] had a choice they'd probably eat rye grass but talk about growing in a drought, it doesn't need moisture! It just grows, and rye grass is struggling. You know more farmers might have to look at stuff like that if we get this sort of extreme weather, to help you through that.

Finally, for those with the available capital – or access to it – purchasing or leasing a runoff in a ‘summer safe’ area, is another long-term adaptation to better manage drought, through secured access to an available food supply.

The other set of strategies used to manage drought are those which match existing or available feed supply, with demand. Producers reduce demand by lowering stocking rates, shifting to once-a-day, or simply ‘pull the pin’ on the season and dry animals off early. Others described moving to a split-calving or shifting lambing dates to earlier in the season when grass growth is more reliable. Farmers also described adjustments in pasture management, using a longer rotation: allowing animals to graze longer in each paddock, and the remaining paddocks time to recover. Several dairy farmers also noted the use of deferred grazing as a short-term anticipatory adaptation to dry conditions.

Dry stock farmers have limited capacity for dealing with drought conditions. Purchasing supplemental feed would be prohibitively expensive, and so in many cases, the only available strategy was to lower stocking rates.

Getting rid of all your priority stock, because if you’ve got stock that have to grow to give you a return, and you’re not growing them, you’ve got to question why you’ve got them. It’s just about recognizing how much feed you’re likely to grow, what the quality of that feed is and matching it to the stock you’ve got, it’s pretty simple really. Old story: you don’t have a drought if you don’t have any stock. We don’t have a drought if we don’t have any stock.

One dairy farmer also described dropping his stocking rate as he was unable to feed them on the farm, which actually had a positive effect. Not only did it reduce demand for feed, but with the number of large-tracts of land being converted to dairy production, the market for dairy cows – even old and sick cows – was better than it had been in years.

While the strategies above were used to deal with adverse conditions, producers also described opportunistic tactical responses to drought. By utilizing a higher stocking rate, some farmers maximized production before the dry conditions affected grass growth, and then simply lowered stock numbers to match pasture availability. Other farmers purchased supplemental feed at a higher cost, but this enabled them to keep milking during the drought. In this way, they took advantage of the record payout for milk solids, capitalizing on the opportunity for profits which would then enable them to better weather the next downturn in either commodity prices, or adverse climatic conditions. “If you were all grass”, said one dairy farmer, “you couldn’t take advantage of the big payout this year, because the climate’s against you, so you have say a twenty-five percent variation in production, whereas with a supplement system, you’re only going to have a sort of five- to ten-percent variation”.

Most of the adaptive strategies for drought used by pastoral farmers are concurrent – i.e., they take place during exposure to the climatic risk – or post-risk. “Most of our responses are after the event really, rather than before”, said one drystock farmer. Very few are anticipatory in nature. Often only in the middle of the drought are the climatic signals evident and why it is often referred to as a ‘creeping’ hazard (Glantz 1988; Hayes et al. 2004; Wisner et al. 2004; Smith & Petley 2009). This may be one reason why farmers identified very few anticipatory strategies.

Producers did describe several strategies that differ from the responses described in their timing, for example noting that “the only one we could do before, which would be prudent I guess, would be having more feed on hand. Insure you a bit”. Purchasing supplemental feed on a forward contract of several months, instead of on the spot market, also reduces exposure to market risks; highlighting the fact adaptation is often in response to more than climatic conditions alone.

Other anticipatory strategies include holding a percentage of stock that ready for sale if climatic conditions are detrimental. Producers also increased monitoring. One dairy farmer ended up doing record production during the drought, an increase in yield that he attributed to closely watching all aspects of production. “When you fall in a hole, you know you’re in it; whereas with monitoring you tend to know you’re going to fall in a hole – try and avoid the hole. It helps knowing”. By closely monitoring soil fertility, not only is the farm better able to withstand dry conditions, but it also has reduced their exposure to a spike in input costs. “It’s preventative... risk, all the things we do – whether it’s fertilizer, our animal health is the same, the emphasis is on preventative care, it makes things a little bit more expensive along the way but the disasters are a lot fewer”. *Table 6.3* summarizes adaptive strategies to drought according to timing and duration of the response.

Type of adaptation	Source of risk	Example of adaptation
Tactical, reactive	Drought	Purchase supplemental feed (spot market) Shift to a longer round (pasture management) Dry off milking cows early Drop to once-a-day milking Drop stock numbers Switch on irrigation
Tactical, anticipatory	Drought	Have % of animals ready for market Plant fast growing fodder crop (e.g. Turnips) Purchase supplemental feed (6-12 month forward contract) Deferred grazing Monitor grass growth Stored supplements Calve earlier
Strategic, anticipatory	Drought	Install irrigation system Switch to drought-tolerant grass species (e.g. sorghum) Purchase runoff Install feed pad Shift from grass-based system to high-input system Improve soil quality Run lower stocking rates Site selection Choice of cultivar Plant trees for fodder Split milking/calving; earlier lambing Monitor soil nutrient levels Lease farm to someone else Diversify income streams

Table 6.3 Types of adaptations employed to manage drought risk identified in bad years (Source: Research findings)

In addition to drought risk, producers in the eastern Bay of Plenty described significant exposure related to damaging floods and extreme rain events. Floods have the greatest impacts on dairy farms, most of which are located on the fertile, flat alluvial plains of the Rangitaiki, or river flats in adjacent valleys. Floods also affect a small number of horticulturalists located on the Plains. For producers, planning for flood is a challenge, not unlike drought, in that it can be difficult to

forecast and there are a limited number of tactical, reactive adaptive responses available. Farmers have few immediate options in the event of a flood. As one farmer stated, “Well you can’t do a lot – having all your drains open, your pumps ready to go, all that sort of thing, it’s all you can do, never mind the rest of it. If you’re going to get it, you’re going to get it”. Most of the adaptive strategies for managing the flood risk instead are long-term strategic responses, including drainage canals, flood levees and stop banks and a network of flood pumps run in conjunction with the regional council and local farmers.

Producers have managed the flood risk by reducing or eliminating their exposure through immediate, tactical adaptive responses in the event of a flood. These responses can be either pre-risk, tactical strategies or concurrent (during) the flood. When possible, the most common tactical, reactive adaptive response among producers was to send animals off the farm. Farmers have relied on neighbours to take on cattle, or in more extreme flood events, moved dairy cows to elsewhere in the country.

What we ended up doing was putting them on trucks and then people, you know some people’s herds were split 6 ways, and then some went to Rotorua, some to Tauranga. Local carriers got on the phone and started ringing farmers and said look, we’ve got a truck and trailer load coming over the hill and we need to find homes for them. Anybody that can take 10, or 15, or 50 – they all found homes. It all had to happen in a hell of a hurry because the water came real fast.

The need to move stock off the farm is, for dairy farmers, not simply a question of being able to feed the animals, but mitigating the carry-on effects of a flood which can impact production for the remainder of the season.

It was the worst flood we’ve had, and it came at the wrong time of the year too, it came right just as everything was starting to calve. It meant we had to take stock off, there was no way we could have milked them if they’d stayed, and if you don’t milk a cow it’ll go dry, you don’t get anything from the rest of your season.

The co-operative nature of this strategy also demonstrates the importance of social capital as a driver of adaptive capacity (Adger 2003). A number of farmers noted how the 2004 flood event created an opportunity to work with neighbours. Farmers described the greater sense of community, and co-operation during and after flood events, which enhances their ability to recover from and plan for future exposures.

Aside from moving stock off the farm or to higher ground, the only other tactical (short-term) adaptation is to ensure that drains are clear and flood pumps are ready – both of which are indicative of a more deliberate, long-term adaptation strategy. Producers located on the Rangitaiki Plains have made significant investment in flood protection. As shown in Chapter 3, flood risk is managed through a combination of a farmer-run co-operative flood pump scheme, additional flood pumps on individual farms, and a network of drainage canals and levees maintained by the regional council. This infrastructure investment represents the major strategic, anticipatory adaptive response to the flood risk in the eastern Bay of Plenty. Producers also maintain their own flood pumps and upgrade drainage systems in order to better cope with flooding. Horticultural producers on the Plains also rely on flood pumps and many have deliberately sited orchards on drier land in order to avoid problems with wet feet and the variable water table. As this grower noted:

Most of my blocks have got flood protection as well, so they've got big pumps - once the water starts coming down, so within 48 hours, 72 hours, it's back to normal. They'll do about a week under water, if you leave it there for two weeks then you get stagnant water, fungus growing on it, they get waterlogged.

In addition to the permanent flood protection on the Rangitaiki Plains, other strategic adaptations include the modification of the local topography and improving drainage or installing a feed pad to ensure animals can be fed while pastures are under water. Another producer took more dramatic steps, and created a purpose-built hill, on which to build a new milking shed, above the 2004 flood, high-water mark. Others use a strategy of risk-avoidance (Wandel & Smit 2000) deliberately selecting and purchasing or leasing land not exposed to flooding, which would enable them to stand animals off during flood events.

Type of adaptation	Source of risk	Example of adaptation
Tactical, reactive	Flood	Shift animals off the farm Turn on flood pumps
Tactical, anticipatory	Flood	Clear drains
Strategic, reactive	Flood/Technology failure	Replace electric pump, with automatic sensor and diesel pump
Strategic, anticipatory	Flood	Sell farm (eliminate exposure)
		Raise profile of land, build new shed on hill
		Recontour land
		Improve drainage
		Install/upgrade flood pumps
		Purchase non-flood prone land to stand animals off
		Feed pad
		Site selection
	Winter precipitation	Covered yards
		Stand-off pad

Table 6.4 Adaptations identified by producer-stakeholders to flood risks in a bad year (Source: Research findings)

6.3.2 Adaptive strategies in horticulture

One reason we wanted to get out of kiwifruit was climate: all you need is a hail storm to come through, or a frost in the spring, and you're wiped out, you know, but dairying you're still there. You get a bad, bad flood – you can still pick up afterwards. Kiwifruit are a lot more variable as far as production with that climatic factor, if it's a hot winter or a wet flowering period, to get good bud burst or pollination – so there's more variance with horticulture.

- Former kiwifruit grower, Rangitaiki Plains

Horticultural producers face unique challenges from climatic conditions. As shown in Chapter 5, kiwifruit growers are sensitive to a much wider range of climatic and non-climatic stressors than pastoral farmers. As the quote from one former grower illustrates, climatic conditions not only affect production and yield, but also have a significant influence on quality (Sale & Lyford 1990; Pailly et al. 1995; Ferguson & Seal 2008) which in turn, is the basis for orchard gate returns. Furthermore, an entire season's production can be adversely effected by a single weather event.

When asked what the most significant exposure was for their orchards, the majority of growers stated: "A bad year? Frosts. No question about it, frosts kill you." or "Frost. Without a doubt. That's the biggest risk". Unseasonable frosts – those occurring early, during flowering, or late, prior to harvest, have a considerable impact, most notably on yields. Producers also identified wind and hail events as problematic. Climatic variability, including cloudy days, low summer temperatures and cold, wet conditions in the spring was also identified. Orchardists can take advantage of opportunistic climatic conditions to improve fruit size, taste, and sweetness, which may compensate for lower yields.

Climatic exposures	Effects on orchard	Orchard-level adaptation
Frost	Yield	Tow "heat dragon" through orchard Overhead frost protection Burn hay bales Helicopters Claim frost insurance Switch on overhead frost protection Switch on frost fan Application of HiCane (to compensate for lack of winter chilling, opportunistic) Apply <i>Thermomaxx</i> Install overhead sprinklers Install frost fan Purchase frost insurance Site selection
Wind	Quality	Shelterbelts Low-vigour pruning Covered orchard, fixed structure Different cultivars (plants), with shorter cane, less exposed
Hail	Yield	Hail cannons Enclosed/covered orchard Hail cloth, enclose orchard Purchase hail insurance Site selection Turn on hail cannons Claim hail insurance
Cloudy days	Quality	Raise temperatures in orchard with reflectors under vines
Cold, wet spring	Quality	Artificial pollination

Table 6.5 Adaptations identified by horticultural producers to climatic conditions that have an adverse affect on yield and quality (Source: Research findings)

Producers have developed a range of strategies to mitigate against climate-related exposures as shown in *Table 6.5*. These have evolved from largely short-term, tactical, reactive adaptations to more strategic, anticipatory strategies. Burning hay bales, the use of portable furnaces (“heat dragon”) and helicopters to mitigate frost damage, for example, are being replaced by permanent frost protection systems. This evolution in risk management has been in response to not only

climatic conditions, but to poor financial returns and a need to minimize losses and increase production. The end of co-operative growers' insurance, which distributed the risk among all growers also led to changes in risk management. Several years of substantial growth and investment followed by several years of significant losses due to frosts resulted in prohibitively high insurance premiums for frost. This had the effect of promoting changes in management practices. As this grower notes:

Growers in frost-prone areas were forced to put some sort of frost-protection in place, because they didn't have any cover. The lot that I got, was the last year that insurance was available, the premiums got so high that it was then economic to invest in a windmill or sprinkler, and so the industry became more stable because of it, production was more consistent, growers were physically looking after their crop instead of relying on that insurance.

This is consistent with Smit's (1994) findings that showed a similar shift took place in New Zealand agriculture with the removal of publicly funded hazard insurance and compensation in the late 1980s. This stimulated numerous adaptations including abandonment of climate-sensitive crops in risk-prone areas, reduction in farming intensity to provide flexibility, diversification of products and inputs, spatial diversification, development and use of more drought-resistant grasses, and expansion of private agricultural insurance (Johnson 1989; Smit 1994).

Changes in regional council policy have also influenced the adoption of certain strategies. For example, growers are required to apply for consent before burning hay bales in the orchard to prevent frost-damage, which is often not practical as there is little warning for impending frost. “The consent issue? Oh we would ignore that, and do it anyway, I’d say right, I’ve done it, what are you going to do about it”, said one grower, “that’s my livelihood out there!”. As the flexibility to utilize reactive strategies has been constrained, there is a greater emphasis on individual stakeholders’ responsibility for orchard management practices. The capacity of individual orchardists to adapt to climatic conditions is closely related to production and income. Strategic, anticipatory adaptations cited by growers include site selection and permanent frost protection. Adaptive strategies used by orchardists are shown in *Table 6.6* (overleaf) organized according to duration and timing of response.

Site selection is among the most important adaptive strategies for managing the frost risk.

For frost management you’ve got fans, helicopter, water, over the canopy – that’s the most expensive but it’s also the most effective. At the end, there’s risks with that too, you lose your power, you have a blowout in one of your main lines. Frost protection is actually pricey stuff. Again, it comes back to choose your site in the first place, that’s the best management – to buy an orchard that doesn’t get frost in the first place.

In addition to selecting sites that were less prone to frost, from the outset, producers also reported ways in which they had reduced their exposure through advantageous topography; removing frost pockets in the orchard through re-contouring; and taking advantage of features that enhanced the movement of air. Other strategies that originate with the establishment of the orchard, include choosing to plant varieties that mature earlier in the season, thereby reducing the chance of their being exposed.

Type of adaptation	Source of risk	Example of adaptation
Tactical, reactive	Frost	Helicopter Burn hay bales Tow "heat dragon" through orchard Claim frost insurance Switch on overhead frost protection Switch on frost fan
	Hail	Turn on hail cannons Claim hail insurance
Tactical, anticipatory	Frost	Application of HiCane (to compensate for lack of winter chilling, opportunistic)
	Wind	Apply <i>Thermomaxx</i> Pruning, tuck in cane earlier Trim shelterbelts later in season
Strategic, anticipatory	Frost	Install overhead sprinklers
	Wind	Install frost fan Purchase frost insurance Site selection Shelterbelts Low-vigour pruning Covered orchard, fixed structure
		Hail

Table 6.6 Adaptations identified by horticultural producers to manage frost, wind and hail events (Source: Research findings)

Once the orchard has been established, additional strategic adaptive responses to the frost risk include overhead frost protection and frost fans. Overhead sprinkler systems, which are often installed in conjunction with irrigation, form a protective layer of ice around the buds of the fruit:

It's not likely we'll get a lot of frosts, but you only need one and it can ruin a crop, ruin one crop and it costs you more than the installation of a frost protection system, so by installing it from the start, you can reap the benefits from it. It coats a load of ice on the buds, and as long as the buds – the area where you're protecting it, as long as it doesn't turn white, if it turns white it burns it; there's a certain amount of heat that radiates from the water, and that protects it. Latent heat transfer.

Frost fans are also employed as permanent, strategic adaptive responses to the frost risk by some growers. Frost fans, which can be stationary or mobile, work by mixing air within the first ten or fifteen metres of the surface for a higher average temperature near the ground. As with other conditions to which producers are exposed-sensitive, adaptive strategies are often made in response to more than simply climatic stimuli. In this case, the decision to install a frost fan was an adaptive response to climate, but also to poor returns in the marketplace. As one grower noted:

If we get a late frost, it can just wipe it. And the last four years, we've been hit with those, and it's affected our production and our flowering, so we've gone and put these frost machines in, big fan. The fan has only been installed six months, and before that, we had got away with it for years, but because the margins got so squeezed, we couldn't risk having seventy-percent of a crop. And that's what was happening; we were probably getting affected by thirty- or forty-percent every year when we'd get these cold snaps. We didn't notice it that much, you'd think "crop's down this year", "flowering's not as good". But you can't afford it. We've got to produce eight-thousand trays a hectare just to break even, hopefully we can get that to ten-thousand trays, and have margin.

In addition to frost, wind and hail events were also described by producers as being problematic.



Plate 6.1 Overhead frost protection sprays kiwifruit vines every 2 minutes if temperatures drop below freezing, coating buds with a layer of ice (Kiwifruit orchard, Rangitaiki Plains, eastern Bay of Plenty, New Zealand)

For both wind and hail, there were few short-term adaptive responses identified by producers. Aside from claiming hail insurance, one grower made use of hail cannons which were turned on as storms approached. Wind events can be managed through pruning practices, trimming vines earlier, to avoid them being blown about too much; or trimming shelterbelts later in the season to ensure a full cover on the shelter in the event of a late-season wind event. Most of the adaptations described by producers in response to wind and hail, were long-term, strategic adaptations and included site selection, as well as structural measures. A number of growers selected orchards in several different locations, at varying elevations to try and reduce their exposure in advance:

There are definite geographic differences; our most northerly block is ten kilometres down the road, and it's had two hail storms since 1997, been growing it up here for thirty years and haven't had one. Being a bit diversified in area means I can almost, grin and bear it.

Another grower described a similar strategy, having purchased blocks of land over a ten-kilometre stretch. "Just the hail going over or something, if they're spread around we're not likely to get hailed over everything. Sort of different aspects to the weather, so strong wind comes through or something some parts will be more protected as they're a bit separate".

Strategic, anticipatory adaptive responses to wind events, which scuff and mark fruit, have relied on the use of shelterbelts. These are usually made up of one or more rows of *casuarina* or *cryptomeria* trees – though more and more growers are considering artificial shelter, or additional shelter within the orchard. Artificial shelter requires less upkeep and reduces the orchard's exposure to pests such as scale and leaf roller which can live in the trees. While shelterbelts reduce exposure to wind events, they can also effect production by reducing fruit yield (fruit numbers and fruit size) on the vines closest to the shelter. Tall shelter blocks sunlight and shelter roots compete with the vines for water and nutrients and shading by shelter also has more indirect effects for example, shading may decrease bee activity and therefore reduce pollination. As with other adaptive strategies, the growers are most often constrained in their ability to respond by financial or market forces.

Ideally I'd like to put a row of artificial shelter in. Hopefully when returns get a bit better, I'll be able to afford to do that. And I plan to, but when the returns in the last couple of years have fallen back, I've just resisted and wait and see a bit.

In taking a longer-term approach to managing wind events, growers have also changed production practices by adopting ‘low-vigour’ pruning. This technique requires orchardists to gradually adjust pruning regimes, to end up with a shorter cane that is less susceptible to wind. Another grower had changed to ‘Cramer’, a Green varietal of kiwifruit, but a naturally low-vigour plant, in order to try and reduce wind-related losses. Several growers noted that their own experiences with severe weather events and climatic variability had prompted them to make long-term adaptations to the way they produced the fruit. A grower in Opotiki, for example, who was developing a new orchard decided to enclose the entire orchard under a protective cloth, to avoid losses from wind and hail.

Because this is a brand new block, a green fields site. I’ve decided to do it this way as a – I guess just looking to the future and saying ‘Well if you’re going to do it, might as well do it properly and minimize the risk of getting wind damage’ and from my calculations, the money invested in the overhead canopy, if we save anywhere between five-and fifteen-percent a year, of damage – we’d pay it off in two to three years.

6.3.3 Summary

In response to interannual climatic variability and extremes, as well attempting to overcome the limitations of soil type and climate, pastoral farmers in the eastern Bay of Plenty have developed a range of short- and long-term adaptive strategies. In response to drought conditions, these include changes in farm production practices, including the installation of irrigation, or meal feeding systems and feed pads to decrease reliance on pasture growth, or the purchase of additional land – runoffs – in ‘summer safe’ areas, to reduce the pressure on the production or milking platform. Other strategies include moving to a high-input system, changes in cultivars or planting new crops, adjusting calving and lambing dates to better match soil moisture

availability, and deliberately diversifying production either through mixtures of stock, growing supplemental feed on the farm, or seeking off farm employment. A similar range of responses were shown to be used in response to flood events, though the reliance was on anticipatory, strategic responses embodied in the regional flood protection scheme.

Horticultural producers were also shown to face unique challenges from climatic conditions that effect production and yield, as well as quality. It was shown that in response to climatic and non-climatic pressures, short-term, reactive strategies were being abandoned in favour of longer-term, anticipatory responses including permanent frost protection, and even covered orchards.

Faced with exposure to weather-related events, pastoral farmers and kiwifruit growers have developed a range of short- and long-term strategies for mitigation. Producers' ability to respond to these risks is closely related to market and financial forces, as well as the strictures of the RMA and local council regulations. For some, this has reduced their flexibility, making it more difficult to respond quickly. Other growers reported investing in long-term, strategic adaptations, designed to reduce losses, and in some cases, also increase yield. As with other adaptive responses, motivations driving adaptations can be complicated as producers respond to multiple stimuli or make opportunistic strategic adaptations to take advantage of opportunities at the same time as reducing exposure to climatic or market forces. As this dairy farmer notes, the decision to install a feed pad was driven both as a reaction to flood, and also to take advantage of a higher payout and increase production.

In the back of my mind I had an inkling to put in a feed pad anyway, so to get the most benefit of your maize silage and your palm kernel a feed pad is normally the way to go and not only that but if there is a flood, it's a bit of a backup. You can pump maize right into them. So whereas the average farm, you look at a feed pad it might just be one benefit – and that's then to increase production – whereas this is dual-purpose if you get a flood. I've got the neighbour up across the river and in the 2004 flood – his production only dropped sort of ten-percent whereas mine dropped thirty-odd percent, because I didn't have the facilities to feed cows.

In addition to the range of adaptive responses outlined above, producer-stakeholders have also developed strategies for responding effectively to pests, and several other exposures that effect a smaller range of producers than the ones already discussed. Significant pests include invasive grasses and facial eczema – both of which affect pastoral farmers. At the moment, farmers reported under sowing rye grass, at great expense, a short-term strategy that may prove inadequate in the future, if present warming trends continue. Facial eczema, which is common in the study area, is combated with zinc bullets and drenching, and losses have been sufficient for some producers, to invest in a long-term adaptive response, of breeding for resistance among sheep and cattle. Horticultural producers reported problems with scale and leaf roller, both of which were treated with regular applications of pesticide, or oils. The other significant class of adaptive strategies, described by farmers during the course of the research, are those that have been developed to respond to market and financial risks. For some the majority of farmers, climatic conditions and market forces are the most significant sources of exposure, and many of the strategies used to adapt to climate, also have co-benefits, in reducing market risks as well. The following discusses the ways in which producers have sought to manage financial risks. While there were a number of other risks associated with market forces that were identified by producers, there is a more limited range of adaptive strategies used, suggesting that the capacity to adapt to market forces is much less than for climate-related exposures.

6.4 Adapting to market and financial risks

What's helped make a good year? When payout's up really. When it's not, you just have to tighten your belt, close your chequebook and consolidate. About all you can do really.

- Dairy farmer, Rangitaiki Plains, New Zealand

As shown in Chapter 5, agricultural producers are also exposed-sensitive to a range of non-climatic stimuli. Markets and financial forces often work in concert with climatic conditions to influence farm and orchard income. Producers described the compounding effects of poor yields, lower commodity prices, and rising input costs, for example, as being detrimental. Market forces were shown to affect producers in other ways too. A high payout may enable an orchardist to invest in a risk-reducing technology such as a wind fan or overhead frost protection, while a low payout may prompt a farmer to reduce inputs of nitrogen or fertilizer in order to save money, and thereby increase their exposure-sensitivity to climatic conditions or pests.

Producers have a limited ability to respond to market and financial risks. In part, this is because these have their origin in conditions beyond farmers' immediate control including world financial and commodity markets and currency exchange rates. Most adaptive strategies related to market risks involved changes in farm production practices or farm financial management strategies. Farm financial management describes using farm income strategies to reduce the risk of climate-related income loss (Smit & Skinner 2002). It can include decisions with respect to insurance, crop shares and futures, income stabilization programs, and household income (Bryant et al. 2000; Wandel & Smit 2000; Berg & Schmitz 2008). Producers can also take advantage of market conditions, through opportunistic adaptive strategies to capitalize on favourable market conditions.

6.4.1 Changes in farm production practices

The greatest market-related risk that was identified by producers during the course of the empirical work was a year in which returns or payout was low. Returns are influenced by market conditions beyond farmers' control, including commodity prices and fluctuations in the value of the New Zealand dollar. Unlike weather-related exposures, for which producers have a range of adaptive strategies, farmers and orchardists have little control over a poor year financially. A common short-term tactical response to poor returns was to simply stop spending or reduce inputs. "We stop spending in the bad years", said one kiwifruit grower, "and then in the good years play catch up". A drystock farmer echoed this statement, saying that in a bad financial year you simply "cut your costs. If we thought it was going to be a low payout next year, we might cut our cow numbers so we didn't have to buy in so much feed". Beyond reducing expenditures, there was little else in described by producers in the way of short term responses. Producers are able to weather poor returns by taking advantage of improved payout in subsequent years. Farmers also make use of strategic, anticipatory adaptive strategies to through forward contracts and closely monitoring inputs.

Inputs vary from farm-to-farm, and can include fertilizer inputs, supplemental feed, electricity for irrigation, fuel for machinery, young stock and labour. In light of cost increases and poor returns producers utilized strategic anticipatory adaptive strategies to better manage this exposure through forward contracts. Forward contracts reduce the risk of purchasing inputs on the spot market, and can be considered a form of risk sharing (Wandel & Smit 2000). As one dairy farmer described their own response for dealing with rising input costs for supplemental feed:

I think if you're forward thinking you can plan, and buy twelve months out. So we've actually purchased 20 ha of grass silage from a maize grower. By forward managing that you get a better price, rather than "Oh hell we're getting a little low on feed", and you go out into the market and holy hell the price is gone through the roof. Do we buy it or don't we? It's very expensive, so we try and forward order.

Other farmers described having a "bit of supplement up [their] sleeves", rather than "farming on a knife edge". One dry stock farmer, whose main inputs is buying calves to rear, managed exposure to rising input costs by purchasing stock throughout the year, and from several different sources.



Plate 6.2 Feed pads are increasingly common as dairy farms intensify production and insure themselves against drought years by having highly-supplemented system (Waimana Valley, eastern Bay of Plenty, New Zealand)

The other strategy that some producers employed was to closely monitor inputs. Producers are exposed-sensitive to rising input costs, some of which is related to global conditions such as valuations in currency, global demand and shortages of certain nutrients. In response, growers and farmers try to ensure a minimum of waste and ensure inputs (either of supplemental feed or soil inputs) are used as efficiently as possible. Dairy farms often use a feed pad (a large concrete block) to stand cows off on so less supplemental feed is trampled. Orchardists described a greater reliance on soil and leaf tests to make sure no more inputs than necessary were being applied. “Certainly not going to dump a surplus on now”, said one kiwifruit grower. Some producers also reduced their exposure by maintaining a low-input system. A low-input system not only reduces exposure-sensitivity to higher costs, but also is an adaptation to poor returns. “Keeping the system low-cost is important”, as one dairy farmer said, “you have to be able to do that; obviously if the payout goes down, you’ve got to make the system as cheap as possible”. Producers are also able to adjust farm financial management practices through diversification and “pluriactivity” to reduce their exposure to climate-related losses.

6.4.2 Diversification and “pluriactivity”

Household income strategies have long been important adaptation options in agriculture. Such financial decisions may also represent a means of dealing with economic losses or risks associated with climate change. Diversification of income sources has been identified as an adaptation option, including off-farm employment and “pluriactivity”, which has the potential to reduce vulnerability to climate-related income loss (Brklacich et al. 1997; Smithers & Smit 1997). The term “pluriactivity” is used by MacKinnon et al. (1991, p.59) to describe the phenomenon of “farming in conjunction with other gainful activity whether on or off farm”. While activities such as agri-food tourism receive a lot of attention in both academic and popular circles, the most common and least glamorous pluriactivity is off-farm work. As with many adaptations, diversification of household incomes is unlikely to be undertaken directly in response to climatic perturbations alone (Le Heron et al. 1994; Bradshaw et al. 1998).

Farm operators have become more “pluriactive”. Off-farm employment was identified as an important adaptive strategy. When asked the difference between a good year and a bad year, one grower simply said “My wife working”. The extra income helped them to get through the years when production from the orchard was particularly low. Another grower held a full-time job, in addition to running the orchard, noting that it was “a form of self-insurance; make sure you don’t put all your eggs in one basket, and that you have a multiple cash flows... there is no way I could live off this orchard entirely”. Other kiwifruit growers had taken on part-time jobs outside the orchard, or supplemented their income with contracting work in other orchards. Diversification of household income was not limited to horticulture. One dairy farmer, when asked if he would

have done anything differently in response to the various climatic risks that had affected production, replied:

I would have worked off the farm, because by working off the farm you can introduce capital that isn't a risk – see, cattle were a part of the farm, and that was capital that was at risk from a whole lot of factors. If you're working off the farm, your income is guaranteed, it's stable, it's not affected by weather, it's not affected by exchange rates, it's not affected by interest rates, you can pay that level regardless of everything else going up and down, and that's the difference as opposed to farming, your income is going up and down: it rains too much, it goes down; it rains not enough, it goes down. If you earn money off the farm it's a constant.

Farmers have also used diversification of production as a strategy. For some, the motivation to diversify was strictly in response to market and financial pressures; while for others, a mix of climatic stimuli and market forces. Changes have also been driven by intensification in the dairy industry. Dairy farmers have increasingly sought to free up the milking platform and so send calves and heifers to graze on neighbouring farms. Because many dry stock farms are located on a mixture of terrain, they are often well suited to supporting a variety of stock. Many drystock farms now include dairy grazers, as well as fewer sheep and more beef cattle. Farmers have also changed land uses. Such diversification reduces exposure to low returns, as well as provides some flexibility to take advantage of favourable market conditions.

Within my system I've built in really, a space around three corners – thirds of risk factors if you like. I've got three different enterprises and not very often is one, or the whole lot of them, down at one time, and history is proven that to be a fact – if you go back years, lamb might have been bad, but wool was good; beef cattle were bad but the dairy side of my business was good; when I was in bulls, the beef side of that was good, and dairying possibly, might not have been so good.

In addition to running a varied range of stock on their farms, some dry stock farmers also described expanding into horticulture, planting kiwifruit on a section of the property; forestry;

one drystock farmer had added a farm-stay that earned more in the year, than raising lambs; and another farm started hosting enduro motorcycle events once a month in order to earn extra income from the property.

6.4.3 Opportunistic adaptive strategies and markets

Producers also make opportunistic tactical adaptations in response to market forces. By taking advantage of premiums offered by supplying the shoulder season; for getting fruit to the packing house early; or increasing production in the short-term to take advantage of high commodity prices, producers are able to offset the pressures from climatic and other stimuli. Horticultural producers also noted potential opportunities from new varieties that may increase yield and offset some of the risks associated with climatic and market forces. One grower described a deliberate adaptive strategy, in response to payout and lack of production.

We used to be not as proactive as we are now, so we've changed our management system considerably, and it's paid off financially. We slowly improved our irrigation, improved our management. Thing is, kiwifruit you've got huge opportunity. You get paid per tray, but that's made up of an 'early start' slice of it, that's made up of a dry-matter slice of it, it's made up of a size slice of it, it's made of numbers per hectare slice of it, taste premium, pest premium, loyalties – these are all things you can get. One year I got twice the industry average for my crop, that's huge. That extra is all profit.

Dry stock farmers as well, have a similar opportunity to supply different parts of the market at different times, taking advantage of the early sale, and setting themselves up for the following year's production. While paid almost exclusively on the basis of milk solids, some dairy farmers did make short-term changes in farm production in response to record high dairy prices. As one farmer said: "We got into a little bit of a higher input system last year, supplementing with palm kernel to maximize our production because the payout was so good and we were in good condition, so trying to take some stresses out of the system". By taking advantage of such opportunities, producers are able to capitalize on production or payout, re-invest into the farm, and increase their ability to weather the next downturn or the next climatic extreme.

There's no insurance for drought, back in the days of subsidies, the government would have jumped in, and probably doubled our payout, or given us feed for cheap. Those days are gone. And they should be, but that's why I get upset when all these townies complain about the \$7 payout. We need that \$7 payout, because we had about four years of bad payout. If we get a few droughts, it takes a lot of catching up from those, there's got to be something to balance it out.

As the dairy farmer cited above, notes, with the removal of subsidies, producers are exposed to a greater degree to climatic and market stimuli and that an important strategy for getting through the bad years, is to have the odd good one.

6.5 Conclusion

I think you learn about making decisions, it's better to be proactive, like they all talk about – when farmers are affected by adverse climatic events, the worst affected are the ones that react the latest, like, I'm being a bit harsh, but sometimes they just dig a hole and they hope it'll go away and by magic, it'll all come right. Whereas if you make decisions – okay, it might rain tomorrow, but you've still made a decision, and you've got a plan based around that, and if you buy feed earlier, or you sell stock earlier you're going to get better prices or buy the feed cheaper than leave it 'til when everyone's looking for it. In the long run you're way better off than digging a hole and doing nothing.

- Dairy farmer, Rangitaiki Plains, New Zealand

Farms in the eastern Bay of Plenty are exposed to a range of climatic and non-climatic stimuli.

While these exposures vary in duration and frequency, and affect nearly all producers in different ways, producers have developed strategies to mitigate against some of the most severe exposure-related impacts, through short- and long-term adaptive responses. The range and heterogeneity of producers' responses is an expression of variations in age, experience, access to capital, and other market forces, as well as the type of farm system being run. The effectiveness of these adaptive responses as well, is related to the severity of the exposure, the timing of the response and the different resources, technologies, and availability of capital that are available that influence their ability to adapt.

For all producer-stakeholders, climatic conditions and market-related exposures are the greatest sources of risk. In light of this, producers more readily identified adaptations to climatic conditions. For pastoral farmers, drought and flood are especially problematic, and producers described a range of short-term tactical and long-term strategic adaptive responses. Horticultural producers in turn, are more sensitive to climate and weather, particularly unseasonable frosts,

wind and hail events which can affect an entire years' production (and related costs) in a single event.

While producers are exposed to a variety of conditions, the degree to which they are vulnerable depends on their ability to cope or adapt. This is complicated because climate is not the only condition to which producers adapt, and an adaptation to one stress may increase exposure to another, as shown in the previous chapter with respect to high- and low-input dairying, and switching varieties of kiwifruit from Zespri Green to Zespri Gold. However, when farmers and growers were asked how they managed the risks in good and bad years, they more readily identified adaptations to manage climate-related risks than other risks. It was shown that these adaptations varied by timing, whether adaptations are taken in anticipation of a potential risk, during the realization of the risk or in reaction to it; although given the dynamic nature of climate, climate change, and farmer decision-making, these distinctions are not always clear. *Table 6.7* summarizes farmers' adaptive responses based on Wandel and Smit's (2000) categorization according to the timing and the level of farmer control.

Tactical adaptations, which are short-term strategies undertaken within the growing season to deal with a problem (Smithers & Smit 1997; Risbey et al. 1999), were more commonly employed in response to daily weather variability. Some tactical adaptations were anticipatory, such as using irrigation to minimize frost risk. Other practices were in reaction to poor weather.

Timing of management (with respect to hazard)		Levels of farmer control	
		Primarily individual	Primarily multi-stakeholder
Pre-risk (Anticipatory)	Risk reduction	Diversification of farm enterprise <i>Adding another farm enterprise; contract labourer</i> Diversification of planting/production system <i>Change cultivar; plant drought tolerant grass species, low vigour vines, higher-yielding varietal; add feed pad for supplement</i> Soil conditioning <i>Increase soil porosity; 'adequately resourced' nutrient levels</i> Technological innovation Change feed management systems Change timing of farming practices <i>Split calving/earlier lambing to take advantage of grass growth</i> Off-farm income Improve drainage <i>Add/upgrade flood pumps; clear drains regularly</i>	Flood protection system of levees and stopbanks
Pre-risk or during risk	Risk hedging	Carrying supplemental feed reserves <i>Maintain feed inventory; increase storage capacity</i> Use pesticides for insect (scale, leafroller) infestation Change timing of operations Livestock husbandry responses for hot summer weather <i>Sheltered area for livestock; salt blocks</i>	Forward contracting

Post-risk (Reactive)	Risk transfer Risk mitigation	<p>Engineer structures to prevent loss/damage</p> <p><i>Upgrade stopbanks for higher flood volume; cover orchard</i></p> <p>Stop growing sensitive cultivars</p> <p>Respond to growing season next year</p> <p><i>Plant sorghum to better withstand dry; add a fodder crop</i></p>	Crop insurance (frost, hail)
----------------------	--	---	------------------------------

Table 6.7 Selected examples of farmers' adaptive strategies based according to timing and the level of farmer control (Source: Research findings)

The strategic, long-term adaptations that were cited were primarily anticipatory management practices, some of which occur at the time of the orchard being established. Producers reduced frost risk through site selection and changing topography, by avoiding or removing frost pockets in the vineyard, or choosing to plant a variety that matures earlier in the season. The selection of varieties however, was not a decision based solely on climate; producers need to strike a balance between a variety that is suited to the climate and one that is marketable. Other strategic adaptations occurred in good years, when the farmer had the finances to invest in more efficient or risk-reducing technologies, such as a frost fan or irrigation. This is an example of a strategic adaptation adopted in response to opportunistic conditions to deal with problematic exposures.

The variety of adaptations cited by producers partly reflects the heterogeneity of individuals' decision-making options, but it also indicates the differential capacity of producers to adapt. This capacity varies by the type and size of operation, and by the risks being adapted to. Dairy farmers, it was shown, have a much broader range of adaptive strategies for dealing with climatic conditions, than do drystock farmers or horticultural producers. Adaptive capacity is also a function of several determinants, including the availability of financial resources, technology, and government policies (refer to *Figure 2.3*). During drought conditions, for example, dairy farmers are able to bring in supplemental feed which can enable them to continue milking, they may also have access to a 'summer-safe' runoff, or in some cases have the option of stopping production in order to preserve animal health for the following season. Drystock farmers have a much more limited range of options to contend with adverse climatic conditions, and most often, resorted to selling stock to relieve pressure on remaining supply.

Adaptive strategies in agriculture are rarely made in response to climatic stimuli alone. A change in feed and management system might be prompted by exposure to climatic conditions, but it is experienced as a drop in production and farm income. As this farmer notes, the addition of a meal-feeder is in response to both climatic and financial risks:

We'll have about a 12 to 14% drop in production this year because of the drought which is pretty big, about 20,000 kilos, at seven dollars a kilo: it's a lot of money. One of the things we're looking at now is putting a meal feeder into the shed, that's probably what we'll do next.

Adaptive capacity is also dynamic. As adaptive capacity increases or decreases, so too does vulnerability, through exposure-sensitivity. As one kiwifruit orchardist noted for example, there has been a steady reduction in the amount of planted shelter in the Bay of Plenty over the last decade. This has allowed for more canopy hectares, but effectively increases exposure by reducing adaptive capacity. Growers have increased production and boosted returns – reducing exposure to market risks – but are now at increased risk from an adverse or unseasonal climatic event.

Touch wood we haven't had a lot of wind at all this year, because a lot of shelter has been removed in the Bay of Plenty compared to what there used to be. All the kiwifruit used to have been planted in six or seven row blocks; most blocks, instead of the size they are now, would have only been one-quarter of the size. It was a very good way for someone to buy an orchard at two-hundred and fifty or three-hundred thousand dollars a canopy hectare, pull all the shelter out and plant it all up and make about ten-percent, increase it straight away. It was good business, but you also now run the risk of exposing your block.

Faced with significant exposure from weather-related events, pastoral farmers and horticultural producers have developed a range of short- and long-term strategies for mitigation. Producers' ability to respond to these risks is closely related to market and financial forces, as well as the strictures of the RMA and local council regulations. For some, this has reduced their flexibility, making it more difficult to respond quickly. Other growers reported investing in long-term, strategic adaptations, designed to reduce losses, and in some cases, also increase yield.

In addition to the range of adaptive responses outlined above, producer-stakeholders have also developed strategies for responding effectively to pests, and several other exposures that affect a small number of producers. Significant pests include invasive grasses and facial eczema – both of which affect pastoral farmers. At the moment, farmers described under sowing rye grass, at great expense, as a short-term strategy which may prove inadequate in the future if present warming trends continue. Facial eczema, which is common in the study area, is managed with zinc bullets and drenching. On some farms, losses have been so severe that producers have invested in selective breeding for resistance among sheep and cattle as a long-term adaptive response. Horticultural producers reported problems with scale and leaf roller, both of which were treated with regular applications of pesticide, or oils. The other significant class of adaptive strategies, described by farmers during the course of the research, are those that have been developed to respond to market and financial risks. For a number of producers, climatic conditions and market forces are the most significant sources of exposure, and many of the strategies used to adapt to climate, also have co-benefits, in reducing market risks as well.

The documentation of current adaptive strategies shows that farmers currently have the capacity to deal with certain climatic and non-climatic exposures identified in the previous chapter.

Technologies are available to enhance farmers' capacities, although their adoption is influenced by other non-climatic conditions or constrained by the availability of financial resources. There are limits to the effectiveness of some management practices, however, and production and yield, and financial losses do occur. The findings suggest that adaptation can indeed reduce the negative effects of climate-related risks, and will be important for reducing the negative effects of climate change. In general it seems that dairy farmers currently have a higher capacity to cope with, or lower vulnerability to, risks that affect the production and yield than do drystock farmers and kiwifruit growers. Kiwifruit growers are also exposed-sensitive to the quantity of a crop yield (frost and winter) as well as those conditions that affect quality (cool temperatures, cloudy days, pests and disease, wind), and hence the ability to compete in the market. Producers' vulnerability will vary between operations due to the unique characteristics of both exposure to stress and the availability of resources, technologies, and capital that influence their ability to adapt. This discussion also shows that adaptive capacity is dynamic. As producers change farming practices in response to climatic events, their capacity to deal with similar events in the future also changes. Drawing on this assessment of current vulnerability then, what can be said of the future vulnerability of pastoral farmers and kiwifruit growers in the eastern Bay of Plenty to anticipated changes in climate?

CHAPTER SEVEN: Future vulnerability to climate-related risks

7.1 Introduction

When we were starting out we had government guarantees – all that sort of thing has gone; twenty-five years ago we were cutting down native bush and turning it into farm land – all that sort of stuff has gone, completely turned about. The last twenty-five years have probably seen more changes in farming practice than ever before. There's been some massive changes, and now the climate thing is coming into it. We've never thought about that before. We didn't think we had to save the planet the planet twenty-five years ago, we were just thinking about getting the feed.

- Dairy farmer, Waimana Valley, New Zealand

Agricultural producers in the eastern Bay of Plenty are exposed-sensitive to a wide-range of climatic and non-climatic conditions. As shown in previous chapters, flood, drought, climatic variability and extremes, fluctuations in commodity price and input costs, all influence production and yield and financial returns at the scale of the individual farm or orchard.

Producers have developed a range of short- and long-term adaptive strategies in response to many of these risks. Both exposure-sensitivity and adaptive capacity continue to be shaped and influenced by conditions internal and external to the farm at a range of scales and comprise producers' current vulnerability. Current vulnerability however, is also situated within the context of dramatic changes in the linked social, economic and environmental systems producers constitute and operate in, as illustrated by the quote from the dairy farmer above. Climate change will not occur in isolation. The “legacy effects” (Liu et al. 2007) of draining the Rangitaiki swamp and agricultural restructuring of the mid-1980s continue to exacerbate stressors to which farmers and growers are exposed-sensitive, years later. It is within this context of dynamic exposure-sensitivity and adaptive capacity that climate change will be experienced by agricultural producers in the eastern Bay of Plenty.

A number of studies have identified the impacts of climate change on various components of agricultural production using coupled climate and plant or crop models (Iglesias & Minguéz 1997; Bindi et al. 1999; Huntingford et al. 2005) in different areas, often focusing on limiting conditions such as temperature increases and the likely impact on yield (Iqbal et al. 2006; Junk et al. 2011). More recent model-based analyses have begun to account for social factors, drawn from national or regional statistics such as household income, in conjunction with a climatic stressor to derive an index or measure of vulnerability (Döll 2009; Iglesias et al. 2010). Nelson et al. (2010b) for example, have used a combination of impacts-based hazards assessment and more holistic measures of livelihood analysis to assess rural vulnerability. Combining the five socioeconomic indicators of rural livelihood capital from which livelihoods are drawn (human, social, natural, physical and financial) together with modelled changes in rainfall and pasture growth, the authors developed an index of future vulnerability for rural communities in Australia. These ‘outcome vulnerability’ (O’Brien et al. 2007) studies however still are unable to account for the interactive effect of multiple climatic and non-climatic exposures.

The following analysis seeks to develop a more contextual understanding of producers’ vulnerability to future climate change. While changes in climate are likely to exacerbate several of the conditions to which they are sensitive, the degree to which farmers and growers are vulnerable will also be a function of their capacity to deal with these changing exposures. Future adaptive capacity will be related to the opportunities and constraints evident in current adaptation processes and how these might be moderated by changes in society, economy and its institutions.

The analysis draws upon the empirical assessment of current vulnerability developed in the previous chapters, scenarios of future climate change and insights from producers regarding their awareness of climate-related risks, opportunities and capacity to adapt to changing conditions. It analyses the extent to which expected future climate change will alter the nature of the identified exposures and in what ways the socio-ecological system, represented by farmers and growers, has the capacity to deal with these changes (Smit & Wandel 2006). Consistent with the conceptual framework developed in Chapter 2, future vulnerability is understood to be a function of exposure-sensitivity and adaptive capacity (*Figure 7.1*, overleaf). Future exposures relate to conditions which are expected to represent risks or opportunities to the community, both those identified by the community and potential conditions (such as those from climate scenarios) that may not yet be realized or problematic to the community. Assessment of future adaptive capacity is based on insights from past and current adaptations and from expected changes in the resources and assets that facilitate or constrain adaptation (Brooks et al. 2005; Pelling et al. 2008; Gupta et al. 2010; Engle 2011)

The chapter begins with a review of those climatic variables most likely to change with continued GHG emissions. Climate models generally estimate future changes in climate over specified time periods (for example 10, 50, 100 years). These estimations are useful for understanding potential future changes in temperature and precipitation and their associated effects. This section includes information from future climate models; however, it does not focus on specific future time periods but rather deals with the progression of current exposure sensitivities and adaptive capacity relative to anticipated changes in climate and society.

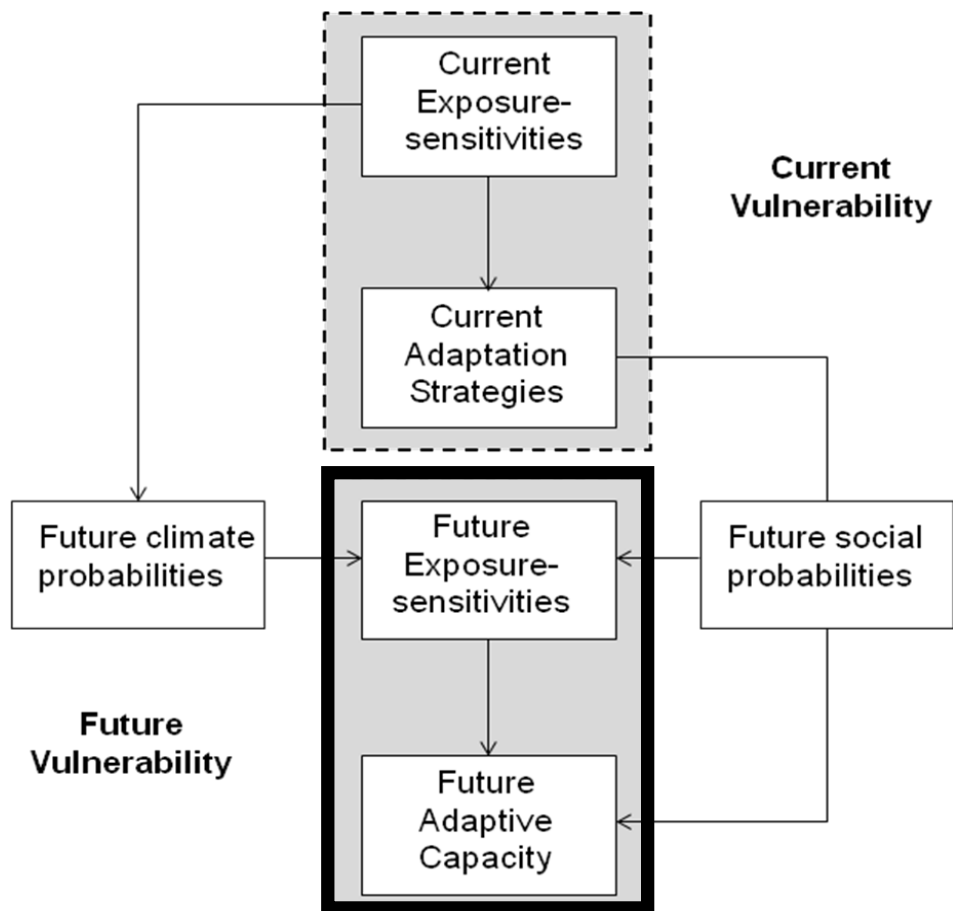


Figure 7.1 Chapter 7 shown within analytical framework used to structure thesis and empirical assessment of vulnerability in the eastern Bay of Plenty.

Future adaptive capacity is the second component of an assessment of producers' vulnerability to anticipated climate variability and change. The analysis focuses on the likely drivers of future adaptive capacity in the study area; to what extent will farmers' and growers' ability to respond to climatic variability and change, be influenced by conditions and forces beyond the farm gate? It also explores producers' awareness of the risks associated with future climatic variability and change, because if climate change is not perceived as a problem, producers may be less likely to prepare for it in advance (Bardsley & Edwards-Jones 2007; Battaglini et al. 2008; Deressa et al. 2011; Frank et al. 2011).

7.2 Future exposure-sensitivity

Yes I'm concerned about climate change, because long-term it's disastrous... it's having an effect on a lot of things around the country and it's not a thing that's being measured. Might turn out to be climate change on inspection but instead people just say "Oh it's just a bad year". But it's not quite a bad year; it's an effect with some other causes. It's there and it's happening.

Used to be you had two bad years out of ten, now you're getting two good years out ten.

– Dairy farmer, Rangitaiki Plains, New Zealand

As illustrated by the quote from the dairy farmer above, vulnerability is dynamic, shifting temporally and spatially in response to changes in exposure-sensitivity and adaptive capacity (Smit & Wandel 2006; Füssel 2007; Ford et al. 2008; Meza & Silva 2009). Future exposure-sensitivity to changes in climatic conditions will continue be influenced by other, non-climatic stressors as well as producers' responses (Belliveau et al. 2006; Pearce et al. 2010; Blazejczak et al. 2011). Climate change will not be experienced in isolation, rather within the broader context of social, political, economic and environmental conditions (Turner et al. 2003; Leichenko & O'Brien 2008; Wilbanks & Kates 2010). In order to assess future exposure-sensitivity to climate change, studies elsewhere have drawn not only on scenarios of future climate, but also trend analyses and probabilities of change as well as insights from stakeholders regarding their awareness of potential change and risks (Keskitalo & Kulyasova 2009; Gamble et al. 2010; Manandhar et al. 2010; Deressa et al. 2011). By accounting for the influence of both climatic and non-climatic influences on exposure-sensitivity, a locally-derived and contextual portrait of future exposure-sensitivity can be derived. While some elements of exposure to climate change are difficult to quantify directly, the empirical assessment of current vulnerability developed in Chapters 5 and 6, is used here as the basis for an investigation of future vulnerability.

7.2.1 Future climate scenarios

The analysis of future exposure-sensitivity begins by extracting insights from existing climate scenarios for the Bay of Plenty. These estimate changes in variables found in traditional climate studies, such as average temperature and precipitation, as well as changes in variability and extremes including hot days, frost-free days and severe winds. Key sources of projections under climate change are Griffiths et al. (2003), MfE (2008) and IPCC (2007). A climate scenario refers to “a plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models” (IPCC 2007, p.78). Climate scenarios have been used as the basis for comparison and analysis in other studies of future vulnerability to climate change, often in conjunction with insights from stakeholders (Reid et al. 2007; Keskitalo & Kulyasova 2009; Young et al. 2009; Hadarits 2011; Garschagen et al. 2011; Sherval & Askew 2011). In these studies, researchers have drawn on national climate scenarios and empirically derived data drawn from a community or district to identify problematic, future climate-related conditions.

The following discussion outlines the changes in the regional climate of the Bay of Plenty that are expected to result from global anthropogenic emissions of greenhouse gases and aerosols. Data are drawn from projections from the General Circulation Model simulations prepared for the IPCC Third and Fourth Assessments and published in Griffiths et al. (2003) and MfE (2008). Modeled changes were statistically downscaled as per Mullan et al. (2001) to provide spatial detail over New Zealand (MfE 2008), and further downscaled to the Bay of Plenty region (Griffiths et al. 2003). While the results discussed are for the entire Bay of Plenty – as opposed to

the districts covered by this study – the changes in climatic conditions and variability provide a useful scenario with which to assess future exposure-sensitivities among pastoral farmers and kiwifruit growers.

Climate projections for the Bay of Plenty indicate warmer temperatures, consistent with those predicted for much of eastern New Zealand and hotter, drier conditions (MfE 2008). The Bay of Plenty warms by an average of approximately $+0.80^{\circ}\text{C}$ by the 2030s, and by about $+1.80^{\circ}\text{C}$ by the 2080s (Griffiths et al. 2003). There is widespread variation in the predicted temperatures. This is a limitation of current global and downscaled models of future climate (Jacques 2006; Moss et al. 2010). There are marked changes in rainfall predicted (Mullan et al. 2005).

Precipitation in New Zealand is strongly influenced by ENSO/IPO (Salinger et al. 2001; Folland 2002) including variability and extremes (Ummenhofer & England 2007). Changes in precipitation will be superimposed on existing inter-annual and inter-decadal variability. There is also significant variation in precipitation within the regional council region and the study area (see *Figures 3.3-3.6*) and so while rainfall projections for the Bay of Plenty have been provided for Tauranga, they are valid only for that location (Griffiths et al. 2003) but can be used to infer a sub-regional trend.

For the Bay of Plenty, changes in rainfall are likely. By the 2030s, annual precipitation may decrease by as much as 15%, varying seasonally from a slightly wetter winter to a much drier spring and summer, with implications for both pastoral farmers and kiwifruit growers. By the 2080s, the drying trend evident in the 2030s in summer and autumn has reversed. Summer rainfall for the Bay of Plenty is projected to return to near the current climatology, with increased

flow in the westerly winds. Autumn is also wetter than currently by the 2080s, and winter also slightly wetter than the 2030s. Spring is expected to continue to get drier and by the 2080s spring rainfall is projected to be about 10% lower throughout the district (Griffiths et al. 2003).

Projections of changes in climatic conditions for the study area are summarized in *Table 7.1*.

Climatic variable	Data source		
	Griffiths et al. (2003)	MfE (2008)	IPCC (2007)
Temperature (Δ in °C)	0.80 (2030), 1.80 (2080)	0.9 (2040), 2.1 (2090)	0.2 to 1.4 (2030s), 0.5 to 3.8 (2080s)
Summer	0.0-1.2, 0.3-3.8	1.0, 2.2	
Autumn	0.1-1.3, 0.4-3.9	1.0, 2.2	
Winter	0.4-1.6, 0.8-4.2	0.9, 2.0	
Spring	0.2-1.2, 0.4-3.6	0.8, 1.8	
Precipitation (Δ %, Tauranga)	(9)-2, (15)-2	(1), (2)	(19) to +7 (2030s), (32) to +2 (2080s)
Summer	(10)-4, (7)-19	2, 2	
Autumn	(16)-4, (18)-15	3, 2	
Winter	(5)-7, (2)-9	(4), (3)	
Spring	(20)-8, (41)-(3)	(5), (9)	
Hot days >25° C		Likely increase in number of hot days	
Frost-free days	Increase in number of frost-free days		
Extreme rainfall			
Wind events	Increase in severe wind risk	Up to a 10% increase in strong winds (> 10m/s)	
Ex-tropical cyclones and mid-latitude storms	More intense mid-latitude storms		

Table 7.1 Projections of climate change in the Bay of Plenty by source, for a range of dates. (Parentheses indicate a negative change or decrease). Temperature changes are the average over all downscaling sites in the Bay of Plenty, whereas the rainfall changes are for the site specified (because of sub-regional spatial gradients) (Drawn from: Griffiths et al. 2003; MfE 2008; data from the IPCC 2007 are for the eastern North Island).

Modelled scenarios can provide estimates of changes in average temperature and precipitation, however small shifts in mean climatic conditions can result in more frequent extremes which are more difficult to quantify directly (Easterling et al. 2000). An increase in the number of hot days and extremes of temperature, more frequent strong wind events, and severe rainfall events and potentially, more severe storms are likely (MfE 2008). Frost free days in the Bay of Plenty are also expected to increase (Kenny et al. 2000a; Hall et al. 2001; MfE 2008).

In addition to changes in average temperature, a greater number of hot days above 25°C are anticipated (MfE 2008) as well as an increase in drought frequency as a function of higher temperatures and decreased precipitation (Mullan et al. 2005). The drying of pastures in eastern New Zealand in spring is very likely to be advanced by one month, with an expansion of droughts into both spring and autumn (MAF 2011). Daily temperature extremes (overnight minimum and daily maximum) will also likely vary with regional warming (Griffiths et al. 2003).

The mean westerly wind component across New Zealand is expected to increase by approximately 10% of its current value in the next 50 years (Mullan et al. 2001) and wind changes may further contribute to a drying trend in the eastern Bay of Plenty (MfE 2008). On a daily-basis, severe wind risk is likely to increase, as it is strongly correlated with intense convection and low-pressure systems which will be more common with a warmer climate (Griffiths et al., 2003). This may also exacerbate the risk of fire, related to dry conditions. By the 2080s, 10-50% more days with very high and extreme fire danger may be likely in eastern areas of New Zealand, including the Bay of Plenty (Pearce et al. 2005).

Other changes in climatic conditions include a likely increase in peak wind intensities and rainfall associated with tropical cyclones (Hennessy et al. 2007). Given that a warmer atmosphere is able to hold more moisture – approximately 8% more moisture per 1°C increase in temperature (Griffiths et al. 2003) – an increase in global flood risk related to extreme rainfall events is anticipated (Lenderink & van Meijgaard 2008; O’Gorman & Schneider 2009) While floods are complex hydrometeorological events, the Bay of Plenty may become more prone to such heavy rainfall (Griffiths et al. 2003). This is likely to exacerbate the existing flood-risk in the study area.

7.2.2 Future climate-related exposure-sensitivity

While it is not possible to predict the future with certainty, important insights into the nature of future vulnerabilities can be found by using current exposure-sensitivities and adaptive strategies as starting points from which to consider the implications of projected changes in climate and society (Næss et al. 2005; Ford et al. 2006; Pelling et al. 2008; Mustelin et al. 2010; Malone & Engle 2011). The results of the empirical analysis showed that across among all production systems, producers are currently exposed-sensitive to a broad range of climatic conditions including climatic variability and extremes of temperature and precipitation. In the future, especially under climate change, several of the conditions to which agricultural producers in the eastern Bay of Plenty are sensitive, are likely to be exacerbated (*Table 7.2*). The capacity of the community to deal with these changing exposures relates to the opportunities and constraints evident in current adaptation processes, and how these might be moderated by changes in the society-economy and its institutions.

Climatic variable	Current related exposure¹	Future related exposure and farm-level impacts^{1,2}
Temperature	Warm weather, timely precipitation	Potential benefit, encouraging pasture growth if sufficient moisture available
	Insufficient heat during growing season (GDDs)	Reduced exposure and opportunity; higher temperatures and drier conditions may result in growers earning higher premiums for taste/sweetness
	Warm winter temperatures	Slower grass growth in the spring Loss of natural winter chilling for kiwifruit
	High summer temperatures	Higher summer temperatures have negative effects on production and animal health, decline in yields
	Cold, wet spring	<i>N/A</i>
	Warmer average temperature/ Invasive subtropical grasses	Likely increase in distribution of subtropical C4 grasses, resulting in lower milk production in grass-based systems; associated with high costs to control spread. Warmer temperatures may also be opportunity to plant drought-tolerant grasses: lucerne, sorghum
Precipitation	Excessive precipitation	Increased problems due to pugging, associated with more severe rainfall events Increased in runoff and erosion on steeper hill country, may require change in stocking rates
	Reduced rainfall	Adverse effects on grass growth
	Wet autumn	<i>N/A</i>
	Cloudy weather	<i>N/A</i>
Climatic variability and extremes	Climatic variability (seasonal, interannual, interdecadal)	Climate change likely to exacerbate existing variability and result in more frequent extremes
	Flood conditions	Severe rainfall events are more likely, increased flood risk for lowland farmers

Climate-related biotic and biophysical exposures	Frost	Number of frost-free days likely to increase, reducing frost risk. However, warmer temperatures may encourage budbreak, increasing length of time to which vines are exposed to unseasonable late-frost. Frosts effective in "knocking back" unwanted grasses and other pests; fewer frosts may have adverse impact on pasture Unclear whether increase in frost-free days will reduce exposure-sensitivity to unseasonable frost for horticultural producers
	Hail	N/A
	Strong winds	Potential for increased severity in Westerly flow; high winds effect kiwifruit vines, reduce yields
	Ex-tropical storms	May increase in frequency/severity
	Livestock diseases	The incidence of facial eczema may increase with higher humidity due to warmer temperatures
	Pest infestation	Existing pests as well as new pests currently confined to Northland (clover root weevil, clover flea), may become more prevalent.
	Variable water table	May be more fluctuation in water table due to rainfall patterns, adversely effecting kiwifruit production
	Salt-water intrusion	Modest sea-level rise may affect low-lying areas, and increase exposure to salt-water intrusion on Plains, especially if irrigation demand increases pressure on existing supply

Table 7.2 Table shows current climatic exposure-sensitivities identified by producers¹. Future impacts are drawn from climate change scenarios, impacts-based studies² and insights from producers¹. N/A indicates there is no clear change, or insufficient data to not a change. (Drawn from: Research findings; MfE 2008; Griffiths et al. 2003; McGlone 2001; Kenny 2006; Kenny et al. 2001; White et al. 1997; Green 2006²)

The following analysis draws on insights from producers and the empirical assessment of current exposure-sensitivity to climatic conditions as well as a range of published scientific literature. Studies identifying some of the impacts of climate change on New Zealand agriculture have already been completed. However, while these are able to determine some of the potential impacts with respect to crop suitability, the distribution of plant species (Field & Forde 1990; Clark et al. 2001; Dynes et al. 2010), or the direct impact on yield (Wilson & Salinger 1994), they neglect to capture the context or significance of other climatic and non-climatic exposures pertaining to producers' vulnerability. The following discussion explores future climate-related risks according to the climatic variables (temperature, precipitation, and changes in variability and extremes) most relevant to farmers and kiwifruit growers in the eastern Bay of Plenty, and where applicable, seeks to account for the influence of other, non-climatic stimuli on exposure-sensitivity.

7.2.2.1 Changes in temperature

According to model scenarios, a trend towards hotter and generally drier conditions is expected for the eastern Bay of Plenty (Griffiths et al. 2003; MfE 2008). These climatic changes may increase certain exposure-sensitivities among farmers and kiwifruit growers. Climate change may also bring opportunities as well risks. Sensitivity to future climate-related exposures will also continue to be influenced in turn by non-climatic stimuli (Belliveau et al. 2006; Bradshaw 2007; Reid et al. 2007; Biggs et al. 2011; Iglesias et al. 2011). For pastoral farmers, one of the most significant sources of future exposure-sensitivity related to changes in temperature will be the likely increase in the range and distribution of subtropical grasses and weeds and biotic pests and for kiwifruit growers, the loss of natural winter chilling.

New Zealand farming is based on a small number of pasture plant species and this number has reduced with intensification (Williams et al. 2007). Scenarios project an increased drought risk and drought severity for eastern regions, including the study area (Tait et al. 2008). Wedderburn et al. (2010) showed that under successive drought conditions, ryegrass root systems sustain significant damage. Future changes of climate and carbon dioxide concentrations may lead to changes in pasture composition and feed quality for animals (Newton et al. 2006).

There is evidence for southward movement of exotic *Paspalum* grasses during warm periods in the past (Field & Forde 1990) and they have become established in the Bay of Plenty where they are increasingly problematic. As noted in Chapter 5, pastoral farmers have identified the presence of subtropical (C4) grasses – *Paspalum dilatatum* and kikuyu grass (*Pennisetum clandestinum*) in particular – as having a negative effect on production. These grasses have low nutritional values and can out-compete rye grass in the pasture (Crush & Rowarth 2007).

Analysis derived from model outputs and test plots show that with further increase in mean temperature, the range and distribution of C4 grasses will likely increase (Field & Forde 1990; Kenny 2006) and was identified by a number of pastoral farmers as being a significant source of future exposure.

Producers earlier described the problems associated with keeping these grasses under control. Most significantly, the costs associated with pasture management and production losses. Climate change and an increase in the distribution of C4 grasses then, is not simply a climate-related exposure but will be felt in conjunction with other, non-climatic pressures. One dairy farmer who

described an increase in the distribution of kikuyu on their own farm and anticipated it being problematic in the future noted:

Do I see it as a risk? It could be a risk to New Zealand farming if it became sort of more widespread, I guess mentally I don't put it in the risk bracket so much as an expense. It is a risk because on a low payout you can't afford to do all the things we're doing to manage it, and it makes you not very competitive – you're getting the same price for your milk as everyone else but you're having to do all this tractor driving, mechanical control spraying, contractors to manage your pastures as opposed to just having the cows go into pastures, eat it, and have them turn it into milk.

Keeping pastures free of these grasses requires input of labour, as well as time on the tractor.

Other inputs include grass seed, fuel and fertilizer. If both fuel and fertilizer prices continue on an upward trajectory, as many analysts believe (Vaccari 2009), pastoral farmers trying to control their exposure to subtropical grasses will in a sense be 'double exposed' to both decreased production associated with these grasses as well as the higher input and management costs, reducing overall profitability. As this drystock, hill country farmer said:

The climate definitely has changed in the time that we've been here, which is going to become a bigger threat. The one for us is *kikuyu* grass which is, they call it a C4, warm climate grass. There was a little bit here when we came here, but the frosts in the winter – because the winter was more severe, really knocked it back – and so it didn't spread much, and it wasn't a specific pasture management issue, where it is now. In fact it's quite widespread on the farm. It doesn't grow in the winter, and it grows too fast in the summer and it's got low ME, we can't economically get rid of it, and so that's altering the way we have our livestock mix. On hill country – you can helicopter in and spray it, but to get something established in its place? Like you've got all sorts of weed problems, and if it's a dry northern face, the other species aren't going to compete anyways.

While there are alternatives to pasture, as this dairy farmer, notes it is a question of whether or not it is economically feasible to do so. “If the climate changes on you, it means that grass production is changing, that’s the one that relies on the sun and the rain for free. You know you could buy in other stuff but then that’s all just relative to milk price”. This demonstrates, once again the not only the limitations of simply projecting an increase in the distribution of C4 grasses but also the need to consider the broader implications.

In addition to the spread of subtropical grasses, warmer temperatures may also lead to new or more pest outbreaks. Producers noted that pests which were prevalent in other, warmer parts of the country were now becoming problematic in the eastern Bay of Plenty. “Black beetle is another issue, and again, it’s climatic. A lot of this stuff again, is all Northland, it’s a Northland problem and it’s I think, warmer winters and droughts and things, so we’re getting it here”, said one dairy farmer. Clover root weevil and clover flea might also become problematic with warmer temperatures. Producers may also be more vulnerable to pests given the higher management costs and the lack of previous experience in dealing with them. Facial eczema, which is already prevalent in the Bay of Plenty, flourishes under warm, humid conditions (Smith & Towers 2002). This too may become more problematic for pastoral farmers as temperature and humidity increase.

It is not only increased summer temperatures that are likely exacerbate current-exposure sensitivities for agricultural producers, but changes in winter temperatures also. Climate scenarios indicate that the greatest warming will occur during the winter months and the number of frost-free days will increase (Griffiths et al. 2003). Cold winters were noted by a number of pastoral farmers as having several benefits: cold temperatures inhibit the spread of subtropical grasses and other pests, as well as providing a boost to grass growth in the spring. “If you get a real cold hard winter, then when the grass grows it just blooms away”, said one pastoral farmer. Warmer winter temperatures therefore are likely to be a negative climate change-related impact. For pastoral farmers – particularly those on grass-based systems – good spring pasture growth is essential (Verkerk 2003) and warmer winters may result in lower production, and overall returns. As this dairy farmer in Opotki describes the future:

I think it’s definitely got warmer, and I’m sure there’s less frosts – which is probably a bit of a negative really... *Why is that a negative?* It seems to stimulate the growth patterns when spring actually comes, but when the winter’s too warm it just doesn’t really come... it’s a bit more like Northland’s climate and grass production in Northland’s generally a lot lower than it is here. Rye grass is designed to grow in about eighteen degrees – too many years above that, and well... not really that good and we end up growing more of this gunky summer grass, and it’s got low nutrient value. So we’re creating a better environment for it. So that’s a negative.

High summer temperatures and the number of days with temperatures exceeding 25°C are also expected to increase (Griffiths et al. 2003). Inland areas, such as Kawerau, away from the moderating influence of the water, may experience greater temperature extremes in temperature. With respect to current exposure, one dairy farmer noted that: “The biggest thing for us is, in the summer, is the heat, because the cows lose their appetite and we get a real drop in production, when it gets hot”. This has been supported by research overseas (Kadzere et al. 2002; West 2003) in which high temperatures were also shown to have adverse effects on animal health, including

reduced feed consumption and declines in production, as well as reproduction (Pennington et al. 1985; Gwazdauskas et al. 1986) . As one farmer noted rain also “has an effect on your reproduction – if you have a lot of cloudy days in the spring, reproduction drops generally”. Exposure-sensitivity can be reduced, and important adaptive strategies might include herd homes or additional on-farm shading. Tucker et al. (2007) have shown that shelter provides benefits for dairy cows in winter in the winter at least. Shelter is regarded by producers as an important adaptation, as this dairy farmer stated:

I think the other threat is that climate. It’s getting hotter and cows don’t like heat. I keep thinking am I going to have to shade top one-hundred and forty hectares so my cows can sort of stand off? I know a guy down our way, has already put a shade over the yard.

Decreased production however, reduces farm income, in turn limiting the capacity of farmers to invest in expensive technological adaptations.

Horticultural producers are also likely to be impacted by future climate change in several ways. The area suitable for horticultural production is likely to decline by the 2040s and 2050s (Kenny et al. 2000b) and warmer temperatures in the northernmost areas of the country may make kiwifruit production uneconomic, as growers will be unable produce sufficient fruit to remain profitable (Hall et al. 2001). As with other climate-related exposures, the effects of warmer temperatures will not be strictly biological or phenological. Growers noted rising input costs – particularly labour – were among the non-climatic stressors to which they were currently exposed sensitive. Richardson et al. (2004) have shown that over successive seasons, higher temperatures result in kiwifruit vines producing excessive vegetative growth at the expense of fruit growth and quality. Greater vegetation and less fruit, as this grower notes, would mean much higher labour costs: “The problem is, once you have a low crop you have very high labour

costs, because you get a lot more vigour because the plant hasn't got anything to slow it down so it's just going". In this case, higher average temperatures due to climate change affects long-term plant growth but is experienced by orchardists as a decline in production and yield as well as a rise in input costs. A climate-change related exposure exacerbates an existing non-climatic stressor; vulnerabilities not recognized or accounted for in strictly biological or model-based impact studies.

Another source of risk associated with warming temperatures, particularly in the winter time, is the loss of natural winter chilling, essential for kiwifruit production. As noted earlier, horticultural producers currently rely on hydrogen cyanamide (HC) to compensate for the effects of warm winters and encourage flowering (Linsley-Noakes 1989). In some growing areas, kiwifruit is only viable using HC as winter temperatures are already too warm and it is required to compensate for variable chilling for Hayward kiwifruit. Warmer temperatures are likely to increase this reliance.

This is not only a potential climate-related risk. As shown in Chapter 5, changes in policy and legislation – both nationally and internationally – can increase producers' exposure-sensitivity to climatic conditions. The use of HC has become a highly politicized community issue in the Bay of Plenty in recent years (Usmar 2009) and has been banned by the European Union for use there. As discussed earlier, audit schemes such as GLOBALGAP have the power to dictate the terms of agricultural production for New Zealand farmers wishing to sell into European supermarkets (Campbell 2005; Rosin 2008). A number of growers identified the potential loss of HC as a significant future exposure. Said one grower:

There's a chance we won't be able to use *HiCane*; so the climate change issue – well, I've always been quite confident that “Oh well they can grow it up in Northland”, and my perception of climate change is two degrees difference and that's the difference between Northland and here and so we'll be able to cope. But the industry up there is totally reliant on *HiCane* because they don't get sufficient cooling in the winter... and my feeling here is those European growers are going to say “Well why are you importing New Zealand fruit? They're still allowed to use *HiCane*”, so I wonder, long-term, if we're going to have it. It would be a lot more dramatic if we didn't have that product available to us.

Pressure is being applied on New Zealand growers to discontinue its use the basis of public health risks and environmental concerns (Usmar 2009). As with other exposures then, this is a climate change-related risk, influenced by other, non-climatic stimuli. Although there is currently no suitable replacement, considerable effort is being made to find a more acceptable alternative. Kiwifruit growers are also currently exposed-sensitive to the risk of unseasonable frost. It is unclear whether the increase in the number of frost free days will in fact reduce exposure to frost and subsequent vine damage. Warmer winters may encourage an earlier bud break, exposing the kiwifruit vine to the chance of a late, unseasonal frost event. The area planted in kiwifruit is also expected to decline rapidly after 2040 (Kenny et al. 2000).

New horticultural pests might also become problematic. Under the current climate, only small areas in the north are suitable for the oriental fruit fly, but by the 2080s it is likely to expand to much of the North Island, including the Bay of Plenty (Stephens et al. 2007). The area of the Bay of Plenty that is suitable climatically, for the distribution of woolly nightshade, a fast-growing pest weed, might also increase 2.5-times by 2080 (Kenny 2006). Pests are typically associated with higher input costs of labour and pesticides, which may make kiwifruit production less economic, increasing the market pressures on growers.

In addition to the changes in exposure-sensitivity outlined above, changes in climatic conditions may also present opportunities for some producers. Pastoral farmers, for example, currently identified long, hot growing seasons as beneficial. As long as there is sufficient water available for irrigation, the higher temperatures have the potential to increase grass growth. Research has also shown that higher concentrations of carbon dioxide may have a beneficial effect on pasture growth under certain soil conditions (Ross et al. 1996). Western and southern parts of New Zealand may see increases of 10 to 20% by 2030 due to higher carbon-dioxide concentrations and fewer frosts by 2030 (MfE 2001). This increased pasture cover would likely be of greatest benefit to those producers operating a low-cost, all-grass system. Eastern New Zealand and Northland, however, are likely to experience an increase in the frequency of droughts (Mullan et al. 2005), this will have adverse effects on pastoral farmers as shown earlier, who are currently exposed-sensitive to these conditions. High temperatures and dry conditions result in a sweeter kiwifruit with higher dry-matter content (Ferguson 1991). While growers earn a premium for fruit quality, as this discussion has shown however, declines in production will likely make up for the shortfall in orchard gate returns.

7.2.2.2 Changes in precipitation

Estimated changes in precipitation also have negative implications for producers. Reduced rainfall will likely increase stress on pasture. Research by White and colleagues (1997) has shown that stressed pastures are in turn more susceptible to colonization by invasive grasses. As described above, the increase in C4 grasses is likely pose a significant source of future exposure-sensitivity for pastoral farmers and represents not only a climate related risk, but affects farm income and is correlated with higher input costs and reduced production and income. Given that climate is predicted to be drier for the area, this will likely further increase the susceptibility of pasture to colonization. Rainfall intensity may increase, though total precipitation declines. This may have important implications for groundwater recharge. Groundwater supplies globally are vulnerable to increased temperature and demand due to climate change (Döll 2009). Locally, higher demands on irrigation – supplied by groundwater – will likely increase exposure-sensitivity. As this kiwifruit grower notes:

If it got warmer and the water dried up that would mean big changes to farming. We take water for granted in New Zealand, and I think that's a big worry, that's the one thing – we wouldn't be able to grow kiwifruit without the underground water. Thirty-thousand litres an hour I'm pouring on, running for 12 hours a day, I take it for granted – it's there.

Groundwater resources in the study area not clearly understood (White 2005). Demand on groundwater supplies in New Zealand is increasing as dairy farms intensify production through higher stocking rates and irrigation (MacLeod & Moller 2006; Basset-Mens et al. 2009), trends also evident in the Bay of Plenty. Since irrigation is also used as frost protection by kiwifruit growers any reduction in available groundwater supply would reduce those producers' capacity to adapt as irrigation is an adaptation to both dry conditions as well as frost risk.

Severe rainfall events were also identified by producers as being problematic. When dairy cows are left standing in saturated fields, they can destroy pasture cover (Nie et al. 2001). If there are have been significant changes in the composition of pasture, there may be increased soil compaction as animals graze for longer periods to eat sufficient grass, decreased interception and drainage and therefore more frequent problems with pugging (Pande et al. 2000).

7.2.2.3 Changes in variability and extremes

Though difficult to predict using current climate models (Easterling et al. 2000; Tebaldi et al. 2006; Fischer & Schär 2008) a shift in the distribution and variability of climatic extremes is also likely to be problematic for farmers and growers. Griffiths et al. (2003) suggest an increase in the severity of rainfall events. This would likely alter flood-risk on the Plains and adjacent valleys. As noted above, pugging would be more problematic if rainfall is concentrated into shorter periods of time, overwhelming the soils' capacity for drainage. Changes in precipitation may also increase fluctuations in the water table on the Plains, a current exposure for kiwifruit growers. Increased drought frequency is very likely in eastern areas (Mullan et al. 2005), with potential losses in agricultural production, particularly for dairying and dry stock farmers. In Chapter 5, current climatic variability was shown to have a significant impact on farmers; many of whom described installing irrigation or shifting production systems as a response. Estimates from MAF (2007) indicate a drop in export revenue from milk production to between 85-90% of the 1972-2002 average for the 2030s, and 83-93% by the 2080s. Similarly, sheep/beef production is also expected to decline. The effects of changes in climate on flood and drought frequency will be further modulated by phases of the ENSO and IPO (McKerchar & Henderson 2003).

According to model scenarios, an increase in severe winds is also likely (Griffiths et al. 2003; MfE 2008). Kiwifruit growers described their exposure to extreme wind events, which can damage fruitlets and vines, resulting in declining production and increased labour and input costs to restore the orchard to full production. Changes in sea-level due to climate change, while difficult to predict, are inevitable (Nicholls et al. 2010). Recent evidence from the South Island of New Zealand shows a significantly higher rate of sea-level rise during the 20th century as compared with preceding centuries (Gehrels et al. 2008). Low-lying coastal areas and settlements are the most vulnerable to changes in sea-level rise (McGranahan et al. 2007). Much of the Rangitaiki Plains is currently below sea-level and requires pumping. Sea-level rise therefore will likely increase flood risk and pumping costs. “Gravity’s not going to work as well at getting rid of excess water” noted one dairy farmer. Some productive agricultural land has already been abandoned due to saltwater intrusion on the Plains. Contamination of coastal aquifers has been shown to increase with changes in sea-level (Werner & Simmons 2009).

7.2.3 Summary

While there are limitations to relying on climate projections for insight into future vulnerability, it is clear from the discussion above that a number of the conditions to which producers are currently exposed-sensitive will increase in severity and/or frequency. Changes in temperature and precipitation, drought, flood and other climatic extremes will impact agricultural producers to varying degrees, according to the type of commodity produced and the characteristics of the individual farms and orchards.

The use of climate projections captures many of the climatic conditions identified as significant by producers, particularly with respect to climatic variability and extremes, however certain vulnerabilities can be overlooked. For example, variability and extremes occurring at the beginning or end of the growing season means that the chance of frost damage is not necessarily decreased. If the season begins earlier in the spring, bud break will also occur earlier, at which time kiwifruit vines are actually more sensitive to frost. More variable weather could also imply that the likelihood of cold and wet periods or cloudy days will not necessarily be reduced with climate change (Griffiths et al. 2003). Cloudy, rainy days affect reproduction in dairy cows (Pennington et al. 1985; Gwazdauskas et al. 1986). If farmers had more “empties” (cows that do not come into calf) this would result in decreased milk yield. Kiwifruit production is also exposed-sensitive to a wider range of climatic conditions that affect fruit quality as well as yield and these are not always accounted for in climate scenarios. The full extent of exposure-sensitivity to changes in climatic conditions then may be difficult to fully describe.

Most importantly however, one cannot rely solely on these projections because the non-climatic conditions found to influence vulnerability will also change in the future. Although this chapter section has addressed the potential changes in climatic conditions due to the climate change focus of the research, changing market, government, economic, technological, and farm-level factors may have an equally important influence on farmers’ and growers’ future vulnerability. Significant increases in agricultural input costs are likely. For example, economic scenarios project an increase in world fuel prices over the long-term (Shafiee & Topal 2010) which will affect agricultural producers, particularly high-input dairy farmers as “feeding out” uses up tractor time. A related concern for high-input dairy farmers may be the expansion of the biofuels

industry. Several farmers noted that the expansion of ethanol production in the EU and US resulted in higher prices for maize, which is used as a supplemental feed. As this farmer noted, “Bush said we want to have twenty-percent biofuels, and suddenly PSSHEWW! Something totally out of your control... A lot of food-producing land is now being used to make petrol for a few Westerners that can afford it – it just doesn’t make sense”. Studies have suggested this trend is likely to continue as alternatives to fossil fuel use are developed (Mitchell 2008; Rozengrant 2008; Balat & Balat 2009). This puts pressure not only on maize prices, but also fertilizer prices which are another key input for pastoral farmers.

The decline in supply of phosphorus, a critical ingredient in fertilizer is another important trend which is likely to have a significant effect, particularly on pastoral farmers, in the future. Readily available supplies are decreasing as demand continues to increase (Cordell et al. 2009; Vaccari 2009). Rising pressure on prices was earlier shown to be a key source of market-related risk for producers in the eastern Bay of Plenty and if climatic conditions trend towards hotter and drier, producers will require greater inputs in order to maintain soil fertility and production. This will further increase exposure-sensitivity to any further rise in price. A recent news item from the Hawkes Bay, in eastern New Zealand, described the toll high fertilizer prices and successive drought years were already having on drystock farmers there (Smith 2009) Some farmers have eliminated fertiliser inputs until price drops, however skipping fertilisation for longer than one or two years means running a significant risk to pasture quality.

Future farm-level exposure-sensitivity will also be influenced by adaptations made in light of climate change or other risks. Adaptive responses can influence future vulnerability and may be a result of the development of new technologies or changes in government support programmes or policy. The following section outlines some of the anticipated drivers of future adaptive capacity that are likely to influence agricultural producers in the region. While it is beyond the scope of this study to predict with accuracy the degree to which these are likely to drive future adaptive responses, it is possible to estimate broad trends and point to some of the benefits and barriers to future responses to climatic variability and change. As with non-climatic influences on exposure-sensitivity, these are subject to much uncertainty. Adaptive capacity is dynamic and continually evolving conditions in response to external forces (Smit & Wandel 2006; Gallopín 2006; Hanson et al. 2007; Meza & Silva 2009; Engle 2011).

7.3 Future adaptive capacity

Future vulnerability to climatic conditions is related both to future exposure-sensitivities and to the capacity of individuals, communities or systems to adapt to those conditions (Ford & Smit 2004; Füssel 2007; Prno et al. 2011). As shown in Chapter 6, agricultural producers in the Eastern Bay of Plenty have developed a range of short- and long-term adaptive strategies to manage climatic and non-climatic risks. This ability to undertake adaptations is understood to be dependent on or influenced by, a variety of conditions related to the farm itself, as well as external drivers, sometimes called “determinants” or “drivers” of adaptive capacity (Brooks et al. 2005; Füssel 2007; Smit & Pilifosova 2001). How and why people have adapted in the past provide indications about their potential to cope with changing conditions in the future (Næss et al. 2005; Pelling et al. 2008).

Factors that may influence adaptive capacity or adaptability include awareness, technology, resources, institutions, social and human capital and information and risk-management (refer to *Table 2.2* and Chapter 6). In the case of agricultural systems, adaptive capacity may also be influenced by commodity prices, financial markets, available technologies, social networks and institutional support (Smithers & Blay-Palmer 2001; Wall et al. 2007; Tarleton & Ramsay 2009). Individual farmers are also informed by the experience of others through formal and informal networks, such as field-days, farm-focus and discussion groups. Literature from a number of scholarly fields offers insights for understanding a system's adaptive capacity, including resilience, risk assessment, risk management, farm-level decision-making and diffusion-of-innovation (Rogers & Shoemaker 1971; Ilbery 1985; Carter et al. 1994; Chiotti & Johnston 1995; Kandlikar & Risbey, 2000; Meinke et al. 2009; Rodriguez et al. 2011).

The following section discusses those drivers of future adaptive capacity, together with conditions external to the farm operation that will influence farm-level vulnerability and the ability of farmers and growers to respond. It outlines the broad influences on future adaptive capacity, including drivers of future change and those internal and external elements of the regional agricultural system that are likely to facilitate or constrain adaptive responses to climatic variability and change within the study area.

7.3.1 Drivers of future adaptive capacity

Based on the results of the empirical work, a review of eastern Bay of Plenty farmers' adaptive capacity identifies a number of factors that may affect the adoption of adaptation measures and strategies. It was shown earlier that eastern Bay of Plenty farmers are very aware of existing

climate climate-related risks that affect their operations. However, they are generally unaware of or, in many cases, unconcerned about the potential effects of climate change. In part this likely reflects the conventional description of climate change as small increases in average temperature over several decades. A lack of concern regarding climate change does not necessarily increase farmers' vulnerability to future climate risks. As Chapter 6 demonstrated, farmers are continually responding to inter-annual climatic variability and employing adaptations to reduce their vulnerability to climate risks; a capacity to adapt to current climatic variability offers a certain level of preparedness for future climate changes. That capacity can be further enhanced by identifying and overcoming factors that constrain adaptation.

In addition to identifying probable future exposures and conditions to which production might be sensitive, producers were also asked for their insights into those conditions which were likely to facilitate or constrain their ability to adapt to changing climatic conditions. Future conditions are likely to be influenced by similar conditions as they are today. Those conditions external to the individual farm that are likely to influence adaptive capacity include awareness, technology, resources, social and human capital, and institutions. While it is difficult to predict with accuracy the degree to which these are likely to drive future adaptive responses, it is possible to estimate broad trends and outline some of the benefits and barriers to future responses to climatic variability and change. *Table 7.3* summarizes some of the factors facilitating and constraining adaptation as they relate to the broad determinants of adaptive capacity and guides the following discussion.

Drivers of adaptive capacity	Influences on adaptation	Barriers relating to adaptation
Awareness	Farmers describe weather as a very important condition influencing any year	Farmers are unaware/unconcerned about climate change
	Type of farm influences perception: kiwifruit growers most sensitive to climatic conditions	Farmers exposed to multiple stimuli (non-climatic) which often require more urgent attention (e.g. financial risks)
		Natural variability and changes in frequency/occurrence of extremes difficult to perceive, little motivation
		Faith in capacity to adapt, postpone adaptation
		Confident in local conditions (“The Bay of Plenty, will become ‘super’ plenty”)
		Generally accepting of their own limitations in the face of extreme weather conditions (“Acts of God”)
		Risk of seismic activity more immediate concern
Technology	New grass species or cultivars able to flourish in hotter, drier temperatures, more resistant to pests	Investment/research required to develop and market
	Opportunity to improve production using C4 grasses	Significant research required to improve production using grasses with low nutritional values
	Introduction of new cultivars of kiwifruit	May be associated with higher input costs
		May require change in management system - additional labour unit, or hire a manager
		May not be a technological response to climate change in immediate future
	Genetic modification	Investment, public concern over GE crops and foods

Resources	Banks are generous with farmers; access to capital	Ability to invest in adaptive strategies a function of returns, if returns decrease, investment less likely; volatile commodity prices increase financial risk, cause producers to cut costs (e.g., input costs)
	Land values have risen consistently	Demand for lifestyle blocks, people unfamiliar with climatic conditions
	Farmers and growers who are expanding their operations are able to incorporate new technology	Retiring farmers not likely to invest in changes Adopting technology is expensive, likely to be taken up only by larger operators (“The day of the little family orchard is gone, or it’s pretty marginal”)
	Owning equipment allows farmers/growers to optimize good weather; not reliant on ‘gangs’ or contractors	Poor returns influence income, ability to invest Farmers and growers reliant on contractors have less control of timing of field work
	Land base able to support diversity of agricultural production	Availability of groundwater for irrigation and frost-protection
Institutions	Climate change is on the agenda of Regional Council (BoPRC) and District Council (Whakatane)	Lack of communication/adversarial communication between Regional Council, and other levels of government regarding climate change and agriculture Emissions Trading Scheme seen as a tax on production; negative association with climate change RMA and consents are perceived barriers to innovation
	Some regulations indirectly encourage adaptation	Some in farming community do not yet perceive climate change as a risk to agricultural producers
	Farmer organizations and grower groups have established networks into farming communities	Farmers and growers receive mixed messages about climate change impacts from union and other groups

Human capital	<p>Farmers in the area have a long history of adapting to local conditions: skilled, knowledgeable, “No. 8 wire”, innovative industries</p> <p>Repeated experience with risks allows farmers to improve risk management ability</p>	<p>Aging population, fewer young people view farming as a career path, loss of knowledge?</p> <p>Some farmers don’t perceive climate change as a risk; late innovators/adopters</p> <p>Inexperience dealing with new risks (e.g., pests) limits response</p> <p>Fewer people choosing to do science degrees, barrier to future innovation</p> <p>If children don’t go into farming, or the farm is sold to outside interests (e.g. overseas buyers)</p> <p>Some may choose to stay small, restricts incorporating new technologies</p>
Social capital	<p>Eastern Bay of Plenty has an established agricultural sector</p> <p>Established social network, including agricultural organizations</p> <p>Established agricultural infrastructural and supply systems, including contractors, retailers, processing and distribution</p>	<p>Farms increasing in size: competition from large farms threatens smaller producers</p> <p>Young people not becoming farmers or growers</p> <p>Union and groups do not perceive climate change as a risk</p>

Risk management/Risk spreading	Some government support available for extreme events (e.g. flood, drought relief)	
	Some farmers have diversified operations	Modernization of agriculture encourages specialization Some farms not able to diversify, limited by biophysical conditions
	Some farmers have off-farm income	
	Pastoral farmers can feed poor crops (e.g. corn waste)	May be vulnerable to cost increases as more widely adopted
	History of risk spreading during extreme events	If extremes become more widespread, e.g. drought in 2008-2009 was across the entire North Island, may be more difficult to share risk
Information management	Budding agents (e.g. HiCane) used in kiwi fruit industry to compensate for winter chilling	Use may be banned under EU regulations, no immediately available substitute
	Farmers and growers in the Eastern Bay of Plenty have well-established adaptive strategies for managing climatic variability	Limited extension services to communicate climate change impacts and adaptation
	Internet improves access to information	Rural broadband limited New weather-related problems catch farmers without a response

Table 7.3 Drivers and barriers to future adaptive capacity and responses to climate change (Source: Research findings)

7.3.1.1 Awareness

Awareness of risks and opportunities is a key component of adaptation (Tarleton & Ramsay, 2009; Deressa et al. 2011; Belliveau et al. 2006). With respect to climate change, if farmers hold the view that climate change is irrelevant, adaptation measures are not likely to be adopted. The likelihood that an individual will adapt is in large part dependent on their perception of risk; if the stimulus is not viewed as a threat then adaptation is less likely (Hewitt 1997). Perceptions of risk are influenced by the way it is communicated and by whom (scientists, media, public agencies, leaders), and the way the information is processed or filtered by the individual (Kasperson & Kasperson 2005).

Farmers were asked broadly about what they see as future risks for their operation and later about their views of climate change. Among the future risks that were identified by pastoral farmers and kiwifruit growers were stimuli that correspond closely to current exposure-sensitivities analysed in Chapter 5. Sources of future exposure are shown in *Table 7.4*. They include greater uncertainty in markets, financial risks, changes in government policy and legislation, and growing pressure from suburban development.

Source of Future Exposure	Example of exposure
Markets and Financial	Intensification and higher input costs Loss of single marketing desk (Zespri) Labour market conditions Decreasing financial returns
Policy and Legislation	Loss of HiCane in horticultural sector Greater restrictions on nutrient/fertilizer/chemical use Emissions trading and carbon tax Restrictions on irrigation
Rural change	Family succession “Townies” and pressure from suburban development

Table 7.4 Future non-climatic exposure-sensitivities and influences on adaptive capacity
(Source: Research findings)

Producers are very aware of existing climate climate-related risks that affect their operations.

There was a high degree of climate change awareness among producers however it was most often described as a natural long-term variation in the global climate system. Illustrative of this perception is the following quote from a dairy farmer who said:

I’m not completely convinced that we’re responsible for any change in climate but in saying that the amount of emissions is probably not helping. But climate is cyclical. I get a bit annoyed when people talk about floods somewhere, and this is because of climate change, greenhouse effect and all that, and you go right back through history and there was a flood 1640 or something happened in 1400 and all that. It’s always happened. One farm is colder than the other, but every year is different.

The majority of producers also described climate change in terms of small increases in average temperature over several decades and did not associate it with changes in climatic variability or extremes. Among the pastoral farmers and kiwifruit growers that were interviewed ($n=77$), 86% did identify weather as a continued risk for the future and of those, nearly all (+90%) made specific reference to climate change.

There was some variation between different farming systems in terms of the results. While half the dairy farmers interviewed expressed concern about or identified weather-related risks as likely to be problematic in the future, nearly all of the horticultural producers described changes in weather as a likely source of future risk. The majority of dairy farmers interviewed described any observed changes in climatic conditions as natural or cyclical, and were less concerned about climate change than those in the horticultural sector. This would appear to be consistent with the findings of Reid et al. (2007), who in a survey of farmers in Ontario, Canada demonstrated that perceptions of climate-related risks from anticipated climate change varied according to farm type. In their study, awareness of future climatic risks was greatest among cash croppers, who were the most directly sensitive to current climatic variability and change and least among hog and dairy farmers (Reid et al. 2007). They concluded the reduced sensitivity to climatic conditions among those producers and the higher returns generated, shielded those producers from perceiving future climate change as a concern. Kiwifruit growers in this study have been shown to be the most vulnerable to climate-related risks. They have the greatest awareness and levels of concern about future climate change, which may influence their capacity to adapt.

Awareness and interest in climatic condition and future climate change, regardless of perceptions of the fundamental drivers, have implications for future vulnerability. Adaptation to climatic conditions is, in a sense, “no respecter of persons”. Farmers have developed a range of tactical and strategic, anticipatory and reactive adaptations to deal with their vulnerability to current inter-annual climatic variability. This is likely to continue. Experience in adapting to climatic variability also offers a certain level of preparedness for the expected effects of long-term climate change on agriculture (Wall et al. 2007; Neudoerffer & Waltner-Toews 2007; Tarleton &

Ramsay 2009). There are some government programs offering financial assistance that provide support following weather-related disasters, however it remains to be seen whether these will continue to be viable if weather-related disasters and losses increase in the future.

Efforts should still be made to promote awareness of climate change among the farming community. There is a considerable amount of scepticism regarding climate change, and this will need to be overcome, particularly if strategic (long-term) anticipatory strategies are to receive attention by producers. However, an important entry for policy development and greater support within the agricultural sector might be to frame climate change as a 'no regrets' policy (Brunner 2001; Bulkeley 2001). As this dairy farmer notes:

In terms of climate change? I think we've got to have it in the back of our minds; it may very well affect how we farm. If we are contributing to climate change, then we've got to change it... I'm not entirely convinced that we are yet, but that's not to say that we shouldn't start taking some precautions now. We used to put all our effluent down the drains, and look at now. We will change, but I don't think it'll be an overnight change. But, over a ten-year period, it might be quite substantial.

Some adaptations could be achieved at no or minimal cost and could possibly lead to an increase in net revenue, as well as reducing greenhouse gas emissions. Examples include minimum-tillage cropping, improved grazing regimes and improved fertiliser and manure management.

As shown by the research findings, the majority of current adaptive strategies are short-term, reactive responses to conditions within a single season. Enhancing the resilience and buffering capacity of agricultural production will be a long-term challenge as many of the most effective

adaptive strategies such as changing cultivars or the development of new varieties, require long lead times (Smithers & Blay-Palmer 2001).

7.3.1.2 Technology

I think the other threat is that climate. It's getting hotter. I'd like to see some, no doubt they're working on it, some genetically modified grasses – deeper rooting, something that handles that bloody heat, because rye grass doesn't like heat and cows don't like heat.

- Dairy farmer, Edgecumbe, New Zealand

For pastoral farmers and kiwi fruit growers, the ability to adapt to changing climatic conditions – not only to reduce exposure to climatic variability and extremes but also to take advantage of opportunities associated with changed climatic conditions – will likely be influenced by technological innovations. Technologies including the development of genetically modified crops, drought- and pest-resistant cultivars, have been identified as being important adaptations to climate change elsewhere (Smithers & Blay-Palmer 2001; Lotze-Campen & Schellnhuber 2009; Metzloff 2009) Both pastoral farmers and kiwifruit growers expressed confidence in technology and identified related adaptive responses. Zespri has an established record of developing new cultivars of kiwifruit (Jaeger et al. 2003) and growers expressed confidence in the likelihood that new varieties will be developed to take advantage of changed conditions, including higher temperatures and lower moisture requirements. As one grower stated:

They say that this area is going to warm up if we go to true climate change, that the Bay of Plenty is going to become more tropical. I guess that's going to have an effect, especially with the kiwifruit, it likes good chilling – though I am sure we'll find – like they're doing variety trials now, they'll make them so they can come earlier or later or whatever.

Warmer temperatures are likely to result in the spread of sub-tropical C4 grasses, shown to be a significant future exposure for pastoral farmers. However, as one farmer noted, it may also present an opportunity for a technological adaptation:

I think it [climate change] is an opportunity. I reckon the Bay of Plenty will get warmer and wetter; we're seeing an increase in what they call C4 species, which are temperate grasses the likes of *kikuyu*, which is seen as a weed but with technology and management these days, somehow we've got to learn to use that. It's going to happen, but we can learn to control that and utilize it – in good growing conditions it can outgrow anything...just got to learn to utilize it. It's another opportunity.

Repeated drought years have been shown to damage ryegrass root systems, meaning that perennial ryegrass cultivars have to be replaced by other grasses (Wedderburn et al. 2010). There is however, a long lead time required for technological innovation (Smithers & Blay-Palmer 2001) and unless climate change is regarded as a viable concern, government, research institutions and other stakeholders are unlikely to invest. There are also social barriers to GMO adoption in New Zealand (Cronin 2008). Technology also often requires significant investment by the individual producer or grower, in terms of equipment, additional labour and replanting. It is possible that only the largest growers and farmers therefore, will be able to take advantage of these opportunities. As one grower said:

The day of the little family orchard is gone, or it's pretty marginal. We've got scale and with scale comes returns but it incurs big costs. The biggest advantage I can see is if you're on the ball, is if you're big enough and quick enough you'll be able to take advantage of one of the new varieties that will be coming out sooner or later. Because they are- with Zespri's history of producing the goods overseas – it will sell. You can't do that if you're a small grower I don't think.

This comment was echoed by a dairy farmer who noted that while shifting to a high-input dairy production system could be an adaptation to climate change due to lower yields and declining pasture quality that:

if you want to go into a more supplemented system, you've got to have the right scale because you might have to put some concrete down to feed, to put in some troughs. Economies of scale: you also need machinery to feed the stuff out. So for a little farm, that all grass is a nice, efficient, low-cost system. For a little guy to go to supplement – there's all those things to do with labour, machinery and all that.

7.3.1.3 Social and human capital

I think that urban one does worry me, we're getting fewer and fewer farmers.

- Dairy farmer, Waimana, New Zealand

Social and human capital are important aspects of an agricultural community's capacity to deal with variable conditions (Wall & Marzall 2006). There is a substantial amount of social learning, or learned adaptive capacity that exists in the farming community. Producers' strategic and anticipatory, tactical and reactive strategies for dealing with climatic and non-climatic risks have been acquired in part through prolonged exposure. For farmers to successfully react/adapt to change, relevant experiential information needs to be available, "practical wisdom" (Schwartz & Sharpe 2006), so that feasible options can be evaluated and their likely technological, social, economic or managerial impacts understood. "In terms of risk management", said one grower, "experience has a lot to do with it. No one can tell you what to do. Every location is different. And what someone does to do something, and looks different, might not necessarily work on your orchard". As the farm work force ages and fewer young people enter farming there is a risk that much of this social and human capital will be lost, as the farmer quoted above notes, and as shown in empirical work in Australian agriculture (Doole et al. 2009).

Population trends for the Whakatane District and eastern Bay of Plenty (BERL 2010) point to an ageing population in coming decades and continued out migration. Rising house prices in response to an influx of retirees (Whakatane District 2009), may act as a further barrier to employment in agriculture. Other barriers to the flow of human and social capital include the high cost of farm ownership and a perception of long work hours for low-returns (Tipples et al. 2002; Clark et al. 2007; Wilson & Tipples 2008). The ageing farming workforce potentially represents a loss of the accumulated experience and wisdom (embodied in individuals and in the collective adaptive strategies employed in the area), that may hinder or slow future adaptive capacity. As one grower said, “There’s nobody new going into the industry. They did a survey, the average age of a kiwifruit grower is fifty-eight or something. Like the sheep farmers in New Zealand, because the reward’s not there. Young people would rather go to Australia”.

Disasters often bring members of a community together and contribute to the development of social capital (Adger 2000; Adger 2003; Neudoerffer & Waltner-Toews 2007; Cashman 2011). In response to flood and drought events, important adaptive strategies were shown earlier to include the sharing of resources among other farmers and neighbours. During recent droughts however, conditions were dry all over the North Island (MAF 2010). With climate change, the effectiveness of traditional risk-management strategies may be reduced. An important adaptation described by dairy farmers was moving animals out of the region during drought; however this may be constrained in the future by the limited availability of pasture elsewhere.

Social and human capitals are also features of the various types of agriculture in the eastern Bay of Plenty and the individuals that comprise those systems. Horticulture, as this grower notes, is attractive to innovators, which may help facilitate future adaptive capacity.

It's quite an innovative industry, the type of person that's gone into it, has really taken that on, like it's a really risky industry and the people that have gone into it from the start have got that sort of drive in them. There's not many industries where your whole income is riding on a single event.

Another grower, who also ran a dairy farm, shared a similar view, saying that:

It's risky, horticulture, no doubt about it. A lot of guys in the industry have got a lot of money tied up in it, so it's in their interest to solve the problems. I'm a bit of a Chinaman [sic], like that, I'm quite happy to let these guys do it and then follow them, copy them, I make no bones about it I'll tell people I rock up to orchards, and say "I hear you're the best Gold grower in Te Puke, I'd like to have a look at your system and copy it if you don't mind" and the guy ended up coming down to my orchard and telling me exactly what to do.

This willingness to share risk management and production strategies with one another, is facilitated by the lack of competition for sales. "The beauty of the New Zealand dairy industry", said one farmer, "is we're not competing with each other – it's all offshore – and so if someone comes up with a good idea, he's only too happy to share it with everyone else. And so the uptake is really quick – and that's been one of our strengths". This rapid uptake and willingness to share ideas was also noted by kiwifruit growers. As one grower remarked, "generally, people are really willing to hand over their ideas and such; we're not competing with each other for gate sales, so it doesn't really matter if you're giving away your ideas".

The loss of innovation and the need for both a “No. 8 wire” approach (the ‘myth’ that New Zealanders can do anything with No. 8 gauge wire) as well as continued investment in the agricultural sciences has been noted recently by commentators (Scott 2008). Continued flexibility and a willingness to adapt are likely to be important aspects of future adaptive capacity. As this farmer said:

I’m into long range things. I go to these people that believe climate change is on and I said, look, I hope that when my farm floods that I retain ownership and when I swap my farm from cows to flounder or other types of fish-farming, that I don’t go through any crap on ownership of my land and everything. And they look at me with a blank face, “You’re prepared to just swap like that?” Well why wouldn’t you? If I’m farming shellfish or flounder, because I’ve now got water all over my place and water buffalo and crocodiles aren’t going to give me the return, shouldn’t I be allowed to?

7.3.1.4 Resources

The capacity for producers to adapt to changing climatic conditions will also continue to be shaped by access to resources. Availability is a function of financial returns and farm income, access to capital, and the biophysical capital represented by components of the landscape such as the availability of groundwater and fertile soils. The ability of producers to invest in risk-reducing technology, for example, is influenced by returns, which in turn are related to exposure-sensitivity to market and financial forces beyond the farm gate. “Right now”, said one producer, “banks are generous with dairy farmers”. Access to capital however can quickly change in response to a fall in commodity prices or a rise in interest rates. The ability to invest in adaptive strategies, such as flood-pumps, herd-homes or irrigation, may also be constrained by the high levels of debt among dairy farmers. The rapid expansion in dairy has been largely debt funded and a number of commentators (Riden 2007; Rennie 2009; Fox 2011; Rutherford 2011) have

expressed concern. Debt servicing can take up a large portion of farm-gate returns, limiting producers' ability to invest in on-farm improvements. As this farmer notes:

Our costs are pretty fixed – most farms between \$2.50 and \$3.00 a kilo, which obviously in a \$4.00 payout year, it's over fifty-percent, and this year it's thirty-percent, so everything's sweet, but if it drops back to \$4.50 – which *was* the long-term average, the banks were all using \$4.25 going out five-years, Fonterra was saying get used to \$4.00 and we were saying we can't live there. My debt servicing is \$1.60, I've got \$2.50 of farm working costs, so I was going backwards, and we were – we were producing a loss each year, and were just farming for capital gain; which we've been doing for years.

Producers also expressed concern about the availability of water for irrigation and frost protection. Irrigation is currently widely employed by a several producers who participated in this research, as a strategy to increase production and as protection against summer drought. Future climatic conditions indicate that increased drought frequency is likely (Mullan et al. 2005), and farmers indicated they were considering investment in irrigation as a long-term strategic adaptation. Producers also noted however, that the availability of groundwater and surface water is likely to be a constraint in coming years.

We're looking at irrigating the dry farm. And listen, I've put a lot of energy and a lot of thought into this because of energy... where's the energy going? We're getting a twenty-year consent out of the river, who knows where the consent is going to go after that first twenty, so we've got to make sure it stacks up for those twenty years. Nobody knows where world energy is going to go, the pressure on water and the Resource Management Act – so if we can get twenty-year consent, we're just going to go for it.

Increased water demand in New Zealand has been largely due to agricultural intensification (Woods & Howard-Williams 2004). The irrigated area has increased by around 55% each decade since the 1960s (Lincoln Environmental 2000). This trend too, is likely to continue, however the availability of moisture may prove to be a significant barrier to adaptation to a drier conditions (MAF 2011). The groundwater resources of the Rangitaiki are not clearly understood (White

2005) and increasing water demand from lifestyle blocks and the intensification of dairying and kiwifruit will place additional pressure on the resource. MAF (2007) estimates that as much as a 40% increase in horticultural production in the area and a 50% increase in the area used for dairying by 2030. Those increases in water demand will place exacerbate stress on supply capacity for irrigation, lifestyle blocks, urban areas and environmental flows (MAF 2011). Other producers, taking a long-term view, are instead focussing on building the buffering capacity of their soils as a strategy to mitigate against future climate. As one dairy farmer stated:

What I'm doing is creating a soil that is a buffer; that is sequestering carbon that is healthy, and passing that down the chain. And if the sun's up there for twenty-four hours a day, burning a bloody hole somewhere, it's having less effect inside my fences than anyone else's.

Intensification of agricultural production is driven by marketing, technology and finance and generally results in fewer and larger farms with more specialized and intensified production (Matson et al. 1997; Rudel et al. 2009) which may increase vulnerability (Lin et al. 2008).

However, eastern Bay of Plenty farmers have shown that that diversification can be an effective strategy for dealing with unpredictable risks, especially those related to climate/weather, and some producers may be able to take advantage of localized soil conditions in order to diversify on farm production in the future.

7.3.1.5 Institutions

Adaptation to climate change is inevitably local while being influenced by conditions at a wider range of scales. Local government, institutions and communities have a critical role to play in adaptation to future climatic variability and change. Research on adaptive governance, for example, is beginning to highlight the links and pathways between vulnerability at the local scale and wider processes of globalization. In the study area, regional council and producer marketing boards in particular, will likely have a significant influence on future adaptive capacity.

Institutions influence adaptation and climate vulnerability in three critical ways: a) they structure impacts and vulnerability, b) they mediate between individual and collective responses to climate impacts and thereby shape outcomes of adaptation, and c) they act as the means of delivery of external resources to facilitate adaptation, and thus govern access to such resources. Institutions can also be an important source for information about climate change and work with farmers and growers on identifying opportunities and available adaptation options.

This is particularly relevant for New Zealand, as the locus of responsibility for climate change adaptation has shifted in recent years from central government to local regional councils. The passage of the 2004 Energy and Climate Change Amendment to the RMA marked a division between responsibilities for mitigation and adaptation with the former remaining a central government responsibility, with the latter shifting to the local level (Greenaway & Carswell 2009) Local responses to climate change are underway. In a recent (2010) review of climate change adaptation projects in New Zealand, 1065 projects were identified, though the majority (76%) are only implicitly to do with climate change and focus more broadly on sustainability (Carbon Partnership 2011). Only 1% of projects are explicitly concerned with adaptation

(Carbon Partnership 2011). The Bay of Plenty Regional Council has undertaken several adaptation initiatives including adaptation to sea-level rise (Climate Change Office 2005) and supporting work in the agricultural community. Climate change is understood to be of concern by both regional and district councils (Whakatane District Council 2009).

Work by Kenny (2005) has been instrumental in demonstrating the benefits of local discussion and engagement with the agricultural sector on climate change. Farmers in eastern New Zealand stressed the need for support and education for ‘bottom-up’ adaptation (Kenny 2005), which might be facilitated best by local government. The need for “bottom up” approaches to climate change adaptation in New Zealand is now recognized (Reisinger et al. 2011). Though there remain significant barriers. As noted earlier, some farmers and councils with a strong rural base have remained rather sceptical about climate change science (Fulton 2008). Farmers and growers continue to receive mixed messages about climate change impacts from union and other groups. This scepticism is also in part motivated by concerns about policies to reduce agricultural greenhouse gas emissions (Brenmuhl 2008). This conflation of mitigation and adaptation represents a significant barrier to climate change adaptation initiatives. An emissions trading scheme or carbon tax; as well as the RMA and consents process were also seen as barriers to innovation among producers. As one drystock farmer said, regarding the environmental consents process, “It really hits anybody that’s an innovator, the hoops you’ve got to jump through to reach the stage where you can just glide – it’s just so frustrating. They [regional council] have no idea of timeliness, of keeping things moving, it’s just frustrating”. Communication and education might also identify some opportunities for adaptation, as some environmental regulations may indirectly encourage adaptation.

Hayward (2008) has also argued that that the devolved decision making processes implicit in local adaptation responses to climate change local government are a poor ‘political fit’ (Few et al. 2007) temporally and spatially. The potential for conflicts over land-use, particularly in vulnerable coastal areas such as the Bay of Plenty, will involve not only agricultural producers, but coastal residents, Maori *iwi* and urban areas such as Whakatane. Resources for adaptation – such as those that may be required in agriculture – are also often beyond the resources of local institutions to invest in. Innovation and research on identifying adaptation options will also be driven in part by the willingness of institutions to engage with climate change on a practical level, and consider the needs and opportunities of agricultural producers and stakeholders (Brown et al. 2010; Reid et al. 2007; Young et al. 2010). Central government must also rebalance balance and support not only mitigation but adaptation as well (Carswell et al. 2007).

7.3.2 Summary

The climatic conditions to which farmers will be vulnerable in the future are those to which they are currently most exposed-sensitive and to which they possess the least ability to adapt to, or that will change in such a way that exceeds their current adaptive capacity. For example, it is likely that with the trend towards drying conditions, the frequency and severity of drought will increase (Mullan et al. 2005) adversely affecting pasture growth. Farmers currently employ long-term strategic adaptations such as irrigation, or short-term reactive responses including the purchase of additional supplemental feed. Irrigation is expensive however, not only to install but has high annual operating costs. With farmers' net incomes changing due to market volatility and the limited availability of groundwater, this adaptation may be constrained in the future. Shifting to a higher input system through the use of supplemental feed may also expose producers to higher fuel and other input costs.

Warmer winters are also likely to permit the spread of invasive sub-tropical grasses. As producers' experience shows, they have a low capacity to adapt to these grasses, particularly during years of low payout. Management of these grasses require extensive (and expensive) tractor time, and once the grasses are established, lead to production and yield losses, further lowering farm-income. With a potential increase in the frequency and severity of droughts, farmers are particularly vulnerable then to repeated drought years.

Adaptive capacity, however, is not static. Farmers have shown a confidence in particular in advancements in technology, such as improved cultivars, changes in management techniques and/or shifting production to take advantage of short-term variation in climate. Farmers on the

Rangitaiki Plains also have a long history of dealing with floods and have developed an extensive infrastructure related to flood control, as well as strategic and tactical adaptive responses. Several farmers observed that management tools and technologies presently available to respond to poor weather conditions were not available to previous generations. Some constraints on continued use of technology to enhance adaptive capacity are affordability, the need to divert time from other aspects of the farm business to research new opportunities and farmers' views of biotechnology. Furthermore, as farmers have to deal with other immediate issues like fluctuating commodity prices, which cause net incomes to vary from year to year, farmers may opt to save money and reduce costs rather than purchasing additional climate risk saving technologies.

As this section has sought to demonstrate, an assessment of future vulnerability must also be cognizant of and account for a broader range of stimuli and influences than climate alone. Producers will continue to be exposed to climatic and non-climatic stimuli in the future, and to a greater degree, however there is a need to consider the role of exogenous forces. While there is limited data to draw on, this might include likely demographic changes and the potential loss of human and social capital; shifts in the availability of resources; technological developments that might enable producers to take advantage of changed climatic conditions through substitution of crops or new varieties; as well as institutional changes and the involvement of government at all levels. As climatic signals become more apparent, as well it is possible that there will be a move towards longer-term strategic adaptations, across the region. While this section has outlined in broad terms, some of the likely drivers of future vulnerability, it is likely that the individual drivers of adaptive capacity will vary significantly – and at different scales.

7.4 Conclusion

Assessment of the characteristics of future vulnerability to climatic variability and change has traditionally relied on the use and application of models of changes in climatic variables (Sauchyn et al. 2005; Iqbal et al. 2006; Gameda et al. 2007). As this chapter has sought to demonstrate, another way of exploring scenarios of future vulnerability is through the use of temporal analogues: exploring current exposure-sensitivity and adaptive capacity as the basis for inferring the likelihood of future conditions. Drawing on insights from climate scenarios, the published literature and insights from those most likely to be affected by changes in climate as they pertain to agricultural production, it was shown that farmers and growers in the eastern Bay of Plenty, as elsewhere in New Zealand, are likely to experience significant changes in mean climatic conditions, as well as shifts in the frequency and variability of extremes. Future climate will likely be characterized by hotter, drier conditions, decreased frost risk and warmer winter temperatures, and possible changes in the frequency and intensity of extreme rain events. Agricultural producers will experience these changed climatic differentially, according to the production system and commodity produced, as well as those characteristics unique to the individual farm.

Producers have developed a range of short- and long-term adaptive responses to manage existing climatic variability. Future adaptive capacity is likely to be influenced not only by those endogenous characteristics unique to each farm, but also broad scale trends across the region including demographic shifts, the availability of resources, and changes in human and social capital.

It is also important to note, that existing climate models and scenarios provide little guidance on shifts in variability or extremes, and as this research has sought to demonstrate, those will be felt in concert with other conditions to which producers are exposed-sensitive, including higher input costs and legislative controls. Furthermore, current adaptations to climatic conditions, such as intensification, may have important long-term implications for sustainability. While it is unlikely that high-input dairying will change in the foreseeable future, it is likely to be associated with higher input costs which may make it a less attractive system for farmers.

The chapter has also demonstrated the need to account more broadly for the influence of climatic variables beyond temperature and precipitation, including the influence of non-climatic stimuli, operating at a range of scales beyond the farm gate. It has sought to outline some of the complexities and influences on adaptation and decision making as they are likely to pertain to climate change; and shows that producers will continue to be influenced, in the future, to multiple-stimuli, which will affect production and yields as well as their ability to adapt to changing conditions. As importantly, in the same way that the research has drawn on insights from producers, the chapter has tried to show that future vulnerability cannot be assumed, but rather draws its analytical power from the application of the conceptual framework in which insights come from producers themselves in order to accurately identify those influences on future vulnerability.

CHAPTER EIGHT: Writing Climate Change Research

8.1 Introduction

Yes I'm concerned about climate change, because long-term its disastrous... it's having an effect on a lot of things around the country and it's not a thing that's being measured, might turn out to be climate change on inspection but because it's not been measured before – you can't measure it now – “Oh it's just a bad year” – it's not quite a bad year, it's an effect with some other causes. It's there and it's happening.

Used to be you had two bad years out of ten, now you're getting two good years out ten.

- Dairy farmer, Rangitaiki Plains, New Zealand

The speed and magnitude of potential climate change is creating major adaptation challenges, as does the on-going nature of uncertainty about the future (Adger & Barnett 2009; Hallegatte 2009). It is increasingly apparent that mitigation will fail to achieve the needed reductions in GHG emissions and 4°C is now regarded as a likely threshold for global average temperature to which adaptation will be required (Betts et al. 2010; Smith et al. 2011). This is of particular relevance for New Zealand where as much as seventy-nine percent of economic activity is vulnerable to changes in climatic conditions (Fitzharris 2007) and climatic extremes already have a demonstrated impact on the economy (Buckle et al. 2007).

Across temporal and spatial scales in this country, future climate change will be superimposed upon existing climatic variability, which exhibits marked interannual variation (Fowler & Adams 2004; Salinger et al. 2004). Regionally and locally, where agriculture remains a predominant landuse (Patterson et al. 2006), agricultural producers will also be exposed to climate change in conjunction with other, non-climatic stressors. These multiple exposures, together with the range of adaptive strategies employed, were shown in this research to characterize the vulnerability of

producers in the eastern Bay of Plenty. Through a place-based case study, employing a bottom-up vulnerability approach, it developed new insights into the potential implications of climate change compared to traditional scenario-based impact assessments. In particular it provided insight into the conditions that are pertinent to producers, the adaptive responses employed, factors that facilitate or constrain their responses and the prospects for adaptation to manage risks in a warmer and more variable climatic future.

This chapter concludes the thesis by summarizing and integrating a selection of the most pertinent findings as they relate to the research objectives and identifies the broader academic and methodological implications of the study. The findings of this research have important implications for policy as entry points for further engagement with agricultural producers and presents exciting directions for further study. It begins by revisiting the four original objectives.

8.2 Identify relevant climatic and non-climatic stressors

Agricultural producers were shown to work in a ‘multi-risk, multi-opportunity’ environment. In order to address this and identify the climatic and non-climatic stressors to which producers in the study area were exposed-sensitive, a conceptual framework was developed and then empirically applied. The framework drew upon the accepted conceptualization of vulnerability in the climate change literature, as being a function of exposure-sensitivity and adaptive capacity (Yohe & Tol 2002; Fraser et al. 2003; Turner et al. 2003; Smit & Wandel 2006; IPCC 2007), and elements of farm-level decision making and agricultural systems in order to further account for those elements of vulnerability that pertain specifically to agricultural producers (Olmstead 1970; Bryant & Johnston 1992; Bowler 1992; Reid et al. 2007). The multiple exposures to which

producers are exposed-sensitive at the farm level were shown to be a function of broad scale forces, including biophysical and climatic conditions, socioeconomic forces and governance and institutions. It was also argued that the “legacy effects” (Liu et al. 2007) of historical conditions and patterns of land use continue to shape current vulnerability. Exposure to flood risks in the eastern Bay of Plenty is related to the drainage of the swamp land that originally covered large portions of the area, consolidation of the underlying peat beds and tectonic activity. The conceptual framework was applied through a bottom-up vulnerability assessment involving producers representative of the three main agricultural commodities produced: dairy and drystock farming and kiwifruit orcharding. The results of the analysis revealed insights into the multiple exposures to which agricultural producers were exposed-sensitive and the interactive effect of those stimuli.

While climatic conditions are of great concern to the majority of producers, the degree to which they are exposed-sensitive, varied. Pastoral farmers, including drystock and dairy farmers, were most sensitive to extremes of temperature and precipitation. Drought conditions slowed or halted grass growth which resulted in feed shortages and production losses. Producers were also sensitive to flooding, which had effects on production, animal health, and farm infrastructure. Kiwifruit growers were more sensitive to climatic conditions overall, than pastoral farmers. Orchard gate returns are based not only on quantity – the amount of fruit produced per canopy hectare – but quality. Growers can earn a premium for fruit size, water content, longevity in cold store, sweetness and taste, all of which are greatly influenced by climatic conditions (Sale & Lyford 1990). Kiwifruit producers are also exposed-sensitive to unseasonable frosts, wind and

hail which can reduce yield. Biophysical exposures include fluctuations in the water table, biotic pests and disease.

As the study also demonstrated, climatic conditions are not experienced in isolation. Producers are exposed-sensitive to a range of non-climatic stressors that influence their ability to compete in or sell to the market. Non-climatic stressors that were identified include financial and market risks such as increased variability in farm income and orchard gate returns, rising input costs and changes in commodity prices and exchange rate. Orchardists in particular, also described government policy and the growing number of 'lifestyle blocks' on agricultural land as having an influence on production. These non-climatic risks had immediate effects, in terms of reduced income, but also affect producers' adaptive capacity. Producers described poor returns as being a reason for not investing in certain technologies that may enhance their ability to deal with climatic conditions or having to reduce inputs in order to maintain a margin on production, but which in the long-term may increase vulnerability. The buffering capacity of the soil, for example, might be reduced through decreased nutrient inputs. The high costs of maintaining a pasture free of invasive, sub-tropical grasses was also mentioned. Producers' identification of these non-climatic risks is illustrative of the multi-risk environment within which they operate. Furthermore, the presence and interaction of these various risks influences producers' exposures, sensitivities and responses. Adaptations within the system demonstrate the interconnectedness of multiple risks.

The findings also indicated that climatic stresses are often expressed in economic terms by farmers, which are simultaneously influenced by non-climatic forces. These external forces present risks to the farm itself, but in turn influence the degree and way in which producers are vulnerable to climatic stresses. The research also demonstrated the synergistic effect of multiple stimuli, including the interaction between climatic and non-climatic risks. It was shown that exposure is dynamic, and that adaptations or strategies to minimize exposure-sensitivity in one part of the farm-system, can have the effect of increasing exposure elsewhere. These considerations demonstrate the importance of, and need to, consider the role and influence of not only climatic conditions, when examining the likely impacts of future climate change, but also non-climatic stressors, and the ways in which those might interact.

8.3 Examine current adaptive strategies

Weather and climatic conditions are the most important production factors for agriculture, however producers are also exposed-sensitive to multiple, non-climatic exposures which affect production and yield, quality and farm income or returns. Within any agricultural system, farmers try to adapt to these conditions as much as possible (Adger et al. 2005). To address this in the study area, producers' responses to multiple exposures were analyzed and classified. Adaptive strategies can be distinguished in a number of different ways (Burton et al. 1993; Carter et al. 1994; Smit & Pilifosova 2001). Results from the empirical work were presented in Chapter 6 and discussed with respect to duration, timing and level of farmer control (Smit & Skinner 2002; Risbey et al. 1999; Wandel & Smit 2000).

In response to a range of climatic and non-climatic stressors, producers have developed and adopted short and long-term, tactical and strategic adaptive responses. Adaptive strategies were shown to take place prior to, during, or after exposure. The majority of strategies were undertaken by individual producers; the greatest range of which was in response to climatic conditions. For dairy farmers the most common adaptation was to supplement grass production with imported feed, or match the available feed supply with demand through lowering stocking rates, selling animals or ending the season early. Drystock farmers described using similar strategies, quickly dropping stock in response to adverse climatic conditions such as drought. Kiwifruit growers have typically employed short-term, tactical responses to frost risk, such as the use of helicopters, burning and portable furnaces. Repeated losses and higher frost insurance premiums have led to more widespread adoption of permanent frost protection, including wind fans and overhead frost protection/irrigation. Hail and wind events are typically managed through anticipatory strategies, including pruning, hail cannons, enclosed orchards and shelterbelts. Adaptive strategies were shown to be dynamic and influenced by a range of conditions, including social and human capital, information and awareness, technology and resources.

The findings suggest that adaptation can indeed reduce the negative effects of climate-related risks and will be important for reducing the negative effects of climate change. Significantly, the research shows that dairy farmers currently have a higher capacity to cope with, or lower vulnerability to, risks that affect production or yield. Farmers are paid on the entire year's production and while climatic conditions do influence overall production and yield, the effects are shorter-term when compared with horticulture. The findings also demonstrate that

intensification of production through the use of supplemental feeds, exposes producers to a greater degree to market risks. High returns to dairy farmers, have been offset to some degree by rising input costs. Growing indebtedness may limit future adaptive capacity by limiting the amount that can be re-invested into the farm. Climatic conditions have the greatest effect on kiwifruit production, as growers are sensitive to both conditions that affect the quantity of a crop yield (frost and winter) and those conditions that affect quality (cool season and extreme heat), and hence the ability to compete in the market. Drystock farmers are similarly exposed-sensitive and vulnerable due to market and financial pressures and possess a more limited range of adaptive strategies to mitigate the worst effects of adverse climatic conditions. Producers' vulnerability will vary between operations due to the way that each is exposed to particular stresses and to the different resources, technologies, and varying capacities of individual farmers that influence their ability to adapt.

8.4 Assess vulnerability to future climate change

To assess the vulnerability of farming systems in the study area to likely changes in climatic variability and extremes, the analysis made use of insights from producers, climate scenarios and other scientific studies, as well as the empirical assessment of current vulnerability. The climatic conditions to which producers are most exposed-sensitive and to which they possess the least ability to adapt to are likely to become increasingly problematic with climate change or will change in such a way that exceeds their current adaptive capacity. Changes in climatic conditions will also occur within the broader context of changing social and economic conditions which may increase producers' sensitivity. Warmer temperatures are likely to encourage the spread of subtropical C4 grasses among pastoral farms. The spread of these grasses will not only reduce

production, owing to the poor nutritional value, but are also associated with higher management costs. The loss of winter chilling for horticultural producers might also be exacerbated by changes in environmental regulations, prohibiting the use of bud enhancement chemical applications. The incidence and severity of drought and flood is also likely to increase with climate change (Mullan et al. 2005; Tait et al. 2008) with implications for agriculture in the area.

It was shown that future adaptive capacity may be constrained and facilitated by a range of factors. Advances in technology, including drought resistant grass cultivars or early budding kiwifruit, may be important adaptive strategies to deal with climatic extremes and unseasonable frosts. Social and human capital will be influenced by the demographics of an ageing farm work force and substantial barriers to farm ownership. Continued access to resources and information as well as policy, sensitive to local conditions will also shape future vulnerability. Assessments of future vulnerability must be cognisant of and account for a broader range of stimuli and influences than just climate. Producers will continue to be exposed to climatic and non-climatic stimuli in the future, and research must consider the role of these non-climatic, exogenous forces.

8.5 Mainstreaming adaptation

The implications for this research with respect to policy and contributing to the emerging discussions on mainstreaming adaptation comprised the final objective of this research. Through the empirical work, the implications of many of the findings from this research for agricultural producers in the eastern Bay of Plenty were identified. The research demonstrates the need to support further research on adaptation at a local and regional level. The research has also alluded to the need for a bottom-up approach with respect to policy development. Many of the agricultural producers who participated in this research identified the apparent disconnect between policy formulation and implementation, as a source of future risk. While significant reductions in GHG emissions are likely to be required, what is also needed is policy to support agricultural decision making in the face of a changing and uncertain climate. Such policy should, ideally, be cognisant of local conditions and concerns. As one producer noted:

There's nothing more scary for a grower than being told to do something. When you do it because you want to, or you've been educated to do something, is a lot easier; a lot easier to use a carrot than a stick, and a lot of growers feel at the moment there's too much of the stick, and they're just losing control.

All levels of government have a role to play. With the devolution the responsibility for adaptation now resting with local government (Greenaway & Carswell 2009) there is a greater need for engagement with local stakeholders in vulnerable sectors. Agriculture in particular is uniquely sensitive to climate change. "Bottom-up" approaches have been formalized through a step-wise assessment of climate change related risks in guidance material developed by the Ministry for the Environment (Mullan et al. 2004, 2008) though there are still significant barriers to overcome (Reisinger et al. 2011). Local consultation as well, is not without its problems (Hayward 2008),

as multiple stakeholders may often have conflicting views on the best adaptive strategies or allocation of crucial resources. There has been important work already done by regional council (MfE 2003; Kenny 2006) and this study might serve as a template for other such initiatives. Studies should also be more closely integrated into the agricultural community. One of the other great challenges for policy and wider uptake regarding the science of climate change will be to overcome misconceptions and misinformation among farmers and growers. The adversarial approach is probably most succinctly represented by disdain for the mislabelled “fart tax” (Fickling 2003; Thorpe 2010).

In order to achieve this, enhanced collective participation among agricultural producers is likely required. This might involve the use of experienced facilitators rather than technical experts or scientists alone (Tompkins et al. 2008). The creation of forums, utilizing existing social networks and venues for information sharing such as field days, might allow for debate and discussion of broader problems and priorities and inclusion of neglected viewpoints and more sensitive attention to appropriate formats for ensuring the participation of different groups. Increased efforts at education regarding climate change and impacts in the region may also be important. In the UK, Tompkins and colleagues (2008) for example, have shown how public education and stakeholder participation and inclusion can increase willingness to participate in and contribute to adaptive responses in coastal areas. Increased scientific knowledge of the biophysical implications of climate change is crucial if the aim is to improve the adaptive capacity of agricultural producers, however the uncertainty of climate modelling must be acknowledged and greater emphasis placed on intensive site-specific research informed by local knowledge and practices. As Batterbury and colleagues (1997, p.129) note:

The challenge... is not just to construct a more informed and democratised explanation of externally real biophysical change; but also to ensure this knowledge is used to influence policy at various spatial scales to enable practical and equitable environmental management.

Perhaps most importantly, engaging with agricultural producers, adopting the “view from the ground” (Kenny & Fisher 2003) might serve to help identify entry points for policy. Concerns about adaptation to climate change have been recently expressed by Adger and Barnett (2009) saying that: the task is unexpectedly urgent and hard; adaptive capacity will not necessarily translate into action; there is widespread existing maladaptation; and the measurement of adaptation success is profoundly complex. Given the uncertainties surrounding the scale of future climate variability and change then, there is a need to adjust practices and decision-making frameworks to account for these realities. Reducing riskiness in the face of uncertainty among agricultural producers will almost certainly require the identification and promotion of ‘no-regret’ strategies that yield benefits even in absence of climate change (Hallegatte 2009). This might be achieved through lower nitrogen-inputs, increased water monitoring, or changes in feed management systems. As the farmer quoted earlier notes however, the identification of alternate strategies should come through education and participatory engagement and collaboration rather than from the ‘top down’. As this study has shown, through consultation with agricultural producers, a more comprehensive and complete assessment of vulnerability to both climatic and non-climatic stressors can be developed, as exposure to changing climatic conditions will not happen in isolation.

8.6 Implications for further research

Some important suggestions for further research have already been mentioned throughout the thesis, for example the need to evaluate impacts of climate change on social ecological systems from the bottom-up and for intensive, location specific assessments of vulnerability that account for multiple exposures to better understand and monitor the complex processes involved. The research has also identified limitations of the existing approach to vulnerability assessment and has highlighted further gaps in our knowledge about climate change and agriculture in New Zealand and the need for additional studies. The following section outlines directions for future research, both in terms of the impacts of climate change and agriculture in New Zealand, as well as the study area specifically. The key areas are: vulnerability assessments; governance institutions and policy development; and the significance of ‘teleconnections’ and globalization.

8.6.1 Regional, local and sectoral vulnerability assessments

New Zealand’s agricultural economy is characterised by diversity and regionalisation (Patterson et al. 2006). While this study has identified and assessed characteristics of the dairy, drystock and horticultural industries in the eastern Bay of Plenty, other agricultural sectors and regions have yet to be examined using this approach. Given the absence of any other vulnerability assessments in New Zealand, studies exploring the varying degrees of exposure-sensitivity and adaptive capacity of agricultural producers are urgently required (Hennessy et al. 2007). New Zealand’s wine industry contributes over NZ\$1.5 billion to GDP and supports over 16,500 full time equivalent jobs. The industry generates over \$3.5 billion of revenue through its own direct sales and the sales it induces from related sectors (NZIER 2009). Viticulture is dependent on climatic conditions for both grape quality and quantity (Beverland 1998; Jones & Davis 2000; Schamel &

Anderson 2003). Climate change is likely to have significant impacts globally on wine production (Tate 2001; Jones et al. 2004; Hadarits 2011) and has been identified as an emerging challenge (Jones 2007; Schultz & Stoll 2010; Diffenbaugh et al. 2011); however no assessment has yet been made of the industry's vulnerability in New Zealand. Forestry is another primary industry that has the potential to be affected by long-term changes in climatic conditions (Leathwick et al. 1996; Millar et al. 2007; Kirilenko & Sedjo 2007). As with agriculture, the impacts will not be limited to biophysical conditions, but will also have consequences for forestry-dependent communities and employment as shown in results from overseas research (Davidson et al. 2003; Kirilenko & Sedjo 2007; Burch 2010; Keskitalo 2010a; Brown et al. 2010; Williamson et al. 2010; Keskitalo et al. 2011).

Additional place-based case studies from elsewhere in New Zealand may also provide further insight into the particular challenges and impacts of climate change on rural production and the varied capacity for adaptation. A collection of vulnerability assessments may help to provide a more comprehensive or longitudinal understanding of the impacts of climate changes on the economy, and provide the basis for comparative analysis. Such studies might also serve as 'spatial analogues' (Glantz 1996; Tol et al. 1998; Ford et al. 2010) to examine more closely future exposure-sensitivity and adaptive capacity (McLeman & Hunter 2010). 'Spatial analogues' involve detailed case studies of past- or present-day behaviour in regions with climate conditions similar to those that might possibly develop in the region of interest (Adger et al. 2003; Ford et al. 2010). The aim is to establish how individuals and institutions anticipate or respond to reduce the risks of different types of climate variability and how policy has influenced these actions (Næss et al. 2005). Understanding the present-day effects and response to climate

variability at all levels of social organization is a prerequisite for studying the effects and responses to future climate change and for identifying the key determinants of successful adaptation in the future (Keskitalo 2010b). Spatial analogues have been used in other climate change research (Diamond 2006; McLeman 2009), to identify the potential impacts and adaptive strategies. Both pastoral farmers and kiwifruit growers noted the similarity between current climatic conditions in Northland and what might be expected in the Bay of Plenty with climate change. Problematic conditions including black beetle, clover weevil, poor pasture growth, an increase in C4 grasses, warmer winters and lower production were identified. Some dairy farmers were already informally investigating farm management techniques from the region. Detailed analysis of producers' responses, feed management systems and other adaptive strategies might provide valuable insights into potential future adaptations for the Bay of Plenty.

There also exist specific opportunities to build upon this study in further detail and extend research in the eastern Bay of Plenty in new directions. As this thesis has sought to demonstrate, by locating the unit of analysis at the farm-level, important insights regarding exposure-sensitivity and adaptive capacity can be uncovered. While this study has pointed to some of the factors at this scale that influence vulnerability, including the type of commodity produced, it is likely that other characteristics of individual farms, farmers and farm-type, have not been accounted for. A more detailed examination of household activity and farm characteristics might reveal the influence of other factors on adaptive capacity. Further refinement of the conceptual framework and methodology, might include as part of the interview, a short form of farm census. Data on nutrient inputs, feed budgets, access to short-term operating capital, input costs, margins, indebtedness and pluriactivity might provide additional insights into the relative vulnerability of

the various agricultural systems in the study area and allow for the development of complementary analysis which might enable closer comparison among different farming systems. Work by Nelson and colleagues (2010) in Australia, for example, has shown how metrics of vulnerability can complement and add value to the sort of empirical work represented by this study.

The wider significance of pluriactivity as an adaptive strategy, and in particular, the role of women in off-farm employment, has not been investigated in this study. Household pluriactivity was identified by a number of farmers as being an important adaptive strategy. While other research in New Zealand has looked at this subject in relation to deregulation (Le Heron et al. 1994; Robertson et al. 2008), it may be increasingly important to households. An important opportunity exists for work to be done on the different perspectives on women's off-farm employment, as well. As farm incomes become increasingly variable from year-to-year, this sort of household diversification may become more important.

It should be noted that vulnerability assessment is only one way to address current and future impacts of climate change (Zhou et al. 2009; Ford et al. 2010; Engle 2011). Resilience frameworks have also been used to examine and enhance the ability of agricultural producers and stakeholders to manage uncertainty and change at a household level (Darnhofer 2010), locally and regionally (Allison & Hobbs 2004; Marshall 2010), though again there are few such studies from New Zealand (Kenny 2011). Opportunities also exist to identify synergies between mitigation and adaptation in agriculture (Lin et al. 2008; Smith & Oleson 2010). This is of particular importance for New Zealand, as nearly half the country's GHG emissions are from

agriculture (Andrew & Forgie 2008). Developing more sustainable agricultural systems may provide one way not only to reduce emissions but also the vulnerability of agricultural production to climatic and non-stressors alike (Wall & Smit 2005; Kenny 2011). Reduced input costs may well be possible, as farmers and growers seek alternatives to fossil-fuel based inputs; higher returns in the marketplace for organic products may offset lower production or yield; and GHG emissions may be lower on organic farms and orchards as opposed to conventional ones. Under the rubric of sustainable agriculture farm production might achieve both ends: a long-term sustainable agricultural system that is more resilient and better able to cope with expected changes in climate.

8.6.2 Governance, institutions and political will

As noted earlier in Chapter 7, a key component of future adaptation to climate change will be local institutions and governance structures. While this has been recognized in climate change research for some time (Wilbanks & Kates 1999) it is only now being implemented in a number of key areas in climate change research. Integrated climate modelling for regional and local scales is regarded as a priority (Shaw et al. 2009; Moss et al. 2010). More importantly for this research, is the role of governance and institutions in facilitating adaptation and building adaptive capacity. This will be critical for New Zealand, as planning authority for adaptation now rests with regional councils (Greenaway & Carswell 2009; Reisinger et al. 2011). Local institutions however are linked across multiple scales, across sectors, and steered by private and other interests (Boland 1999; Hooghe & Marks 2003). Examination of the role of institutions and the multiple scales of governance that influence exposure-sensitivity and adaptive capacity has been identified as a key research area internationally (Keskitalo 2010b) and is an emerging focus

in the climate change adaptation literature (Keskitalo 2008; Engle & Lemos 2010; Westerhoff 2010). While the impacts of and responses to climate change are most likely to be felt by individuals and households locally (Næss et al. 2005), the influences and drivers of adaptive capacity are institutionalized and problematized at larger scales (Keskitalo 2010). Adaptation will require the mobilization of resources, policy, investment, and action to be undertaken by all levels of government as well as private and other interests (Boland 1999; Hooghe & Marks 2003; Keskitalo 2010b). The role of national government in formulating climate change policy, for example, and how that is implemented at the local level; the differences in adaptive capacity of regional and local government; the impacts, priorities and concerns at different scales of governance and across agricultural, economic and environmental sectors, groups and networks must also be examined (Plummer & Armitage 2010).

Insights from the field of adaptive governance might provide a practical way to begin to apply the results of this study as a pathway to policy development at a local scale. Brunner and Lynch (2010,p.35) argue that the failure of top-down approaches to emissions reduction should be supplanted, that the problem of climate change be localised by “factoring the global climate change problem into thousands of local problems, each of which is more tractable scientifically and politically than the global problem”. Such policy formation would also work from the bottom-up , involve a wide range of stakeholders, and aim at reducing vulnerability, through local, community-development and adaptive capacity building initiatives (Armitage et al. 2009). Through “field testing” policy measures, Lynch (2008) suggests it would reduce vulnerability to loss already occurring in the system; would require less investment and through learning-by-doing, be more sensitive to evolving local needs; would not conflate impacts assessment with

adaptation response; and would not be dependent upon the detection of climate change in order to reduce vulnerability. Rather, reducing vulnerability to *existing* climatic and non-climatic stressors would be the goal. Adaptive governance has been the subject of several case studies overseas (Tompkins & Adger 2004; Armitage 2005; Young & Lipton 2006; Huntington et al. 2007; Lynch & Brunner 2010) and the current study may provide the basis for further analysis in the region. With respect to the study area, for example, responsibility for the flood control systems that have been established on the Rangaitaki Plains are slowly being handed down to greater levels of farmer control (BoPRC 2011). As the regional council does so, this may have important ramifications for the exposure-sensitivity of lowland dairy farmers. Adaptive governance might be used to explore ways of supporting policy development among agricultural producers through existing social networks and institutions.

The ability to overcome the barriers to effective communication on climate change within the agricultural community and political will at a range of scales are likely determine whether or not further research linked to practical intervention aimed at reducing vulnerability to climate change is undertaken. While individual producers often showed a high-level of awareness regarding climatic conditions and the associated risks and opportunities, there remain pronounced gaps between awareness and action. Adaptation to climate change will require long-term, anticipatory and strategic responses. One of the challenges, by no means unique to the study area, is investing in adaptation, when there is much uncertainty regarding the degree of expected changes (Hallegatte 2009; Smith et al. 2011). One way to address this might be through research on the information gaps: where are farmers and growers getting their information on climate change? Is the information being provided accurate? Is it relevant? What are the levels of understanding

regarding changes in climatic variability and extremes and the effects for agricultural producers? Secondly, more work to be done on understanding the links between perception of climate change – including interannual variability – and motivation to adapt (Grothmann & Patt 2005). Such studies are beyond the scope of the existing research, but may provide important avenues for other social scientists.

8.6.3 ‘Teleconnections’ and the globalization of vulnerability

New Zealand’s agricultural economy is export oriented (Buckle et al. 2007), and dependent on economic conditions elsewhere (Gillmore & Briggs 2010). While this has long been recognized in the literature on agricultural production (Smith & Montgomery 2004; Jay 2007) and more recently, globalization (Le Heron et al. 1989; McKenna et al. 2001; Gray & Le Heron 2010), there is a significant gap. As this research has demonstrated, agricultural producers in New Zealand are uniquely sensitive to changes to changes in policy and overseas financial markets for example. Climate change will not be experienced in isolation, rather in conjunction with other non-climatic stressors (Turner et al. 2003), of which globalization is among the most significant (Eakin & Lemos 2006; Young et al. 2006; Leichenko & O’Brien 2008). While this study has begun to illuminate some of the links between vulnerabilities, an important direction for future research is to trace in more detail the “teleconnections” and investigate the nested nature of the vulnerability of agricultural production in this country. How do climatic and non-climatic conditions elsewhere affect the vulnerability of New Zealand producers? In turn, does agricultural production here have repercussions for vulnerability in spatially distant places? And to what degree do non-climatic stressors associated with climate change, such as ‘carbon footprinting’, influence vulnerability at the farm level?

New Zealand agricultural producers are “teleconnected” to distant overseas markets through networks and systems of marketing (McKenna et al. 2001; Hayward & Le Heron 2002; Gray & Le Heron 2010). Kiwifruit grown in Whakatane may end up in a supermarket in Amsterdam, or dairy products from the Bay of Plenty in milk powder sold in London, however there has been no research yet on the links between vulnerability at local levels, and wider processes, though the findings of this study begin to point in some important directions. Changing market demands might, for example, have significant impacts for local agricultural producers. Horticultural producers must currently comply with GLOBALGAP regulations, in order to sell to European supermarket chains and these chains are able to dictate conditions under which production takes place (Campbell et al. 2006). The use of HiCane was discussed earlier as one way in which this might affect future vulnerability to climate change. Consumer demand might also create additional pressures on agriculture. ‘Carbon footprinting’ and food miles may further altering exposure-sensitivity to climatic and other non-climatic stressors (Saunders et al. 2006; Edwards-Jones et al. 2009). Markets for pesticide-free fruit or grass-fed milk require changes in production that increase exposure-sensitivity to future climatic conditions if producers are required to reduce pesticide use in order to stay competitive or retain access (Green et al. 2007; Haggerty et al. 2009). There is growing demand for the traceability of agricultural commodities in a globalized production system (Opara & Mazaud 2001; Prache et al. 2005; Campbell et al. 2006). This too may be a significant driver of future vulnerability to climate change at the farm level. For New Zealand producers, emphasis on the clean, green image of agriculture, changes in trade barriers or overseas environmental legislation, also driven by changing market demand, may operate through economic, political, and environmental pathways and nodes, to place

additional pressure on farmers and kiwifruit growers increasing exposure to climatic or market conditions, or reducing the capacity to adapt effectively.

Conversely, adaptive capacity might also potentially be driven by such global teleconnections; adoption of a range of ‘no regrets’ strategies in agriculture might have a number of advantages. The cultivation of organic fruit, or more sustainably produced or niche products might be a selling point and help distinguish New Zealand products in a crowded market (Campbell & Fairweather 1998; Hayward & Le Heron 2002). The benefits would accrue to producers, increasing adaptive capacity. As shown earlier with the example of ZESPRI Gold kiwifruit, consumer preference in Asia for a more saccharine fruit resulted in the development of a new varietal (Beverland 2001). Consumer demand for organic or niche products then, might spur innovation in the agricultural sector and enable New Zealand producers to take advantage of new opportunities.

Adaptations here might also have consequences for vulnerability or environmental change elsewhere. It was shown that the use of palm kernel expeller (PKE) was an important adaptation by dairy producers to respond to climatic variability as well as intensify production to take advantage of higher returns. A by-product of palm oil production, its import is the subject of much debate political and economic (Rennie 2007; Norman 2009) It has been blamed for deforestation and biodiversity loss in Indonesia and Malaysia (Fitzherbert et al. 2008; Koh & Wilcove 2008). While this is a contentious issue, it demonstrates the interconnected nature of vulnerability and the ways in which crucial adaptive strategies might have wider implications. New Zealand is among the world’s largest milk exporters (Gray & Le Heron 2010). Changing

climatic conditions elsewhere might create new areas in which dairying be cost-effective. This might in turn, have an impact on prices, and producers.

More research is also needed to better inform debates about macroeconomic policy, including the importance and influence of marketing boards with respect to adaptive capacity. These institutions have a vested interest in ensuring the long-term viability of agricultural production. Fonterra and its cooperative shareholders may in fact comprise a collective type of risk-sharing with respect to market exposures. It has been suggested that the days of the single-marketing desk for kiwifruit are numbered. This would have important consequences for kiwifruit growers, leading to greater competition in the marketplace, and have significant impacts on orchard gate returns.

8.7 Implications for broader academic and methodological debates

In addition to the practical findings and directions for future research, the study presented has also contributed to the academic literature on theoretical, conceptual and methodological levels. First, it has argued for and demonstrated the value of a place based case study using a bottom up approach across a range of temporal and spatial scales to enable comparison between different farms within a region. The research has developed a robust, holistic, contextualised, yet fine-grained understanding of vulnerability at the farm level. This research has thus informed methodological and theoretical debates and promoted use of an integrated approach to vulnerability assessment and the effects of climatic variability and change on agricultural production in the study area. By seeking to uncover the multiple exposures to which producers are exposed-sensitive, the research has challenged the traditional scenario-based approach to

climate change studies, bringing alternative perspectives into view. It could also be argued that the research has challenged “the pretensions of orthodox science to achieve universal accuracy” (Forsyth 2003, p.218) and confirmed the need to democratise science and attend to local people’s knowledge, priorities, innovations and practices.

Second, it has devised and used a vulnerability assessment framework that contributes to key theoretical debates discussed in Chapter Two. The framework emphasises and enables the analysis of the multiple exposures – both climatic and non-climatic – to which agricultural producers are exposed-sensitive. It highlights the roles played by climatic, biophysical, institutional and socioeconomic forces at a range of scales, and their influence on farm income, production and yield. This is important because, as this research has demonstrated, climate is only one stressor to which agricultural producers are exposed. Scenario based studies often assume the climatic variables to which producers are most sensitive, and neglect the role of other, non-climatic factors in determining the overall impact. A critical implication of this research is that studies of the impacts of climate change on social ecological systems, in New Zealand and elsewhere, should attend more closely to the interactive and synergistic effect of multiple climatic and non-climatic stressors as they influence and pertain to vulnerability.

The vulnerability-based framework used here also has significant implications for work done elsewhere in New Zealand. While this research concentrated on the eastern Bay of Plenty, the implications for intervention outlined above have relevance far beyond this region, contributing to broader debates about vulnerability, resilience, climate change adaptation and approaches to analyzing the impacts of climate change among various socio ecological systems. For example,

the findings are important for wider conceptual and methodological debates about the best means to assess climate change impacts, the relevance of vulnerability, linkages between vulnerability and resilience and the capacity for farmers to understand and adapt to changing climatic conditions, and the best means to adaptive capacity within the context of the multiple stressors to which producers are exposed-sensitive. It also informs debates about the impacts of climate change in New Zealand, however the findings should be generalised with caution since, as this research has emphasised, different people in different socio-economic, organisational and biophysical circumstances experience vulnerability in different ways and place varying emphasis on the importance of climate relative to agricultural production and as a consequence, generalised narratives of change are often highly misleading (Schröter et al. 2005; Hulme 2010)

Finally, this research demonstrates the critical issue of scientific uncertainty, especially with regard to predicting the impacts of climate change using a linear, model based approach and its implications. Models tend to simplify the situation in order to control and isolate a small number of key variables. This can be very useful for more precisely defining problems and understanding different processes, but as the level of system complexity and dynamism increases, so does the scale of the task of comprehension and the level of uncertainty. Acknowledging the inability to reliably predict the future in spatially and temporally dynamic and complex systems, at least without extremely intensive site-specific research, a shift in approach is encouraged to move towards a strategy of efficiently and effectively responding to changes (Lindblom 1959).

Lindblom (1959) coined the expression, “the science of muddling through”, to capture a practical approach to large-scale policy problems that could not be completely understood. Through a process of limited comparisons, case studies, reliance on experience, educated guess work and

rules of thumb incremental progress is made. This approach is arguably similar to the way in which many agricultural producers attempt to learn-through-doing, taking small, often reversible, steps to adaptively manage their land. Indeed, agricultural producers may be the ‘experts’ in the location-specific science of ‘muddling through’ the impacts of climatic variability and change as they have most experience of observing and interpreting early signs, a sense of possible surprises and hence an ability to adapt more efficiently to changes (predicted or otherwise) in their biophysical and socio-economic environment (Laidler 2006; Mertz et al. 2008; Byg & Salick 2009; Manandhar et al. 2010).

Climate science can be used to confirm, support and reveal implications and processes and help to build site-specific hybrid knowledge of system functioning and strengthen the ability of local people to maintain the buffer capacity or resilience of the system (Ekins et al. 2003; Turner, Matson, et al. 2003). While there are biophysical, social, economic and geographical constraints to realising more secure, profitable and sustainable forms of agriculture, these can be overcome with the precision use of science, as slow and laborious an undertaking as it may be (Scott 1998).

8.8 Climate change adaptation in New Zealand agriculture

Looking ahead do you see risks or opportunities?

There's always opportunities, there's no doubt about that. It's always cyclical, I've farmed through a few cycles now, one marriage, quite a few droughts, a few floods, fluctuations in the dollar and payout, and there's no doubt about it, if you have to do anything, you've got to do it when things are good. When things are bad, you don't do anything stupid.

Dairy farmer and horticulturalist, Waimana, New Zealand

Scholars have characterized some public policy problems such as healthcare, AIDS and terrorism as “wicked problems” (Rittel & Webber 1973); ones that defy resolution because of the enormous interdependencies, uncertainties, circularities, and conflicting stakeholders implicated by any effort to develop a solution, “social messes”. Climate change, however, can be fairly described as a “super wicked problem” because of its even further exacerbating features: time is running out, there is no central authority responsible and those seeking an end to the problem are also causing it (Lazarus 2008).

During the writing of this chapter, New Zealand's National Institute for Water and Atmosphere (NIWA) announced that this had been the warmest June on record; weeks later, the city of Christchurch had its coldest day since 1918, and snow blanketed South Africa. There is mounting evidence that such localized climatic events are in fact, manifestations of what Hulme (2010) refers to as a “hybrid climate”. The “globally coherent fingerprint of climate change” (Parmesan & Yohe 2003; Root et al. 2005), has now been identified in extreme rainfall events in the UK (Pall et al. 2011), and Asia (Min et al. 2011). It is becoming more difficult to distinguish between natural climatic variation and the influence of anthropogenic GHG emissions. Climate

everywhere has now been marked by what novelist Ian McEwan (2005) calls the “hot breath of our civilization” and yet GHG emissions continue to increase. The evidence for anthropogenic climate change is clear (Stott et al. 2006; Smith et al. 2009; Anderegg et al. 2010). Yet the failure of international agreement to stabilize emissions means that the 2°C threshold of “dangerous” interference with the climate is likely to be exceeded (Ramanathan & Feng 2008; Parry et al. 2009; Smith et al. 2009) and changes in average global temperature of up to 4°C by 2100 are likely (Adger & Barnett 2009; Parry et al. 2009). As this thesis has argued, an emphasis must be placed on adapting to the inevitable aspects of this “super wicked problem”. As Lynch (2008) has written:

In this atmosphere of uncertainty, then, it is worth being explicit in defining the goal: to secure the common interest in the face of climate change. A good approximation to the common interest in response to climate change is to reduce the vulnerability of things valued in the world’s many and diverse communities, and *not* in the stabilization of concentrations of greenhouse gases in the atmosphere *per se*.

Weather has always moved in cycles, and with it, agricultural production, through good years and bad, wetter and drier, hotter and colder, however the scale and speed with which such changes are now occurring and are likely to occur, threaten to undermine traditional adaptive strategies. The need then to engage with local stakeholders, actors and producers, is clear (van Aalst et al. 2008; Byg & Salick 2009; Moser & Ekstrom 2011). By uncovering and examining the vulnerability of agricultural production; through the identification of the sources of risk that are relevant to producers themselves, and the examination of those conditions which will serve to facilitate or constrain adaptation, it might be possible to take advantage of the opportunity to make progress while things are good. As the quote from the farmer above notes, before things are bad, is the time to assess opportunities and make changes.

As this thesis has sought to demonstrate, the changes that might be required in social ecological systems, including agriculture, cannot be adequately understood by science alone (Berkes & Jolly 2002; Kloprogge & Sluijs 2006; van Aalst et al. 2008). Local knowledge, observation and experience can instead, be complementary to scientific modelling and support policy formation and development. Local knowledge can provide information about local conditions and redirect the foci of empirical investigations to issues that have been overlooked by science alone (Kloprogge & Sluijs 2006). With respect to policy formation, local perception reflects local concerns (Danielsen et al. 2005) and helps focus on the actual impacts of climate change on people's lives (Laidler 2006), which are dependent on local factors and cannot be estimated through models (van Aalst et al. 2008). Local knowledge and perceptions influence people's decisions in deciding whether to act or not (Alessa et al. 2008) and what adaptive measures are taken over both short- and long-terms (Berkes & Jolly 2002; Brunner & Lynch 2010).

Such a research agenda will require active and innovative ways to engage with stakeholders (Tompkins et al. 2008; van Aalst et al. 2008; Meinke et al. 2009). It will require the misconceptions and barriers to action around climate change be addressed and it will require both climate and social science to become more proficient at "muddling through". It will mean greater reliance on the wisdom, knowledge and experience of people in local places (Laidler 2006; Folke et al. 2005) and less emphasis on computer models. It will require us to employ Jasanoff's "technologies of humility" (2007) to uncover the vulnerabilities of daily life and agricultural practice in a variable and changing climate, to support the capacity for creative solutions and resilience, to discern what matters on the ground and how best to support that as we move forward into a new and uncertain future.

References

- Acosta-Michlik, L. & Espaldon, V., 2008. Assessing vulnerability of selected farming communities in the Philippines based on a behavioural model of agent's adaptation to global environmental change. *Global Environmental Change*, 18(4), pp.554-563.
- Adger, W.N. et al., 2004. *New indicators of vulnerability and adaptive capacity*, Tyndall Centre for Climate Change Research. University of East Anglia: Norwich.
- Adger, W.N., Brown, K., et al., 2003. Governance for sustainability: towards a "thick" analysis of environmental decision making. *Environment and Planning A*, 35(6), pp.1095–1110.
- Adger, W.N., Eakin, H. & Winkels, A., 2009. Nested and teleconnected vulnerabilities to environmental change. *Frontiers in Ecology and the Environment*, 7(3), pp.150-157.
- Adger, W.N., 1996. *Approaches to vulnerability to climate change*, Centre for Social and Economic Research on the Global Environment: University of East Anglia and University College London.
- Adger, W.N., 2000. Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers*, 90(4), pp.738-758.
- Adger, W.N., 2003. Social Aspects of Adaptive Capacity. In J.B. Smith, R.J.T. Klein, & S. Huq, eds. *Climate Change, Adaptive Capacity and Development*. London: Imperial College Press, pp. 29-50.
- Adger, W.N., 1999. Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. *World Development*, 27(2), pp.249-269.
- Adger, W.N. & Barnett, J., 2009. Four reasons for concern about adaptation to climate change. *Environment and Planning A*, 41(12), pp.2800-2805.
- Adger, W.N. & Brown, K., 2009. Vulnerability and Resilience to Environmental Change: Ecological and Social Perspectives. , pp.109-122.
- Adger, W.N. & Kelly, P.M., 1999. Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, 4(3-4), pp.253-266.
- Adger, W.N., Dessai, S., et al., 2009. Are there social limits to adaptation to climate change? *Climatic Change*, 93(3-4), pp.335-354.
- Adger, W.N., Huq, S., et al., 2003. Adaptation to climate change in the developing world. *Progress in Development Studies*, 3(3), pp.179 -195.
- Adger, W.N., 2006. Vulnerability. *Global Environmental Change*, 16(3), pp.268-281.

- Adger, W.N. et al., 2007. Assessment of adaptation practices, options, constraints and capacity. In M.L. Parry et al., eds. *Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.
- Adger, W.N., Arnell, N.W. & Tompkins, E.L., 2005. Successful adaptation to climate change across scales. *Global Environmental Change*, 15(2), pp.77-86.
- Adger, W.N., 2001. Scales of governance and environmental justice for adaptation and mitigation of climate change. *Journal of International Development*, 13(7), pp.921-931.
- AgFirst Consultants, 1997. *Rural Subdivisions on the Rangitaiki Plains and Galatea Basin*, Hastings, NZ: AgFirst Consultants.
- Alessa, L. et al., 2008. The Arctic Water Resource Vulnerability Index: An Integrated Assessment Tool for Community Resilience and Vulnerability with Respect to Freshwater. *Environmental Management*, 42(3), pp.523-541.
- Allison, E.H. & Hobbs, R.J., 2004. Resilience, adaptive capacity, and the lock-in trap of the Western Australian agricultural region. *Ecology and Society*, 9(1).
- Allison, E.H. et al., 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, 10(2), pp.173–196.
- Altieri, M.A. & Trujillo, J., 1987. The agroecology of corn production in Tlaxcala, Mexico. *Human Ecology*, 15(2), pp.189-220.
- Alwang, J., Siegel, P.B. & Jorgensen, S.L., 2001. *Vulnerability: A view from different disciplines*, The World Bank.
- Amos, N., Mowat, A. & Kay, S., 2002. Harvest maturity criteria and cool chain practices for ZESPRI™ GOLD kiwifruit. *New Zealand Kiwifruit Journal*, 150, pp.10-15.
- Anderegg, W.R.L. et al., 2010. Expert credibility in climate change. *Proceedings of the National Academy of Sciences*, 107(27), pp.12107-12109.
- Anderson, D.C., 1985. Wastage and disease in Bay of Plenty dairy herds. *New Zealand Veterinary Journal*, 33(5), pp.61-65.
- Andrew, R. & Forgie, V., 2008. A three-perspective view of greenhouse gas emission responsibilities in New Zealand. *Ecological Economics*, 68(1-2), pp.194-204.
- Armitage, D. et al., 2009. Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment*, 7(2), pp.95-102.
- Armitage, D.R., 2005. Adaptive capacity and community-based natural resource management. *Environmental Management*, 35(6), pp.703-715.

- Askew, S.J., 1965. Utilisation of kikuyu grass. *New Zealand Journal of Agriculture*, 110, pp.377-397.
- Asseng, S. et al., 2004. Simulated wheat growth affected by rising temperature, increased water deficit and elevated atmospheric CO₂. *Field Crops Research*, 85(2-3), pp.85-102.
- Badjeck, M.-C. et al., 2009. Climate variability and the Peruvian scallop fishery: the role of formal institutions in resilience building. *Climatic Change*, 94(1-2), pp.211-232.
- Baird, A. et al., 1975. *Towards an Explanation and Reduction of Disaster Proneness, Occasional Paper No. 11*, Bradford: Disaster Research Unit, University of Bradford.
- Baisden, W.T., 2006. Agricultural and forest productivity for modelling policy scenarios: evaluating approaches for New Zealand greenhouse gas mitigation. *Journal of the Royal Society of New Zealand*, 36, pp.1-15.
- Balat, M. & Balat, H., 2009. Recent trends in global production and utilization of bio-ethanol fuel. *Applied Energy*, 86, pp.2273-2282.
- Ballinger, C.E., 1962. Kikuyu grass provides valuable feed on some Northland farms. *New Zealand Journal of Agriculture*, 105, pp.497-506.
- Bardsley, D.K. & Edwards-Jones, Gareth, 2007. Invasive species policy and climate change: social perceptions of environmental change in the Mediterranean. *Environmental Science & Policy*, 10(3), pp.230-242.
- Barkle, G.F. et al., 2000. Effect of regular irrigation with dairy farm effluent on soil organic matter and soil microbial biomass. *Soil Res.*, 38(6), pp.1087-1097.
- Barnett, J. & O'Neill, S., 2010. Maladaptation. *Global Environmental Change*, 20(2), pp.211-213.
- Barnett, J., Dessai, S. & Jones, R.N., 2007. Vulnerability to climate variability and change in East Timor. *AMBIO: A Journal of the Human Environment*, 36(5), pp.372-378.
- Barnett, J. & Pauling, J., 2005. The Environmental Effects of New Zealand's Free-Market Reforms. *Environment, Development and Sustainability*, 7(2), pp.271-289.
- Barnston, A.G. et al., 2005. Improving Seasonal Prediction Practices Through Attribution of Climate Variability. *Bulletin of the American Meteorological Society*, 86(1), pp.59-72.
- Basset-Mens, C., Ledgard, S. & Boyes, Mark, 2009. Eco-efficiency of intensification scenarios for milk production in New Zealand. *Ecological Economics*, 68(6), pp.1615-1625.
- Battaglini, A. et al., 2008. European winegrowers' perceptions of climate change impact and options for adaptation. *Regional Environmental Change*, 9(2), pp.61-73.

- Batterbury, S., Forsyth, T. & Thomson, K., 1997. Environmental transformations in developing countries: Hybrid research and democratic policy. *The Geographical Journal*, 163, pp.126-132.
- Baxter, J. & Eyles, J., 1997. Evaluating qualitative research in social geography: establishing “rigour” in interview analysis. *Transactions of the Institute of British Geographers*, 22, pp.505-525(21).
- Beanland, S., Blick, G.H. & Darby, D.J., 1990. Normal Faulting in a Back Arc Basin: Geological and Geodetic Characteristics of the 1987 Edgecumbe Earthquake, New Zealand. *Journal of Geophysical Research*, 95(B4), pp.4693-4707.
- Belliveau, S., Smit, B. & Bradshaw, B., 2006. Multiple exposures and dynamic vulnerability: Evidence from the grape industry in the Okanagan Valley, Canada. *Global Environmental Change*, 16(4), pp.364-378.
- Benatar, J.R. et al., 2011. Trans-fatty acids in New Zealand patients with coronary artery disease. *European Journal of Cardiovascular Prevention & Rehabilitation*.
- Berg, E. & Schmitz, B., 2008. Weather-based instruments in the context of whole-farm risk management. *Agricultural Finance Review*, 68(1), pp.119-133.
- Berkes, F. & Jolly, D., 2002. Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Conservation Ecology*, 5(2), p.18.
- Berkes, F. & Folke, C. eds., 2000. *Linking social and ecological systems: management practices and social mechanisms for building resilience*, Cambridge University Press.
- Bernard, R.H., 2005. *Research Methods in Anthropology: Qualitative and Quantitative Approaches* 4th ed., Lanham, MD: Altamira Press.
- Berry, P.M. et al., 2006. Assessing the vulnerability of agricultural land use and species to climate change and the role of policy in facilitating adaptation. *Environmental Science & Policy*, 9(2), pp.189-204.
- Betteridge, K. et al., 2002. Cattle treading on wet soils: implications for pasture growth and soil physical condition. In L. D. Currie & P. Loganathan, eds. *Dairy Farm Soil Management*. Palmerston North, NZ: Massey University, pp. 47-59.
- Betts, R.A. et al., 2010. When could global warming reach 4°C? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1934), pp.67-84.
- Beverland, M., 2001. Creating value through brands: the ZESPRI kiwi fruit case. *British Food Journal*, 103(6), pp.383–399.

- Beverland, M., 1998. Wine Tourism in New Zealand — Maybe The Industry Has Got It Right. *International Journal of Wine Marketing*, 10(2), pp.24-33.
- Biggs, D., 2011. Understanding Resilience in a Vulnerable Industry: the Case of Reef Tourism in Australia. *Ecology and Society*, 16(1), p.30.
- Biggs, D. et al., 2011. Are We Entering an Era of Concatenated Global Crises? *Ecology and Society*, 16(2).
- Bindi, M. et al., 1999. Modelling climate change impacts on grapevine in Tuscany. *Climate Change, Climatic Variability and Agriculture in Europe: An Integrated Assessment*, pp.191-216.
- Blaikie, P., 1989. Environment and Access to Resources in Africa. *Africa: Journal of the International African Institute*, 59(1), pp.18-40.
- Blaikie, P., 1985. *The Political Ecology of Soil Erosion in Developing Countries*, London: Longman Scientific and Technical.
- Blaikie, P. & Brookfield, H., 1987. *Land Degradation and Society*, London: Methuen.
- Blaikie, P. et al., 1994. *At Risk: Natural Hazards, People's Vulnerability, and Disasters* 1st ed., London: Routledge.
- Blaikie, Piers, 1981. Class, Land-use and Soil Erosion. *Development Policy Review*, A14(2), pp.57-77.
- Blaschke, P.M., Trustrum, N.A. & DeRose, R.C., 1992. Ecosystem processes and sustainable land use in New Zealand steeplands. *Agriculture, Ecosystems & Environment*, 41(2), pp.153-178.
- Blazejczak, J., Gornig, M. & Hartje, V., 2011 [In press]. Downscaling nonclimatic drivers for surface water vulnerabilities in the Elbe river basin. *Regional Environmental Change*. Available at: <http://www.springerlink.com/index/10.1007/s10113-011-0237-6> [Accessed August 30, 2011].
- Bohle, H.G., Downing, Thomas E. & Watts, M.J., 1994. Climate change and social vulnerability: Toward a sociology and geography of food insecurity. *Global Environmental Change*, 4(1), pp.37-48.
- Boland, P., 1999. Contested Multi-Level Governance: Merseyside and the European Structural Funds. *European Planning Studies*, 7(5), p.647.
- Bolin, B., 2007. *A history of the science and politics of climate change: the role of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press.

- BoPRC, 2011. *Sustainable Land Management Activity Report on Operational Work 2009/2010*, Whakatane, N.Z.: Bay of Plenty Regional Council.
- Bowler, I., 1992. *The Geography of Agriculture in Developed Market Economies*, New York: Longman Scientific and Technical.
- Bradshaw, B., 2007. Climate Change Adaptation in a Wider Context: Conceptualizing Multiple Risks in Primary Agriculture. In S. E. Wall, B. Smit, & J. Wandel, eds. *Farming in a changing climate: agricultural adaptation in Canada*. Vancouver, Canada: UBC Press, pp. 103-114.
- Bradshaw, B., Cocklin, C. & Smit, B., 1998. Subsidy Removal and Farm-Level Stewardship in Northland. *New Zealand Geographer*, 54(2), pp.12-20.
- Bradshaw, B., Dolan, H. & Smit, B., 2004. Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian Prairies. *Climatic Change*, 67(1), pp.119-141.
- Bradshaw, M. & Stratford, E., 2005. Qualitative research design and rigour, 2nd ed. In I. Hay, ed. *Qualitative Research Methods in Human Geography*. Melbourne: Oxford University Press, pp. 67-76.
- Bremer, R.J., 1993. Federated farmers and the state. In B. Roper & C. Rudd, eds. *State and economy in New Zealand*. Oxford Readings in New Zealand Politics, No. 2. Auckland, N.Z: Oxford University Press, pp. 108-127.
- Brenmuhl, F., 2008. Opinion: emissions trading and agriculture. *Straight Furrow*. Available at: <http://straightfurrow.farmonline.co.nz/news/nationalrural/agribusiness-and-general/general/opinion-emissions-trading-and-agriculture/1262947.aspx>. [Accessed July 25, 2011].
- Brklacich, M. et al., 2000. Agricultural adaptation to climatic change: a comparative assessment of two types of farming in central Canada. In H. Millward et al., eds. *Agricultural and Environmental Sustainability in the New Countryside*. Winnipeg, MB: Hignell Printing, pp. 40-51.
- Brklacich, M. et al., 1997. Adaptability of agricultural systems to global climate change: a Renfrew County, Ontario, Canada Pilot Study. In B. Ilbery, Q. Chiotti, & T. Rickard, eds. *Agricultural restructuring and sustainability: a geographical perspective*. Winnipeg, MB: Hignell Printing, pp. 40-51.
- Brock, M.A., Smith, R.G.B. & Jarman, P.J., 1999. Drain it , dam it: alteration of water regime in shallow wetlands on the New England Tableland of New South Wales , Australia. *Wetlands Ecology and Management*, 7, pp.37-46.
- Brooks, N., 2003. *Vulnerability, risk and adaptation: A conceptual framework*, Norwich, UK: Tyndall Centre for Climate Change Research, University of East Anglia.

- Brooks, N., Adger, W.N. & Kelly, P.M., 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, 15(2), pp.151-163.
- Brooks, N., 2006. Cultural responses to aridity in the Middle Holocene and increased social complexity. *Quaternary International*, 151(1), pp.29-49.
- Brown, M.E. & Funk, C.C., 2008. Food Security Under Climate Change. *Science*, 319(5863), pp.580 -581.
- Brown, P.R. et al., 2010. Enabling natural resource managers to self-assess their adaptive capacity. *Agricultural Systems*, 103(8), pp.562-568.
- Bruges, M. & Smith, W., 2007. Participatory approaches for sustainable agriculture: A contradiction in terms? *Agriculture and Human Values*, 25(1), pp.13-23.
- Brunner, R.D., 2001. Science and the climate change regime. *Policy Sciences*, 34(1), pp.1-33.
- Brunner, R.D. & Lynch, A.H., 2010. *Adaptive Governance and Climate Change*, Chicago: University of Chicago Press.
- Bryant, C.R. & Johnston, T.R.R., 1992. Agriculture in the city's countryside. *Agriculture in the city's countryside*.
- Bryant, C.R., Singh, B. & André, P., 2007. The perception of risk to agriculture and climatic variability in Québec: implications for farmer adaptation to climatic variability and change. In E. Wall, B. Smit, & J. Wandel, eds. *Farming in a changing climate: agricultural adaptation in Canada*. Vancouver, Canada: UBC Press, pp. 142-154.
- Bryant, C.R. et al., 2000. Adaptation in Canadian agriculture to climatic variability and change. *Climatic Change*, 45(1), pp.181-201.
- Buckle, R.A. et al., 2007. A structural VAR business cycle model for a volatile small open economy. *Economic Modelling*, 24(6), pp.990-1017.
- Bulkeley, H., 2001. No regrets?: Economy and environment in Australia's domestic climate change policy process. *Global Environmental Change*, 11(2), pp.155-169.
- Bunce, M., Rosendo, S. & Brown, Katrina, 2009. Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. *Environment, Development and Sustainability*, 12(3), pp.407-440.
- Burch, S., 2010. Transforming barriers into enablers of action on climate change: insights from three municipal case studies in British Columbia, Canada. *Global Environmental Change*, 20(2), pp.287-297.

- Burt, T.P. et al., 2002. Water table fluctuations in the riparian zone: comparative results from a pan-European experiment. *Journal of Hydrology*, 265(1-4), pp.129-148.
- Burton, I., 2011. Adaptation to Climate Change: Context, Status, and Prospects. In J.D. Ford & L. Berrang-Ford, eds. *Climate Change Adaptation in Developed Nations*. Dordrecht: Springer Netherlands, pp. 477-483.
- Burton, I., 1997. Vulnerability and adaptive response in the context of climate and climate change. *Climatic Change*, 36(1-2), pp.185-196.
- Burton, I. & Lim, B., 2005. Achieving adequate adaptation in agriculture. *Climatic Change*, 70(1), pp.191–200.
- Burton, I., Kates, R.W. & White, G.F., 1993. *The Environment As Hazard*,
- Byg, A. & Salick, J., 2009. Local perspectives on a global phenomenon--Climate change in Eastern Tibetan villages. *Global Environmental Change*, 19(2), pp.156-166.
- Cai, X., McKinney, D.C. & Rosegrant, Mark W, 2003. Sustainability analysis for irrigation water management in the Aral Sea region. *Agricultural Systems*, 76(3), pp.1043-1066.
- Campbell, A., 2009. Kiwifruit growers asked for dollars. Available at: <http://www.sunlive.co.nz/news/6334-kiwifruit-growers-asked-dollars.html> [Accessed August 12, 2011].
- Campbell, E.O., Heine, J.C. & Pullar, W.A., 1973. Identification of Plant Fragments and Pollen from Peat Deposits in Rangitaiki Plains and Maketu Basins. *New Zealand Journal of Botany*, 11, pp.317-330.
- Campbell, H., 2005. The rise and rise of EurepGAP: European (re) invention of colonial food relations. *International journal of sociology of food and agriculture*, 13(2), pp.1–19.
- Campbell, H. & Fairweather, J.R., 1998. *The development of organic horticultural exports in New Zealand*, Lincoln University. Agribusiness and Economics Research Unit.
- Campbell, H. & Le Heron, R., 2007. Supermarkets, producers and audit technologies: the constitutive micro-politics of food, legitimacy and governance. In G. Lawrence & D. Burch, eds. *Supermarkets and Agri-Food Supply Chains: Transformations in the Production and Consumption of Foods*. London: Edward Elgar, pp. 131-153.
- Campbell, H., Fairweather, J. & Steven, David, 1997. *Recent Developments in Organic Food Production in New Zealand: Part 2, Kiwifruit in the Bay of Plenty*, Dunedin, N.Z.: Dept. of Anthropology, University of Otago.

- Campbell, H., Lawrence, G. & Smith, K., 2006. Audit Cultures and the Antipodes: The Implications of EurepGAP for New Zealand and Australian Agri-food Industries. In T. Marsden & J. Murdoch, eds. *Between the local and the global: confronting complexity in the contemporary agri-food sector*. Research in Rural Sociology and Development. pp. 69-93.
- Cannon, T., 2002. Gender and climate hazards in Bangladesh. *Gender and Development*, 10(2), pp.45–50.
- Carbon Partnership, 2011. *Climate Change Knowledge Networks: A national database of community climate change projects*, Wellington, NZ: Carbon Partnership.
- Carswell, F. et al., 2007. Reducing terrestrial greenhouse gas emissions: a human dimensions contribution. *International Journal of Sustainable Development*, 10(4), pp.294-318.
- Carter, T. R et al., 1994. *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*, London: Department of Geography, University College London.
- Carter, T.R., Porter, J.H. & Parry, M.L., 1991. Climatic warming and crop potential in Europe: Prospects and uncertainties. *Global Environmental Change*, 1(4), pp.291-312.
- Casale, M. et al., 2009. Understanding vulnerability in southern Africa: comparative findings using a multiple-stressor approach in South Africa and Malawi. *Regional Environmental Change*, 10(2), pp.157-168.
- Cash, D.W. & Moser, S.C., 2000. Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, 10(2), pp.109-120.
- Cashman, A.C., 2011. Case study of institutional and social responses to flooding: reforming for resilience? *Journal of Flood Risk Management*, 4(1), pp.33-41.
- Challinor, A. et al., 2007. Assessing the vulnerability of food crop systems in Africa to climate change. *Climatic Change*, 83(3), pp.381-399.
- Chambers, R., 1989. Vulnerability, coping and policy. *IDS bulletin*, 37(4), pp.33–40.
- Chambers, R. & Conway, G.R., 1992. *Sustainable rural livelihoods: practical concepts for the 21st century*, Brighton: Institute of Development Studies.
- Chapin, F.S. et al., 2006. Building resilience and adaptation to manage Arctic change. *AMBIO: A Journal of the Human Environment*, 35(4), pp.198–202.
- Chase, T.N., Pielke Sr, R.A. & Avissar, R., 2005. Teleconnections in the Earth System. In M. G. Anderson & J. J. McDonnell, eds. *Encyclopedia of Hydrological Sciences*. West Sussex: Wiley.

- de Chazal, J. et al., 2008. Including multiple differing stakeholder values into vulnerability assessments of socio-ecological systems. *Global Environmental Change*, 18(3), pp.508-520.
- Chettri, N.B. et al., 2010. Modeling Path Dependence in Agricultural Adaptation to Climate Variability and Change. *Annals of the Association of American Geographers*, 100(4), pp.894-907.
- Cheung, W.W.L. et al., 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries*, 10(3), pp.235-251.
- Chiotti, Q.P. & Johnston, T., 1995. Extending the boundaries of climate change research: a discussion on agriculture. *Journal of Rural Studies*, 11(3), pp.335-350.
- Clark, D.A. et al., 2007. Issues and options for future dairy farming in New Zealand. *New Zealand Journal of Agricultural Research*, 50(2), pp.203-221.
- Clark, H. et al., 2001. The Sensitivity of New Zealand's Managed Pastures to Climate Change. In R. A. Warrick, G. J. Kenny, & J. J. Hardman, eds. *The Effects of Climate Change and Variation in New Zealand: An Assessment Using the CLIMFACTS System*. Hamilton N.Z.: International Global Change Institute, University of Waikato, pp. 65-78.
- Climate Change Office, 2005. *Community-based Dune Management for the Mitigation of Coastal Hazards and Climate Change Effects: A Guide for Local Authorities*, Wellington, N.Z.: Climate Change Office. Available at: <http://www.boprc.govt.nz/media/33232/Report-050400-CommunityBasedDuneManagementMitigationCoastalHazardsClimateChangeEffects.pdf>.
- Cloke, P., 1996. Looking Through European Eyes? A Re-evaluation of Agricultural Deregulation in New Zealand. *Sociologia Ruralis*, 36(3), pp.307-330.
- Cloke, P., 1989. State Deregulation and New Zealand's Agricultural Sector. *Sociologia Ruralis*, 29(1), pp.34-48.
- Conde, C. & Lonsdale, K., 2005. Engaging stakeholders in the adaptation process. In B. Lim et al., eds. *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge: Cambridge University Press, pp. 47-66.
- Conway, G. R., 1987. The properties of agroecosystems. *Agricultural Systems*, 24(2), pp.95-117.
- Cope, M., 2005. Coding transcripts and diaries. In N. Clifford & G. Valentine, eds. *Key methods in geography*. London, UK: Sage Publications, pp. 445-459.
- Corbin, J.M. & Strauss, A.C., 2008. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* 3rd Edition., Sage Publications, Inc.

- Cordell, D., Drangert, J.-O. & White, S., 2009. The story of phosphorus: Global food security and food for thought. *Global Environmental Change*, 19(2), pp.292-305.
- Costello, A. et al., 2009. Managing the health effects of climate change. *Lancet*, 373(9676), pp.1693–1733.
- Coulthard, S., 2008. Adapting to environmental change in artisanal fisheries--Insights from a South Indian Lagoon. *Global Environmental Change*, 18(3), pp.479-489.
- Cradock-Henry, N., 2008. Exploring Perceptions of Risks and Vulnerability To Climate Change in New Zealand Agriculture. *Political Science*, 60(1), pp.151-155.
- Creswell, J.W., 2007. *Qualitative Inquiry and Research Design: Choosing among Five Traditions* 2nd ed., London, UK: Sage Publications, Inc.
- Cronin, K., 2008. Science and society “dialogue”: A new communication approach for reducing conflict around controversial science and technology. *New Zealand Science Review*, 65(3), pp.47-49.
- Crush, J.R. & Rowarth, J.S., 2007. The role of C4 grasses in New Zealand pastoral systems. *New Zealand Journal of Agricultural Research*, 50(2), pp.125-137.
- Curtis, B. & Reveley, J., 2001. Producers, Processors and Unions: The Meat Producers Board and Labour Relations in the New Zealand Meat Industry, 1952–1971. *Australian Economic History Review*, 41(2), pp.135-158.
- Cutter, S.L., 1996. Vulnerability to environmental hazards. *Progress in Human Geography*, 20(4), pp.529-539.
- Cutter, S.L. & Finch, C., 2008. Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the National Academy of Sciences*, 105(7), pp.2301-2306.
- Cutter, S.L., Boruff, B.J. & Shirley, W.L., 2003. Social vulnerability to environmental hazards. *Social Science Quarterly*, 84(2), pp.242-261.
- DairyNZ, 2010. *Facts and Figures for New Zealand Dairy Farmers*, Hamilton, NZ: DairyNZ.
- Dale, V.H. et al., 2001. Climate Change and Forest Disturbances. *BioScience*, 51(9), p.723.
- Dalziel, P., 2002. New Zealand’s economic reforms: An assessment. *Review of Political Economy*, 14(1), pp.31–46.
- Danielsen, F., Burgess, N.D. & Balmford, A., 2005. Monitoring Matters: Examining the Potential of Locally-based Approaches. *Biodiversity and Conservation*, 14(11), pp.2507-2542.
- Darnhofer, I., 2010. Strategies of family farms to strengthen their resilience. *Environmental Policy and Governance*, 20(4), pp.212-222.

- Darnhofer, I., Fairweather, J. & Moller, H., 2010. Assessing a farm's sustainability: insights from resilience thinking. *International Journal of Agricultural Sustainability*, 8(3), pp.186-198.
- Daugbjerg, C. & Studsgaard, J., 2005. Issue Redefinition, Venue Change and Radical Agricultural Policy Reforms in Sweden and New Zealand. *Scandinavian Political Studies*, 28(2), pp.103-124.
- Davenport, P.G., 1958. A survey of losses due to bloat in dairy cows in the Bay of Plenty. *New Zealand Veterinary Journal*, 6(5), pp.138-139.
- Davidson, D.J., Williamson, T. & Parkins, J.R., 2003. Understanding climate change risk and vulnerability in northern forest-based communities. *Canadian Journal of Forest Research*, 33(11), pp.2252-2261.
- Davis, M., 1999. *Ecology of Fear: Los Angeles and the Imagination of Disaster*, New York: Vintage.
- Defoer, T., 2002. Learning about methodology development for integrated soil fertility management. *Agricultural Systems*, 73(1), pp.57-81.
- Denton, F., 2002. Climate change vulnerability, impacts, and adaptation: why does gender matter? *Gender and Development*, pp.10–20.
- Deressa, T.T., Hassan, R.M. & Ringler, C., 2011. Perception of and Adaptation to Climate Change by Farmers in the Nile Basin of Ethiopia. *The Journal of Agricultural Science*, 149(01), pp.23-31.
- Dessai, S. & Hulme, M., 2004. Does climate adaptation policy need probabilities. *Climate Policy*, 4(2), pp.107–128.
- Dessai, S. et al., 2004. Defining and experiencing dangerous climate change: An editorial essay. *Climatic Change*, 64(1-2), pp.11-25.
- Diamond, J., 2006. *Collapse: how societies choose to fail or succeed*, New York: Penguin.
- Diamond, J.M., 1999. *Guns, Germs, and Steel: The Fates of Human Societies*, New York, NY: W. W. Norton & Company.
- Dias, F.N. et al., 2008. The effect of palm kernel expeller as a supplement for grazing dairy cows at the end of lactation. *Proceedings of the New Zealand Society of Animal Production*, 68, pp.111-112.
- Diffenbaugh, N.S. et al., 2005. Fine-scale processes regulate the response of extreme events to global climate change. *Proceedings of the National Academy of Sciences of the United States of America*, 102(44), pp.15774 -15778.

- Diffenbaugh, N.S. et al., 2011. Climate adaptation wedges: a case study of premium wine in the western United States. *Environmental Research Letters*, 6, pp.1-11.
- Dilley, M. & Boudreau, T.E., 2001. Coming to terms with vulnerability: a critique of the food security definition. *Food Policy*, 26(3), pp.229-247.
- Döll, P., 2009. Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment. *Environmental Research Letters*, 4, p.035006.
- Doole, G.J., Bathgate, A.D. & Robertson, M.J., 2009. Labour scarcity restricts the potential scale of grazed perennial plants in the Western Australian wheatbelt. *Animal Production Science*, 49(10), pp.883-893.
- Doran, P.T. & Kendall Zimmerman, M., 2009. Examining the Scientific Consensus on Climate Change. *Eos, Transactions American Geophysical Union*, 90(3), p.22.
- Dover, M.J. & Talbot, L.M., 1987. *To Feed the Earth: Agro-Ecology for Sustainable Development* First Edition., Washington, DC: World Resources Institute.
- Dovers, S.R., 2009. Normalizing adaptation. *Global Environmental Change*, 19(1), pp.4-6.
- Dovers, S.R. & Hezri, A.A., 2010. Institutions and policy processes: the means to the ends of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, 1(2), pp.212-231.
- Dow, K., 1992. Exploring differences in our common future (s): the meaning of vulnerability to global environmental change. *Geoforum*, 23(3), pp.417-436.
- Downing, T. E, 2003. Lessons from Famine Early Warning and Food Security for Understanding Adaptation to Climate Change: Toward a Vulnerability Adaptation Science? In J.B. Smith, R.J.T. Klein, & S. Huq, eds. *Climate Change, Adaptive Capacity and Development*. London: Imperial College Press, pp. 71-100.
- Downing, T. E & Patwardhan, A., 2005. Assessing vulnerability for climate adaptation. In B. Lim et al., eds. *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge: Cambridge University Press, pp. 67-90.
- Downing, T.E., 1991. Vulnerability to hunger in Africa: a climate change perspective. *Global Environmental Change*, 1(5), pp.365-380.
- Dunn, K., 2005. Interviewing. In I. Hay, ed. *Qualitative Research Methods in Human Geography*, 2nd ed. Melbourne: Oxford University Press, pp. 79-105.
- Dynes, R. et al., 2010. New Zealand's land-based primary industries & climate change: Assessing adaptation through scenario-based modelling. *Climate Change Adaptation in New Zealand*, p.44.

- Eakin, H., 2005. Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development*, 33(11), pp.1923-1938.
- Eakin, H. & Lemos, M.C., 2006. Adaptation and the state: Latin America and the challenge of capacity-building under globalization. *Global Environmental Change*, 16(1), pp.7-18.
- Eakin, H. & Luers, A.L., 2006. Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources*, 31, pp.365-394.
- Eakin, H. & Wehbe, M.B., 2008. Linking local vulnerability to system sustainability in a resilience framework: two cases from Latin America. *Climatic Change*, 93(3-4), pp.355-377.
- Eakin, H., Winkels, A. & Sendzimir, J., 2009. Nested vulnerability: exploring cross-scale linkages and vulnerability teleconnections in Mexican and Vietnamese coffee systems. *Environmental Science & Policy*, 12(4), pp.398-412.
- Eakin, H., 2003. The Social Vulnerability of Irrigated Vegetable Farming Households in Central Puebla. *The Journal of Environment & Development*, 12(4), pp.414-429.
- Eakin, H. & Bojórquez-Tapia, L.A., 2008. Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*, 18(1), pp.112-127.
- Easterberg, K., 2002. *Qualitative Methods in Social Research*, New York: McGraw Hill.
- Easterling, D.R. et al., 2000. Climate extremes: Observations, modeling, and impacts. *Science*, 289(5487), pp.2068-2074.
- Easterling, W.E., 1996. Adapting North American agriculture to climate change in review. *Agricultural and Forest Meteorology*, 80(1), pp.1-53.
- Easterling, W.E. et al., 1992. Simulations of crop response to climate change: effects with present technology and no adjustments (the “dumb farmer” scenario). *Agricultural and Forest Meteorology*, 59(1-2), pp.53-73.
- Ebi, K.L., Burton, I. & McGregor, G.R. eds., 2009. *Biometeorology for Adaptation to Climate Variability and Change*, Dordrecht: Springer Netherlands.
- EBoP, 2004. *Bay trends: report on the state of the Bay of Plenty environment*, Tauranga, NZ: Environment Bay of Plenty.
- EBoP, 2008. *Rangitaiki Tarawera Floodplain Management Strategy*, Whakatane, N.Z.: Environment Bay of Plenty.
- Edwards-Jones, G. et al., 2009. Vulnerability of exporting nations to the development of a carbon label in the United Kingdom. *Environmental Science & Policy*, 12(4), pp.479-490.

- Ekins, P. et al., 2003. A framework for the practical application of the concepts of critical natural capital and strong sustainability. *Ecological Economics*, 44(2-3), pp.165-185.
- Elliott, S., 1999. And the Question Shall Determine the Method. *The Professional Geographer*, 51(2), pp.240-243.
- Engle, N.L., 2011. Adaptive capacity and its assessment. *Global Environmental Change*, 21(2), pp.647-656.
- Engle, N.L. & Lemos, M.C., 2010. Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change*, 20(1), pp.4-13.
- Erez, A., 1995. Means to compensate for insufficient chilling to improve bloom and leafing. *Acta Hort*, 395, pp.81-96.
- Eriksen, S.H. & Brown, K., 2011. Sustainable adaptation to climate change. *Climate and Development*, 3(1), pp.3-6.
- Eriksen, S.H. et al., 2011. When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate and Development*, 3(1), pp.7-20.
- Eriksen, S.H., Brown, K. & Kelly, P.M., 2005. The dynamics of vulnerability: Locating coping strategies in Kenya and Tanzania. *Geographical Journal*, 171(4), pp.287-305.
- Euliss, N.H. & Mushet, D.M., 1996. Water-level fluctuation in wetlands as a function of landscape condition in the prairie pothole region. *Wetlands*, 16(4), pp.587-593.
- Evans, L. et al., 1996. Economic Reform in New Zealand 1984-95: The Pursuit of Efficiency. *Journal of Economic Literature*, 34(4), pp.1856-1902.
- Fallow, B. & Beston, A., 2006. Alarm erupts over climate tax on trade. *The New Zealand Herald*. Available at: http://www.nzherald.co.nz/section/1/story.cfm?c_id=1&objectid=10408414.
- Fankhauser, S., Smith, J.B. & Tol, R.S.J., 1999. Weathering climate change: some simple rules to guide adaptation decisions. *Ecological Economics*, 30(1), pp.67-78.
- Faraco, L.F.D., Andriquetto-Filho, J.M. & Lana, P.C., 2010. A methodology for assessing the vulnerability of mangroves and fisherfolk to climate change. *Pan-American Journal of Aquatic Sciences*, 5(2), pp.205-223.
- Fazey, I.R.A. et al., 2010. Adaptation strategies for reducing vulnerability to future environmental change. *Frontiers in Ecology and the Environment*, 8(8), pp.414-422.
- Federated Farmers, 2001. *Life After Subsidies: The New Zealand Farming Experience – 15 Years Late*, Wellington, N.Z.: Federated Farmers of New Zealand.

- Fedoroff, N.V. et al., 2010. Radically Rethinking Agriculture for the 21st Century. *Science*, 327(5967), pp.833 -834.
- Feenstra, J.F. et al., 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*, Nairobi: United Nations Environment Program (UNEP).
- Fekete, A., 2009. Validation of a social vulnerability index in context to river-floods in Germany. *Natural Hazards and Earth System Sciences*, 9(2), pp.393–403.
- Ferguson, A.R., 1991. *Actinidia arguta* — the hardy kiwi fruit. *New Zealand Kiwifruit*, 81, pp.23-24.
- Ferguson, A.R. & Seal, A.G., 2008. Kiwifruit. In J. F. Hancock, ed. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer, pp. 235-264.
- Ferris, J.N., 1999. *An analysis of the impact of ENSO (El Nino/Southern Oscillation) on global crop yields*, Nashville, TN: American Agricultural Economics Association Annual Meeting.
- Few, R., 2003. Flooding, vulnerability and coping strategies: Local responses to a global threat. *Progress in Development Studies*, 3(1), pp.43-58.
- Few, R. & Tran, P.G., 2010. Climatic hazards, health risk and response in Vietnam: Case studies on social dimensions of vulnerability. *Global Environmental Change*, 20(3), pp.529-538.
- Few, R., Brown, K. & Tompkins, E.L., 2007a. Climate Change and Coastal Management Decisions: Insights from Christchurch Bay, UK. *Coastal Management*, 35(2-3), pp.255-270.
- Few, R., Brown, K. & Tompkins, E.L., 2007b. Public participation and climate change adaptation: avoiding the illusion of inclusion. *Climate Policy*, 7, pp.46-59.
- Fickling, D., 2003. Farmers raise stink over New Zealand “fart tax.” *The Guardian*. Available at: <http://www.guardian.co.uk/world/2003/sep/05/australia.davidfickling> [Accessed July 26, 2011].
- Field, T.R.O. & Forde, M.B., 1990. Effects of Climate Warming on the Distribution of C4 Grasses in New Zealand. *Proc. N.Z. Grassland Assoc.*, 51, pp.47–50.
- Fischer, E.M. & Schär, C., 2008. Future changes in daily summer temperature variability: driving processes and role for temperature extremes. *Climate Dynamics*, 33(7-8), pp.917-935.
- Fischer, G. et al., 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences.*, 360(1463), pp.2067-2083.

- Fitzharris, B., 2007. How vulnerable is New Zealand to the impacts of climate change? *New Zealand Geographer*, 63(3), pp.160-168.
- Fitzherbert, E.B. et al., 2008. How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution*, 23(10), pp.538-545.
- Flaten, O., Lien, G. & Tveterås, R., 2011. A comparative study of risk exposure in agriculture and aquaculture. *Food Economics - Acta Agriculturae Scandinavica, Section C*, 8(1), pp.20-34.
- Fleisher, B., 1990. *Agricultural Risk Management*, Boulder: Lynne Rienner Publishers.
- Flyvbjerg, B., 2006. Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, 12(2), pp.219-245.
- Folke, C., 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. *Global environmental change*, 16(3), pp.253–267.
- Folke, C. et al., 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, 30(1), pp.441-473.
- Folland, C.K., 2002. Relative influences of the Interdecadal Pacific Oscillation and ENSO on the South Pacific Convergence Zone. *Geophysical Research Letters*, 29(13). Available at: <http://www.agu.org/pubs/crossref/2002/2001GL014201.shtml>.
- Ford, J.D., 2007. Emerging trends in climate change policy: the role of adaptation. *Journal of Climate*, 3(2), pp.5-16.
- Ford, J.D. & Berrang-Ford, L. eds., 2011. *Climate Change Adaptation in Developed Nations: From Theory to Practice*, Dordrecht: Springer Netherlands.
- Ford, J.D. & Smit, B., 2004. A framework for assessing the vulnerability of communities in the Canadian Arctic to risks associated with climate change. *Arctic*, 57(4), pp.389-400.
- Ford, J.D., Berrang-Ford, L., et al., 2010. Vulnerability of Aboriginal health systems in Canada to climate change. *Global Environmental Change*, 20(4), pp.668-680.
- Ford, J.D., Gough, W., et al., 2009. Sea ice, climate change, and community vulnerability in northern Foxe Basin, Canada. *Climate Research*, 38, pp.137-154.
- Ford, J.D., Keskitalo, E. C. H., et al., 2010. Case study and analogue methodologies in climate change vulnerability research. *Wiley Interdisciplinary Reviews: Climate Change*, 1(3), pp. 374-392.
- Ford, J.D., Pearce, Tristan, et al., 2009. Perceptions of climate change risks in primary resource use industries: a survey of the Canadian mining sector. *Regional Environmental Change*, 10(1), pp.65-81.

- Ford, J.D., Smit, B. & Wandel, J., 2006. Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. *Global Environmental Change*, 16(2), pp.145–160.
- Ford, J.D. et al., 2008. Climate change in the Arctic: current and future vulnerability in two Inuit communities in Canada. *Geographical Journal*, 174(1), pp.45–62.
- Fordham, M., 2004. Gendering Vulnerability Analysis: Towards a More Nuanced Approach. In Greg Bankoff, G. Frerks, & Dorothea Hilhorst, eds. *Mapping vulnerability: disasters, development, and people*. London: Earthscan, pp. 174-182.
- Forsyth, T., 2003. *Critical political ecology: the politics of environmental science*, Routledge.
- Fowler, A. & Adams, K., 2004. Twentieth century droughts and wet periods in Auckland (New Zealand) and their relationship to ENSO. *International Journal of Climatology*, 24(15), pp.1947-1961.
- Fowler, F.J., 2002. *Survey research methods* 3rd ed., Thousand Oaks, CA: Sage Publications.
- Fox, A., 2011. Dairy farmers deep in debt. *Stuff.co.nz*. Available at: <http://www.stuff.co.nz/business/5005469/Dairy-farmers-deep-in-debt> [Accessed June 23, 2011].
- Frank, E., Eakin, H. & López-Carr, D., 2011. Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global Environmental Change*, 21(1), pp.66-76.
- Fraser, E.D., 2003. Social vulnerability and ecological fragility: building bridges between social and natural sciences using the Irish Potato Famine as a case study. *Conservation Ecology*, 7(2), p.9.
- Fraser, E.D., Mabee, W. & Slaymaker, O., 2003. Mutual vulnerability, mutual dependence: The reflexive relation between human society and the environment. *Global Environmental Change*, 13(2), pp.137-144.
- Froggatt, P.C. & Lowe, D.J., 1990. A review of late Quaternary silicic and some other tephra formations from New Zealand: their stratigraphy, nomenclature, distribution, volume, and age. *New Zealand Journal of Geology and Geophysics*, 33(1), pp.89-109.
- Fulton, T., 2008. Doubts on human-induced climate change. *The New Zealand Farmers Weekly*. Available at: <http://www.farmersweekly.co.nz/article/7384.html> [Accessed July 25, 2011].
- Füssel, H.M., 2007. Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, 17(2), pp.155–167.
- Füssel, H.M. & Klein, R.J.T., 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change*, 75(3), pp.301-329.

- Gaillard, J.C., 2010. Vulnerability, capacity and resilience: Perspectives for climate and development policy. *Journal of International Development*, 22(2), pp.218-232.
- Gallopin, G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*, 16(3), pp.293-303.
- Gamble, D.W. et al., 2010. Climate Change, Drought, and Jamaican Agriculture: Local Knowledge and the Climate Record. *Annals of the Association of American Geographers*, 100(4), pp.880-893.
- Gameda, S.B., Bootsma, A. & McKenney, D.J., 2007. Potential impacts of climate change on agriculture in Eastern Canada. In E. Wall, B. Smit, & J. Wandel, eds. *Farming in a Changing Climate: Agricultural Adaptation in Canada*. Vancouver, Canada: UBC Press, pp. 53-66.
- Garnaut, R., 2008. *The Garnaut Climate Change Review: final report.*, Port Melbourne, Australia: Cambridge University Press. Available at: http://www.garnautreview.org.au/pdf/Garnaut_prelims.pdf [Accessed June 28, 2010].
- Garschagen, M., Renaud, F.G. & Birkmann, J., 2011. Dynamic Resilience of Peri-Urban Agriculturalists in the Mekong Delta Under Pressures of Socio-Economic Transformation and Climate Change. *Environmental Change and Agricultural Sustainability in the Mekong Delta*, pp.141–163.
- Gaughan, J. et al., 2009. Response of Domestic Animals to Climate Challenges. In K. L. Ebi, I. Burton, & G. R. McGregor, eds. *Biometeorology for Adaptation to Climate Variability and Change*. Dordrecht: Springer Netherlands, pp. 131-170.
- Gawith, M. et al., 2009. Application of the UKCIP02 climate change scenarios: Reflections and lessons learnt. *Global Environmental Change*, 19(1), pp.113-121.
- Gay, C. et al., 2006. Potential Impacts of Climate Change on Agriculture: A Case of Study of Coffee Production in Veracruz, Mexico. *Climatic Change*, 79(3-4), pp.259-288.
- Geertz, C., 1973. *The Interpretation of Cultures*, New York: Basic Books.
- Gehrels, W.R. et al., 2008. A 20th century acceleration of sea-level rise in New Zealand. *Geophysical Research Letters*, 35, p.5 PP.
- Gerber, R. & Chuan, G.K. eds., 2000. *Fieldwork in Geography: Reflections, Perspectives and Actions* 1st ed., Berlin: Springer.
- Giampietro, M., 2004. *Multi-Scale Integrated Analysis of Agroecosystems: a complex system approach*, Boca Raton, FL: CRC Press.
- Gibbons, W.H., 1990. *The Rangitaiki, 1890–1990: settlement and drainage on the Rangitaiki*, Whakatane: Whakatane & District Historical Society.

- Gillmore, D. & Briggs, P., 2010. World trade interdependencies: a New Zealand perspective. *Reserve Bank of New Zealand: Bulletin*, 73(2), pp.36-46.
- Giordano, T. et al., 2010. *Rethinking agriculture to anticipate the local impacts of climate change*, Available at: <http://knowledge.cta.int/en/Dossiers/S-T-Issues-in-Perspective/Climate-change/Articles/Rethinking-agriculture-to-anticipate-the-local-impacts-of-climate-change> [Accessed July 6, 2011].
- Gitay, H. et al., 2001. Ecosystems and Their Goods and Services. In IPCC_II, ed. *Climate Change 2001. Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses – Contributions of Working Group II to the Intergovernmental Panel of Climate Change. Third Assessment Report*. Cambridge: Cambridge University Press.
- Glantz, M.H., 1996. Forecasting by Analogy: Local Responses to Global Climate Change. In J.B. Smith et al., eds. *Adapting to Climate Change: An International Perspective*. New York: Springer Verlag, pp. 407-426.
- Glantz, M.H., 1988. *Societal Responses to Regional Climatic Change: Forecasting by Analogy*, Boulder: Westview Press.
- Gonzalez, M.V., Coque, M. & Herrero, M., 1998. Influence of pollination systems on fruit set and fruit quality in kiwifruit (*Actinidia deliciosa*). *Annals of applied biology*, 132(2), pp.349–355.
- Goodwin, M. & Steven, D., 1993. Behaviour of honey bees visiting kiwifruit flowers. *New Zealand Journal of Crop and Horticultural Science*, 21, pp.17-24.
- Gössling, S. & Hall, C.M., 2006. *Tourism and global environmental change: ecological, social, economic and political interrelationships*, Routledge.
- Gray, S. & Le Heron, R., 2010. Globalising New Zealand: Fonterra Co-operative Group, and shaping the future. *New Zealand Geographer*, 66(1), pp.1–13.
- Green, R.B., 2008. Innovative and adaptive future farming particularly as it relates to profitable use of dry land country in New Zealand—a personal view. *Proceedings of the New Zealand Grassland Association*, 70, pp.7-11.
- Green, S. et al., 2008. Measuring and Modeling the Stress Response of Grapevines to Soil-Water Deficits. In L. R. Ahuja et al., eds. *Response of crops to limited water: understanding and modeling water stress effects on plant growth processes*. Madison, WI: American Society of Agronomy, pp. 357-386.
- Green, S.R. et al., 2007. A water and nitrogen budget for “Hort16A”. *Kiwifruit Vines. Acta Hort*, 753, pp.527–534.

- Greenaway, A. & Carswell, F., 2009. Climate change policy and practice in regional New Zealand: How are actors negotiating science and policy? *New Zealand Geographer*, 65(2), pp.107–117.
- Griffiths, G.M. et al., 2003. *The Climate of the Bay of Plenty: Past and Future?*, Auckland, NZ: NIWA.
- Grothmann, T. & Patt, A., 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change Part A*, 15(3), pp.199-213.
- Gupta, A. & Ferguson eds., 1997. *Anthropological locations : boundaries and grounds of a field science*, Berkeley: University of California Press.
- Gupta, J. et al., 2010. The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science & Policy*, 13(6), pp.459-471.
- Gwazdauskas, F.C. et al., 1986. Evaluation of Reproductive Efficiency of Dairy Cattle with Emphasis on Timing of Breeding. *Journal of Dairy Science*, 69(1), pp.290-297.
- Hadarits, M., 2011. Climate Change and Economic Uncertainty in the Wine Sector: A Case Study of the Maule Region, Chile. In W. L. Filho, ed. *The Economic, Social and Political Elements of Climate Change*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 245-265.
- Haddad, B.M., 2005. Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. *Global Environmental Change Part A*, 15(2), pp.165-176.
- Haggerty, J., Campbell, H. & Morris, C., 2009. Keeping the stress off the sheep? Agricultural intensification, neoliberalism, and “good” farming in New Zealand. *Geoforum*, 40(5), pp.767–777.
- Hahn, M.B., Riederer, A.M. & Foster, S.O., 2009. The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change*, 19(1), pp.74–88.
- Hall, A.J. et al., 2001. Changes in kiwifruit phenology with climate. In R. A. Warrick, G. J. Kenny, & J. J. Hardman, eds. *The Effects of Climate Change and Variation in New Zealand: An Assessment Using the CLIMPACTS System*. Hamilton N.Z.: International Global Change Institute, University of Waikato, pp. 33-46.
- Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. *Global Environmental Change*, 19(2), pp.240-247.
- Handmer, J.W., Dovers, S. & Downing, T. E., 1999. Societal vulnerability to climate change and variability. *Mitigation and adaptation strategies for global change*, 4(3), pp.267–281.

- Hansen, J.E. et al., 2011. Climate Sensitivity: Analysis of Feedback Mechanisms. In D. Archer & R. Pierrehumbert, eds. *The Warming Papers*. New York: John Wiley and Sons, pp. 154-190.
- Hanson, J.D. et al., 2007. Dynamic Cropping Systems: Increasing Adaptability Amid an Uncertain Future.
- Hardaker, J.B. et al., 2004. *Coping with Risk in Agriculture* 2nd ed., London, UK: CABI.
- Harrington, L.M.. & Lu, M., 2002. Beef feedlots in southwestern Kansas: local change, perceptions, and the global change context. *Global Environmental Change*, 12, pp.273-282.
- Harwood, J. et al., 1999. *Managing risk in farming: Concepts, research, and analysis*, Washington, DC: Economic Research Service, U.S. Department of Agriculture.
- Hatfield, J.L. et al., 2011. Climate Impacts on Agriculture: Implications for Crop Production. *Agronomy Journal*, 103(2), pp.351-370.
- Hausermann, H. & Eakin, H.C., 2008. Producing “Viable” Landscapes and Livelihoods in Central Veracruz, Mexico: Institutional and Producer Responses to the Coffee Commodity Crisis. *Journal of Latin American Geography*, 7(1), pp.109-131.
- Hayes, M.J., Wilhelmi, O.V. & Knutson, C.L., 2004. Reducing drought risk: Bridging theory and practice. *Natural Hazards Review*, 5(2), pp.106-113.
- Hayward, B., 2008. “Nowhere Far From the Sea”: Political Challenges of Coastal Adaptation To Climate Change in New Zealand. *Political Science*, 60(1), pp.47-59.
- Hayward, D.J. & Le Heron, R.B., 2002. Horticultural Reform in the European Union and New Zealand: Further developments towards a global fresh fruit and vegetable complex. *Australian Geographer*, 33(1), p.9.
- Head, L. et al., 2011. A Fine-Grained Study of the Experience of Drought, Risk and Climate Change Among Australian Wheat Farming Households. *Annals of the Association of American Geographers*, pp.1-1.
- Hedger, M.M.E., Martinot, E. & Onchan, T., 2000. Enabling Environments for Technology Transfer. In B. Metz et al., eds. *Methodological and Technological Issues in Technology Transfer*. Cambridge: Cambridge University Press.
- Heltberg, R., Siegel, P.B. & Jorgensen, S.L., 2009. Addressing human vulnerability to climate change: Toward a “no-regrets” approach. *Global Environmental Change*, 19(1), pp.89–99.

- Hennessey, K.J. et al., 2007. Australia and New Zealand. In Martin L. Parry et al., eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press, pp. 507-540.
- Henson, S. & Humphrey, J. 2010. Understanding the Complexities of Private Standards in Global Agri-Food Chains as They Impact Developing Countries, *Journal of Development Studies*, 46(9), pp.1628-1646.
- Le Heron, R., 1989. A political economy perspective on the expansion of New Zealand livestock farming, 1960-1984 -- Part II. Aggregate farmer responses -- Evidence and policy implications. *Journal of Rural Studies*, 5(1), pp.33-43.
- Le Heron, R., 1991. New Zealand agriculture and changes in the agriculture - finance relation during the 1980s. *Environment and Planning A*, 23(11), pp.1653-1670.
- Le Heron, R. & Pawson, E. eds., 1996. *Changing Places: New Zealand in the Nineties* 2nd ed., Auckland: Longman Publishing Group.
- Le Heron, R., Roche, M. & Johnston, T., 1994. Pluriactivity: An exploration of issues with reference to New Zealand's livestock and fruit agro-commodity systems. *Geoforum*, 25(2), pp.155-171.
- Le Heron, R., Roche, M. & Anderson, G., 1989. Reglobalisation of New Zealand's food and fibre system: Organisational dimensions. *Journal of Rural Studies*, 5(4), pp.395-404.
- Hewitt, K., 1997. *Regions of Risk: A Geographical Introduction to Disasters*, Harlow, Essex: Addison Wesley Longman.
- Hewitt, K. ed., 1983. *Interpretations of Calamity: From the Viewpoint of Human Ecology*, Boston: Allen and Unwin.
- Hey, D.L. & Philippi, N.S., 1995. Flood Reduction through Wetland Restoration: The Upper Mississippi River Basin as a Case History. *Restoration Ecology*, 3(1), pp.4-17.
- Hillel, D. & Rosenzweig, C. eds., 2010. *Handbook of Climate Change and Agroecosystems: Impacts, Adaptation, and Mitigation*, London: Imperial College Press.
- Hinkel, J., 2011. "Indicators of vulnerability and adaptive capacity": Towards a clarification of the science-policy interface. *Global Environmental Change*, 21(1), pp.198-208.
- Hinzman, L.D. et al., 2005. Evidence and Implications of Recent Climate Change in Northern Alaska and Other Arctic Regions. *Climatic Change*, 72(3), pp.251-298.
- Hodgson, J. et al., 2005. New Zealand's pastoral industries: efficient use of grassland resources. In S. G. Reynolds & J. Frame, eds. *Grasslands, Developments, Opportunities, Perspectives*. Enfield, NH: Science Publishers Inc.

- Hoegh-Guldberg, Ove & Bruno, J.F., 2010. The Impact of Climate Change on the World's Marine Ecosystems. *Science*, 328(5985), pp.1523 -1528.
- Holling, C.S., 1973. Resilience and stability of ecological systems. *Annual review of ecology and systematics*, 4, pp.1–23.
- Holling, C.S., 2001. Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems*, 4(5), pp.390-405.
- Holman, I.P. & Trawick, P., 2011. Developing adaptive capacity within groundwater abstraction management systems. *Journal of Environmental Management*, 92(6), pp.1542-1549.
- Hooghe, L. & Marks, G., 2003. Unraveling the Central State, but How? Types of Multi-Level Governance. *American Political Science Review*, 97(02), pp.233-243.
- Hovelsrud, G. K et al., 2010. Community adaptation and vulnerability Integrated. *Community Adaptation and Vulnerability in Arctic Regions*, pp.335–348.
- Howden, S. M. et al., 2007. Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences*, 104(50), p.19691.
- Howden-Chapman, P. et al., 2010. Climate change & human health: Impact & adaptation issues for New Zealand. *Climate change adaptation in New Zealand: Future scenarios and some sectoral perspectives*. Nottage, RAC, Wratt, DS, Bornman, JF, Jones, K.(eds). New Zealand Climate Change Centre. Wellington, pp.112–121.
- Huang, W.-Y. & Service, U.S.D. of A.E.R., 2009. *Factors contributing to the recent increase in U.S. fertilizer prices, 2002-08*, DIANE Publishing.
- Hufschmidt, G., 2011. A comparative analysis of several vulnerability concepts. *Natural Hazards*, 58(2), pp.621-643.
- Hulme, M., 2010a. Cosmopolitan Climates: Hybridity, Foresight and Meaning. *Theory, Culture & Society*, 27(2-3), pp.267-276.
- Hulme, M., 2010b. Moving beyond climate change. *Environment: Science and Policy for Sustainable Development*, 52(3), pp.15–19.
- Hulme, M., 2010c. Problems with making and governing global kinds of knowledge. *Global Environmental Change*, 20(4), pp.558-564.
- Hulme, M., 2011. Meet the humanities. *Nature Climate Change*, 1(4), pp.177-179.
- Huntingford, C. et al., 2005. Aspects of climate change prediction relevant to crop productivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1463), pp.1999-2009.

- Huntington, H.P. et al., 2007. Toward understanding the human dimensions of the rapidly changing arctic system: insights and approaches from five HARC projects. *Regional Environmental Change*, 7(4), pp.173-186.
- Huq, S. & Reid, H., 2004. Mainstreaming Adaptation in Development. *IDS Bulletin*, 35(3), pp.15-21.
- ICNZ, 2009. The Cost of Disaster events. Available at: <http://www.icnz.org.nz/current/weather/index.php> [Accessed January 14, 2011].
- Iglesias, A. & Minguez, M.I., 1997. Modelling crop-climate interactions in Spain: Vulnerability and adaptation of different agricultural systems to climate change. *Mitigation and Adaptation Strategies for Global Change*, 1(3), pp.273-288.
- Iglesias, A. et al., 2010. Towards adaptation of agriculture to climate change in the Mediterranean. *Regional Environmental Change*, 11(S1), pp.159-166.
- Iglesias, A., Quiroga, S. & Diz, A., 2011. Looking into the future of agriculture in a changing climate. *European Review of Agricultural Economics*.
- Ilbery, B.W., 1985. Factors affecting the structure of horticulture in the Vale of Evesham, U.K.: a behavioural interpretation. *Journal of Rural Studies*, 1(2), pp.121-133.
- IPCC, 2007a. *Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change* Martin L. Parry et al., eds., Cambridge: Cambridge University Press. Available at: <http://www.ipcc-wg2.gov/AR4/website/fi.pdf>.
- IPCC, 2007b. *Climate Change 2007: The Physical Science Basis, Summary for Policymakers*. Cambridge: Cambridge University Press.
- IPCC, 1990. *Climate Change. The IPCC Scientific Assessment*, Cambridge: Cambridge University Press.
- IPCC, 1995. *Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change*, Cambridge: Cambridge University Press.
- IPCC, 2001. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, J. T. Houghton et al., eds., Cambridge: Cambridge University Press.
- Iqbal, M. et al., 2006. A simulation study for assessing yield optimization and potential for water reduction for summer-sown maize under different climate change scenarios. *The Journal of Agricultural Science*, 1(-1), pp.1-15.

- Irvine, E., 2009. Hail storm damage claims set to top \$5m. *Bay of Plenty Times*. Available at: <http://www.bayofplentytimes.co.nz/local/news/hail-storm-damage-claims-set-to-top-5m/3900433/> [Accessed August 12, 2011].
- Irwin, G.J. ed., 2004. *Kohika: The Archaeology of a Late Māori Lake Village in the Ngāti Awa Rohe, Bay of Plenty, New Zealand*, Auckland, N.Z: Auckland University Press.
- Irwin, G.J. et al., 2004. An introduction to Kohika in historical and archaeological context. In G. J. Irwin, ed. *Kohika: the archaeology of a late Maori lake village in the Ngati Awa Rohe, Bay of Plenty, New Zealand*. Auckland, N.Z: Auckland University Press.
- Iso, N. et al., 1982. Fission-track ages of late Pleistocene tephra on the Bay of Plenty coast, North Island, New Zealand. *New Zealand Journal of Geology and Geophysics*, 25(3), pp.295-303.
- Ivey, J.L. et al., 2004. Community Capacity for Adaptation to Climate-Induced Water Shortages: Linking Institutional Complexity and Local Actors. *Environmental Management*, 33(1), pp.36-47.
- Izac, A.-M. & Swift, M., 1994. On agricultural sustainability and its measurement in small-scale farming in sub-Saharan Africa. *Ecological Economics*, 11(2), pp.105-125.
- Jackson, T. & Dixon, J., 2007. The New Zealand Resource Management Act: an exercise in delivering sustainable development through an ecological modernisation agenda. *Environment and Planning B: Planning and Design*, 34(1), pp.107–120.
- Jacques, P., 2006. Downscaling climate models and environmental policy: From global to regional politics. *Journal of Environmental Planning and Management*, 49(2), pp.301-307.
- Jaeger, S.R. et al., 2003. Consumer-driven product development in the kiwifruit industry. *Food Quality and Preference*, 14(3), pp.187-198.
- Janssen, M. A et al., 2006. Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global Environmental Change*, 16(3), pp.240–252.
- Jasanoff, S., 2010. A New Climate for Society. *Theory, Culture & Society*, 27(2-3), pp.233-253.
- Jasanoff, S., 2007. Technologies of humility. *Nature*, 450(7166), pp.33-33.
- Jay, G.M.M., 2005. Remnants of the Waikato: Native forest survival in a production landscape. *New Zealand Geographer*, 61(1), pp.14-28.
- Jay, G.M.M., 1999. Rugged individualism versus co-operative enterprise: different responses by New Zealand pastoral farmers to agricultural change. *Development Bulletin*, 49.

- Jay, G.M.M., 2007. The political economy of a productivist agriculture: New Zealand dairy discourses. *Food Policy*, 32(2), pp.266-279.
- Jay, G.M.M. & Morad, M., 2006. Crying Over Spilt Milk: A Critical Assessment of the Ecological Modernization of New Zealand's Dairy Industry. *Society & Natural Resources*, 20(5), pp.469-478.
- Jentsch, A., Kreyling, J. & Beierkuhnlein, C., 2007. A new generation of climate-change experiments: events, not trends. *Frontiers in Ecology and the Environment*, 5(7), pp.365-374.
- Johnsen, S., 1999. Agricultural Restructuring and Response: Inter-relationships Between Farm Adjustment Strategies in Waihemo, 1984–1997. *New Zealand Geographer*, 55(1), pp.25-34.
- Johnsen, S., 2003. Contingency Revealed: New Zealand Farmers' Experiences of Agricultural Restructuring. *Sociologia Ruralis*, 43(2), pp.128-153.
- Johnson, R.W.M., 1989. *The Agricultural Sector in a Deregulated Economy. Agricultural Policy Paper No. 15.*, Palmerston North, NZ: Centre for Agricultural Policy Studies, Massey University.
- Jones, G. V, 2007. Climate change: observations, projections, and general implications for viticulture and wine production.
- Jones, G. V & Davis, R.E., 2000. Using a synoptic climatological approach to understand climate-viticulture relationships. *International Journal of Climatology*, 20(8), pp.813-837.
- Jones, G. V, White, M. & Cooper, O., 2004. Climate change and global wine quality. *Bulletin of the American Meteorological Society*, 85, pp.504-506.
- Jones, R.N., 2001. An environmental risk assessment/management framework for climate change impact assessments. *Natural Hazards*, 23(2), pp.197–230.
- Joseph, A.E., Lidgard, J. & Bedford, R., 2004. *Rural Trajectories: Diversification and Farm-Community Linkages in Whakatane District, 1999-2003*, Hamilton, NZ: Population Studies Centre, University of Waikato.
- Junk, J. et al., 2011. Ensemble-based analysis of regional climate change effects on the cabbage stem weevil (*Ceutorhynchus pallidactylus* (Mrsh.)) in winter oilseed rape (*Brassica napus* L.). *The Journal of Agricultural Science*, pp.1-12.
- Kadzere, C., et al., 2002. Heat stress in lactating dairy cows: a review. *Livestock Production Science*, 77(1), pp.59-91.

- Kaiser, H.M. et al., 1993. A Farm-Level Analysis of Economic and Agronomic Impacts of Gradual Climate Warming. *American Journal of Agricultural Economics*, 75(2), pp.387-398.
- Kajikawa, Y., 2008. Research core and framework of sustainability science. *Sustainability Science*, 3(2), pp.215-239.
- Kandlikar, M. & Risbey, J., 2000. Agricultural impacts of climate change: if adaptation is the answer, what is the question? *Climatic Change*, 47, pp.325-352.
- Kane, S. & Yohe, G., 2000. Societal Adaptation to Climate Variability and Change: An Introduction. *Climatic Change*, 45(1), pp.1-4.
- Kasperson, R. E & Kasperson, J.X., 2001. *Climate change, vulnerability and social justice*, Stockholm: Stockholm Environment Institute.
- Kasperson, R.E. & Kasperson, J.X., 1996. The social amplification and attenuation of risk. *Annals of the American Academy of Political and Social Science*, (545), pp.95-104.
- Kasperson, R.E. et al., 2005. Vulnerable people and places. In R. Hassan, R. Scholes, & N. Ash, eds. *Ecosystems and Human Well-being: Current States and Trends*. Washington DC: Island View Press, pp. 143-164.
- Kasperson, R.E. et al., 1988. The social amplification of risk: A conceptual framework. *Risk Analysis*, 8(2), pp.177-187.
- Kates, R.W., 1985. The Interaction of Climate and Society. In *Climate Impact Assessment: Studies of the Interaction of Climate and Society*. John Wiley, pp. 3-36. Available at: <http://rwkates.org/pdfs/a1985.01.pdf>.
- Katz, R.W. & Brown, B.G., 1992. Extreme events in a changing climate: Variability is more important than averages. *Climatic Change*, 21(3), pp.289-302.
- Kay, J.E., Holland, M.M. & Jahn, A., 2011. Inter-annual to multi-decadal Arctic sea ice extent trends in a warming world. *Geophysical Research Letters*, 38(15). Available at: <http://www.agu.org/pubs/crossref/2011/2011GL048008.shtml>.
- Kay, R., Edwards, W. & Duffy, P., 2007. *Farm Management* 6th ed., McGraw-Hill Science/Engineering/Math.
- Keenan, T. et al., 2011. Predicting the future of forests in the Mediterranean under climate change, with niche- and process-based models: CO2 matters! *Global Change Biology*, 17(1), pp.565-579.
- Keller, E.A. & DeVecchio, D.E., 2011. *Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes* 3rd ed., Prentice Hall.

- Kelly, G., 2010. Climate Change Policy: Actions and Barriers in New Zealand. *International Journal of Climate Change Impacts and Responses*, pp.277-290.
- Kelly, P.M. & Adger, W.N., 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, 47(4), pp.325-352.
- Kenny, G.J., 2011. Adaptation in agriculture: lessons for resilience from eastern regions of New Zealand. *Climatic Change*, 106(3), pp.441-462.
- Kenny, G.J., 2006a. *Adapting to climate change: A view from the ground*, Wellington N.Z.: Parliamentary Commission on Sustainable Development.
- Kenny, G.J., 2006b. *Biotic Effects of Climate Change in the Bay of Plenty*,
- Kenny, G.J. & Fisher, F., 2003. *The view from the ground: a farmer perspective on climate change and adaptation*, Hastings: Earthwise Consulting Ltd.
- Kenny, G.J. & Harrison, P.A., 1992. The effects of climate variability and change on grape suitability in Europe. *J. Wine Res.*, 3(3), pp.163-183.
- Kenny, G.J. et al., 2001. The impact of climate change on regional resources: A case study for Canterbury and Waikato regions. In R. A. Warrick, G. J. Kenny, & J. J. Harman, eds. *The Effects of Climate Change and Variation in New Zealand: An Assessment Using the CLIMPACTS System*. Hamilton N.Z.: International Global Change Institute, University of Waikato, pp. 85-98.
- Kenny, G.J., Warrick, R.A., Campbell, B. D., et al., 2000. Investigating climate change impacts and thresholds: an application of the CLIMPACTS integrated assessment model for New Zealand agriculture. *Climatic Change*, 46(1), pp.91–113.
- Kenny, G.J., Warrick, R.A., Campbell, B.D., et al., 2000. Investigating climate change impacts and thresholds: An application of the climacts integrated assessment model for New Zealand agriculture. *Climatic Change*, 46(1-2), pp.91-113.
- Kenny, G.J. et al., 1995. CLIMPACTS: An Integrated Model for Assessment of the Effects of Climate Change on the New Zealand Environment. *Journal of Biogeography*, 22(4/5), pp.883-895.
- Keskitalo, E.C.H. & Kulyasova, A.A., 2009. The role of governance in community adaptation to climate change. *Polar Research*, 28(1), pp.60–70.
- Keskitalo, E.C.H., 2010a. Adaptive Capacity and Adaptation in Swedish Multi-Use Boreal Forests: Sites of Interaction Between Different Land Uses. In Derek Armitage & R. Plummer, eds. *Adaptive Capacity and Environmental Governance*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 89-106.

- Keskitalo, E.C.H., 2010b. Climate Change, Vulnerability and Adaptive Capacity in a Multi-use Forest Municipality in Northern Sweden. In G.K. Hovelsrud & B. Smit, eds. *Community Adaptation and Vulnerability in Arctic Regions*. Dordrecht: Springer Netherlands, pp. 285-311.
- Keskitalo, E.C.H., 2008. Governance in vulnerability assessment: the role of globalising decision-making networks in determining local vulnerability and adaptive capacity. *Mitigation and Adaptation Strategies for Global Change*, 14(2), pp.185-201.
- Keskitalo, E.C.H. ed., 2010c. *Developing Adaptation Policy and Practice in Europe: Multi-level Governance of Climate Change*, Dordrecht: Springer Netherlands.
- Keskitalo, E.C.H. et al., 2010. Adaptive capacity determinants in developed states: examples from the Nordic countries and Russia. *Regional Environmental Change*, 11(3), pp.579-592.
- Keskitalo, E.C.H., 2004. A framework for multi-level stakeholder studies in response to global change. *Local Environment*, 9(5), pp.425-435.
- Keskitalo, E.C.H. & Kulyasova, A.A., 2009b. Local adaptation to climate change in fishing villages and forest settlements in north-western Russia. In S. Nystén-Haarala, ed. *The changing governance of renewable natural resources in Northwest Russia*. Ashgate: Aldershot, pp. 227-243.
- Keskitalo, E.C.H. et al., 2011. Preparing for and Responding to Disturbance: Examples from the Forest Sector in Sweden and Canada. *Forests*, 2, pp.505-524.
- Kirilenko, A.P. & Sedjo, R.A., 2007. Climate change impacts on forestry. *Proceedings of the National Academy of Sciences*, 104(50), pp.19697 -19702.
- Kitchin, R. & Tate, N., 2000. *Conducting Research in Human Geography: Theory, Methodology and Practice*, London, UK: Longman.
- Klopprogge, P. & Sluijs, J.P.V.D., 2006. The Inclusion of Stakeholder Knowledge and Perspectives in Integrated Assessment of Climate Change. *Climatic Change*, 75(3), pp.359-389.
- Knafli, K. & Breitmeyer, B.J., 1989. Triangulation in qualitative research: Issues of conceptual clarity and purpose. In J. Morse, ed. *Qualitative nursing research: A contemporary dialogue*. Rockville, MD: Aspen, pp. 193-203.
- Koh, L.P. & Wilcove, D.S., 2008. Is oil palm agriculture really destroying tropical biodiversity? *Conservation Letters*, 1(2), pp.60-64.
- Kovats, R.S., Campbell-Lendrum, D. & Matthies, F., 2005. Climate Change and Human Health: Estimating Avoidable Deaths and Disease. *Risk Analysis*, 25(6), pp.1409-1418.

- Krefting, L., 1990. Rigor in Qualitative research: The assessment of trustworthiness. *American Journal of Occupational Therapy*, 45(3), pp.214-222.
- Kruse, J.A. et al., 2004. Modeling Sustainability of Arctic Communities: An Interdisciplinary Collaboration of Researchers and Local Knowledge Holders. *Ecosystems*, 7(8), pp.815-828.
- Kurz, W.A. et al., 2008. Mountain pine beetle and forest carbon feedback to climate change. *Nature*, 452(7190), pp.987-990.
- Ladurie, E.L., 1979. *Montaillou: The Promised Land of Error* 1st ed., New York:Vintage.
- Laidler, G.J., 2006. Inuit and scientific perspectives on the relationship between sea ice and climate change: The ideal complement? *Climatic Change*, 78(2-4), pp.407-444.
- Lambin, E.F., 2005. Conditions for sustainability of human-environment systems: Information, motivation, and capacity. *Global Environmental Change Part A*, 15(3), pp.177-180.
- Lazarus, R.J., 2008. Super wicked problems and climate change: Restraining the present to liberate the future. *Cornell Law Rev.*, 94, p.1153.
- Leamy, M.L. & Fieldes, M., 1976. Soils, Land classification and use. In I. Wards & A. R. Shearer, eds. *New Zealand atlas*. Wellington N.Z.: Government printer, pp. 122-133.
- Leathwick, J.R., Whitehead, D. & McLeod, M., 1996. Predicting changes in the composition of New Zealand's indigenous forests in response to global warming: a modelling approach. *Environmental Software*, 11(1-3), pp.81-90.
- Leichenko, R.M. & O'Brien, K., 2008. *Environmental Change and Globalization: Double Exposures*, Oxford: Oxford University Press.
- Lemmen, D.S. & Warren, F.J., eds. 2004. *Climate Change Impacts and Adaptation: A Canadian Perspective*, Ottawa: Canadian Government Publishing.
- Lenderink, G. & van Meijgaard, E., 2008. Increase in hourly precipitation extremes beyond expectations from temperature changes. *Nature Geoscience*, 1(8), pp.511-514.
- Lenoir, J. et al., 2008. A Significant Upward Shift in Plant Species Optimum Elevation During the 20th Century. *Science*, 320(5884), pp.1768 -1771.
- Leroy, S.A.G., 2010. Pollen analysis of core DS7-1SC (Dead Sea) showing intertwined effects of climatic change and human activities in the Late Holocene. *Journal of Archaeological Science*, 37(2), pp.306-316.
- Leslie, M., Aspin, M. & Clark, H., 2008. Greenhouse gas emissions from New Zealand agriculture: issues, perspectives and industry response. *Australian Journal of Experimental Agriculture*, 48(2), pp.1-5.

- Liepins, R., 1995. Women in agriculture: advocates for a gendered sustainable agriculture. *Australian Geographer*, 26(2), pp.118-126.
- Liepins, R. & Bradshaw, B., 1999. Neo-Liberal Agricultural Discourse in New Zealand: Economy, Culture and Politics Linked. *Sociologia Ruralis*, 39(4), pp.563-582.
- Lin, B., Perfecto, I. & Vandermeer, J., 2008. Synergies between Agricultural Intensification and Climate Change Could Create Surprising Vulnerabilities for Crops. *BioScience*, 58(9), p.847.
- Lincoln Environmental, 2000. *Information on Water Allocation in New Zealand*, Lincoln, N.Z.: Lincoln Environmental.
- Lincoln, Y.S. & Guba, E.G., 1985. *Naturalistic Inquiry* 1st ed., London, UK: Sage Publications.
- Lindblom, C.E., 1959. The Science of "Muddling Through." *Public Administration Review*, 19(2), pp.79-88.
- Lindner, M. et al., 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management*, 259(4), pp.698-709.
- Linsley-Noakes, G.C., 1989. Improving flowering of kiwifruit in climatically marginal areas using hydrogen cyanamide. *Scientia Horticulturae*, 38(3-4), pp.247-259.
- Liu, J. et al., 2007. Complexity of Coupled Human and Natural Systems. *Science*, 317(5844), pp.1513-1516.
- Liverman, D., 2008. Assessing impacts, adaptation and vulnerability: Reflections on the Working Group II Report of the Intergovernmental Panel on Climate Change. *Global Environmental Change*, 18(1), pp.4-7.
- Liverman, D., 2009. Conventions of climate change: constructions of danger and the dispossession of the atmosphere. *Journal of Historical Geography*, 35(2), pp.279-296.
- Liverman, D., 2010. Seeking inspiration: a scientist turns to the cultural sector. In Julie's Bicycle, ed. *Long Horizons: an exploration of art and climate change*. London, UK: British Council, pp. 21-25. Available at: <http://www.britishcouncil.org/climatechange-longhorizons-2.pdf>.
- Lobell, D.B. et al., 2008. Prioritizing Climate Change Adaptation Needs for Food Security in 2030. *Science*, 319(5863), pp.607-610.
- De Loe, R., Kreutzwiser, R. & Moraru, L., 2001. Adaptation options for the near term: Climate change and the Canadian water sector. *Global Environmental Change*, 11(3), pp.231-245.
- Lorenzoni, I., Pidgeon, N.F. & O'Connor, R.E., 2005. Dangerous climate change: The role for risk research. *Risk Analysis*, 25(6), pp.1387-1398.

- Lotze-Campen, H. & Schellnhuber, H.-J., 2009. Climate impacts and adaptation options in agriculture: what we know and what we don't know. *Journal für Verbraucherschutz und Lebensmittelsicherheit*, 4(2), pp.145-150.
- Lowe, D.J. et al., 1998. Radiocarbon age of the Kaharoa Tephra, a key marker for late-Holocene stratigraphy and archaeology in New Zealand. *The Holocene*, 8, pp.499-507.
- Lowe, J.A. et al., 2009. How difficult is it to recover from dangerous levels of global warming? *Environmental Research Letters*, 4(1), p.014012.
- Luers, A.L., 2005. The surface of vulnerability: An analytical framework for examining environmental change. *Global Environmental Change*, 15(3), pp.214-223.
- Luers, A.L. et al., 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change*, 13(4), pp.255-267.
- Lynch, A.H., 2008. Climate change adaptation: mapping the context. Victoria, AU: Monash University. Retrieved from [http://garnautreview.org.au/CA25734E0016A131/WebObj/ClimateChangeAdaptation-MappingtheContext-AmandaLynch-MonashUniversity26March08/\\$File/Mapping%20the%20Context](http://garnautreview.org.au/CA25734E0016A131/WebObj/ClimateChangeAdaptation-MappingtheContext-AmandaLynch-MonashUniversity26March08/$File/Mapping%20the%20Context).
- Lynch, A.H. & Brunner, R.D., 2010. Learning from Climate Variability: Adaptive Governance and the Pacific ENSO Applications Center. *Weather, Climate, and Society*, 2(4), pp.311-319.
- Lyon, S., Bezaury, J.A. & Mutersbaugh, T., 2010. Gender equity in fairtrade-organic coffee producer organizations: Cases from Mesoamerica. *Geoforum*, 41(1), pp.93-103.
- Mackinnon, N. et al., 1991. Pluriactivity, Structural Change and Farm Household Vulnerability in Western Europe. *Sociologia Ruralis*, 31(1), pp.58-71.
- MacLeod, C.J. & Moller, H., 2006. Intensification and diversification of New Zealand agriculture since 1960: An evaluation of current indicators of land use change. *Agriculture, Ecosystems & Environment*, 115(1-4), pp.201-218.
- MAF (Ministry of Agriculture and Forestry), 2010. *Horticulture Monitoring: Bay of Plenty kiwifruit*, Wellington N.Z.: Ministry of Agriculture and Forestry.
- MAF (Ministry of Agriculture and Forestry), 2011. *Improving sustainable life-time performance of pastures learning from extreme climatic events*, Wellington, N.Z.: Ministry of Agriculture and Forestry.
- MAF (Ministry of Agriculture and Forestry), 2009. *Situation and outlook for New Zealand Agriculture and Forestry*, Wellington, N.Z.: Ministry of Agriculture and Forestry.
- Malone, E.L & Engle, N.L., 2011. Evaluating regional vulnerability to climate change: purposes and methods. *Wiley Interdisciplinary Reviews: Climate Change*, 2(3), pp.462-474.

- Manandhar, S. et al., 2010. Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. *Regional Environmental Change*, 11(2), pp.335-348.
- Marshall, N.A., 2010. Understanding social resilience to climate variability in primary enterprises and industries. *Global Environmental Change*, 20(1), pp.36-43.
- Marshall, N.A. & Marshall, P.A., 2007. Conceptualizing and Operationalizing Social Resilience within Commercial Fisheries in Northern Australia. *Ecology and Society*, 12(1). Available at: <http://www.ecologyandsociety.org/vol12/iss1/art1/>.
- Masuda, J.R. & Garvin, T., 2006. Place, culture, and the social amplification of risk. *Risk Analysis*, 26(2), pp.437-454.
- Matson, P.A. et al., 1997. Agricultural Intensification and Ecosystem Properties. *Science*, 277(5325), pp.504 -509.
- Matthews, H.D. et al., 2009. The proportionality of global warming to cumulative carbon emissions. *Nature*, 459(7248), pp.829-832.
- Maxwell, N., 2008. Are philosophers responsible for global warming? *Philosophy Now*, 65, pp.12-13.
- McAneney, K.J. & Judd, M.J., 1987. Comparative shelter strategies for kiwifruit: A mechanistic interpretation of wind damage measurements. *Agricultural and Forest Meteorology*, 39(2-3), pp.225-240.
- McBean, G.A. & Ajibade, I., 2009. Climate change, related hazards and human settlements. *Current Opinion in Environmental Sustainability*, 1(2), pp.179-186.
- McCarthy, J.J. & Martello, M.L., 2010. Climate Change in the Context of Multiple Stressors and Resilience. In *Arctic Climate Impact Assessment*. Cambridge: Cambridge University Press, pp. 945-988.
- McCarthy, J.J. et al., 2001. *Climate change 2001 : impacts, adaptation, and vulnerability : contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*, Cambridge, UK: Cambridge University Press. Available at: <http://www.loc.gov/catdir/toc/cam023/2001025972.html>.
- McEntire, D., 2005. Why vulnerability matters: Exploring the merit of an inclusive disaster reduction concept. *Disaster Prevention and Management*, 14(2), pp.206-222.
- McEntire, D., Crocker, C.G. & Peters, E., 2010. Addressing vulnerability through an integrated approach. *International Journal of Disaster Resilience in the Built Environment*, 1(1), pp.50-64.

- McEntire, D.A., 2001. Triggering agents, vulnerabilities and disaster reduction: towards a holistic paradigm. *Disaster Prevention and Management*, 10(3), pp.189-196.
- McEwan, I., 2005. The Hot Breath of Civilization: On Earth Day a call for good data, not dogma. *Los Angeles Times*. Available at: <http://articles.latimes.com/2005/apr/22/opinion/oe-mcewan22> [Accessed December 28, 2010].
- McGlone, M., 2001. *Linkages Between Climate Change and Biodiversity in New Zealand*, Wellington NZ: Ministry for the Environment.
- McGlone, M., 1983. Polynesian deforestation of New Zealand: a preliminary synthesis. *Archaeology in Oceania*, 18, pp.11-25.
- McGlone, M. & Jones, K.L., 2004. The impact of Polynesian settlement on the vegetation of the coastal Bay of Plenty. In G. J. Irwin, ed. *Kohika: the archaeology of a late Maori lake village in the Ngati Awa Rohe, Bay of Plenty, New Zealand*. Auckland: Auckland University Press, pp. 20-44.
- McGranahan, G., Balk, D. & Anderson, B., 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, 19(1), pp.17-37.
- McKenna, M., Le Heron, R. & Roche, M., 2001. Living local, growing global: Renegotiating the export production regime in New Zealand's pipfruit sector. *Geoforum*, 32(2), pp.157-166.
- McKerchar, A.I. & Henderson, R.D., 2003. Shifts in flood and low-flow regimes in New Zealand due to interdecadal climate variations. *Hydrological Sciences*, 48(4), pp.637-654.
- McKerchar, A.I. & Pearson, C.P., 2001. Factors causing flooding to be New Zealand's Number One Hazard. *Tephra*, 18, pp.9-15.
- McLaughlin, P. & Dietz, T., 2008. Structure, agency and environment: Toward an integrated perspective on vulnerability. *Global Environmental Change*, 18(1), pp.99-111.
- McLeman, R., 2009. Impacts of population change on vulnerability and the capacity to adapt to climate change and variability: a typology based on lessons from "a hard country." *Population and Environment*, 31(5), pp.286-316.
- McLeman, R. & Hunter, L.M., 2010. Migration in the context of vulnerability and adaptation to climate change: insights from analogues. *Wiley Interdisciplinary Reviews: Climate Change*, 1(3), pp.450-461.
- McLeman, R. et al., 2007. Drought adaptation in rural eastern Oklahoma in the 1930s: lessons for climate change adaptation research. *Mitigation and Adaptation Strategies for Global Change*, 13(4), pp.379-400.

- McLeman, R.A. & Ploeger, S.K., 2011. Soil and its influence on rural drought migration: insights from Depression-era Southwestern Saskatchewan, Canada. *Population and Environment*, In press. Available at: <http://www.springerlink.com.ezproxy.canterbury.ac.nz/content/w18300r260626822/> [Accessed August 4, 2011].
- McMichael, A.J., Woodruff, R.E. & Hales, S., 2006. Climate change and human health: present and future risks. *The Lancet*, 367(9513), pp.859-869.
- McMillan, J., 1998. Managing Economic Change: Lessons from New Zealand. *The World Economy*, 21(6), pp.827-843.
- McNeeley, S.M. & Shulski, M.D., 2011. Anatomy of a closing window: Vulnerability to changing seasonality in Interior Alaska. *Global Environmental Change*, 21(2), pp.464-473.
- McPherson, H.G. et al., 2001. Effects of hydrogen cyanamide on budbreak and flowering in kiwifruit (*Actinidia deliciosa* 'Hayward'). *New Zealand Journal of Crop and Horticultural Science*, 29(4), p.277.
- McVerry, G.H., Cousins, W.J. & Hefford, R.T., 1989. Ground-motion accelerograph records from the 1987 Edgecumbe earthquake, New Zealand. *New Zealand Journal of Geology and Geophysics*, 32, pp.155-166.
- Meinke, H. et al., 2009. Adaptation science for agriculture and natural resource management -- urgency and theoretical basis. *Current Opinion in Environmental Sustainability*, 1(1), pp.69-76.
- Meinke, H. et al., 2006. Actionable climate knowledge: from analysis to synthesis. *Climate Research*, 33(1), p.101.
- Mendelsohn, R., Dinar, A. & Williams, L., 2006. The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, 11(02), p.159.
- Mendelsohn, R., Nordhaus, W.D. & Shaw, D., 1994. The Impact of Global Warming on Agriculture: A Ricardian Analysis. *The American Economic Review*, 84(4), pp.753-771.
- Merriam, S.B., 1988. *Case study research in education: A qualitative approach*, San Francisco, CA: Jossey-Bass.
- Mertz, O. et al., 2008. Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. *Environmental Management*, 43(5), pp.804-816.
- Metcalfe, S. et al., 2009. Why New Zealand must rapidly halve its greenhouse gas emissions. *The New Zealand Medical Journal*, 122(1304), pp.72-95.

- Metzlaff, M., 2009. Adapting Crops to Climate Change. In A. Eaglesham & R. W. F. Harvey, eds. *Adapting Agriculture to Climate Change: Proceedings of the twenty-first annual conference of the National Agricultural Biotechnology Council, hosted by the College of Agriculture and Bioresources, University of Saskatchewan, Saskatoon, Saskatchewan, June 24–26, 2009*. Ithaca, New York: National Agricultural Biotechnology Council, pp. 73-79.
- Meza, F.J. & Silva, D., 2009. Dynamic adaptation of maize and wheat production to climate change. *Climatic Change*, 94(1-2), pp.143-156.
- Meze-Hausken, E., 2004. Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. *Climate Research*, 27, pp.19–31.
- MfE (Ministry for the Environment), 2003. *Climate Change Case Study: Local Government Adaptation to Climate Change - Environment Bay of Plenty and Coastal Hazards: "Issues, Barriers and Solutions,"* Wellington, N.Z.: New Zealand Climate Change Office, Ministry for the Environment.
- MfE (Ministry for the Environment), 2008. *Climate change effects and impacts assessment: A Guidance Manual for Local Government in New Zealand, 2nd edition*, Wellington, N.Z.: Ministry for the Environment.
- Millar, C.I., Stephenson, N.L. & Stephens, S.L., 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications*, 17(8), pp.2145-2151.
- Milly, P.C.D. et al., 2008. Stationarity is dead: whither water management? *Earth*, 4, p.20.
- Min, S.-K. et al., 2011. Human contribution to more-intense precipitation extremes. *Nature*, 470(7334), pp.378-381.
- Misselhorn, A.A., 2005. What drives food insecurity in southern Africa? a meta-analysis of household economy studies. *Global Environmental Change Part A*, 15(1), pp.33-43.
- Mitchell, D., 2008. *A Note on Rising Food Prices*, Washington DC: World Bank Development Prospects Group, World Bank.
- Mitchell, J.K., Devine, N. & Jagger, K., 1989. A contextual model of natural hazard. *Geographical Review*, 79(4), pp.391-409.
- Mitsch, W.J. & Gosselink, J.G., 2000. The value of wetlands: importance of scale and landscape setting. *Ecological Economics*, 35(1), pp.25-33.
- Mizina, S.V. et al., 1999. An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. *Mitigation and Adaptation Strategies for Global Change*, 4(1), pp.25–41.

- Monaghan, R.M., de Klein, C.A.M. & Muirhead, R.W., 2008. Prioritisation of farm scale remediation efforts for reducing losses of nutrients and faecal indicator organisms to waterways: A case study of New Zealand dairy farming. *Journal of Environmental Management*, 87(4), pp.609-622.
- Morad, M. & Jay, G.M.M., 1999. Conservation, Market Pressures and the New Zealand Dairy Sector. *British Review of New Zealand Studies*, 12, pp.45-54.
- Moran, W., Blunden, G. & Bradly, A., 1996. Empowering Family Farms through Cooperatives and Producer Marketing Boards. *Economic Geography*, 72(2), pp.161-177.
- Morgan, W.B. & Munton, R.J.C., 1971. *Agricultural geography*, London: Methuen.
- Morris, S.T., 2009. Economics of sheep production. *Small Ruminant Research*, 86(1-3), pp.59-62.
- Moser, C. & Stein, A., 2010. *Implementing Urban Participatory Climate Change Adaptation Appraisals: A Methodological Guideline*, Manchester: University of Manchester.
- Moser, S.C., 2010. Now more than ever: The need for more societally relevant research on vulnerability and adaptation to climate change. *Applied Geography*, 30(4), pp.464-474.
- Moser, S.C. & Ekstrom, J.A., 2010. A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*, 107(51), pp.22026 -22031.
- Moser, S.C. & Ekstrom, J.A., 2011. Taking ownership of climate change: participatory adaptation planning in two local case studies from California. *Journal of Environmental Studies and Sciences*, 1(1), pp.63-74.
- Moss, R.H., Brenkert, A.L. & Malone, E.L., 2001. *Vulnerability to Climate Change: A Quantitative Approach*, Pacific Northwest National Laboratory. Available at: http://www.globalchange.umd.edu/data/publications/Vulnerability_to_Climate_Change.PDF.
- Moss, R.H. et al., 2010. The next generation of scenarios for climate change research and assessment. *Nature*, 463(7282), pp.747-756.
- Mulet-Marquis, S. & Fairweather, J., 2008. *New Zealand farm structure change and intensification*, Lincoln N.Z.: Agribusiness and Economics Research Unit Lincoln University.
- Mullan, A.B., 1998. Southern hemisphere sea-surface temperatures and their contemporary and lag association with New Zealand temperature and precipitation. *International Journal of Climatology*, 18(8), pp.817-840.
- Mullan, A.B. et al., 2005. *Changes in Drought Risk with Climate Change*, Wellington N.Z.: NIWA.

- Mullan, A.B., Wratt, D. & Renwick, J.A., 2001. Transient model scenarios of climate changes for New Zealand. *Weather and Climate*, 21, pp.3-34.
- Mullings, B., 1999. Insider or outsider, both or neither: some dilemmas of interviewing in a cross-cultural setting. *Geoforum*, 30(4), pp.337-350.
- Mustelin, J. et al., 2010. Understanding current and future vulnerability in coastal settings: community perceptions and preferences for adaptation in Zanzibar, Tanzania. *Population and Environment*, 31(5), pp.371-398.
- Mwinjaka, O., Gupta, J. & Bresser, T., 2010. Adaptation strategies of the poorest farmers in drought-prone Gujarat. *Climate and Development*, 2(4), pp.346-363.
- Næss, L.O. et al., 2005. Institutional adaptation to climate change: flood responses at the municipal level in Norway. *Global Environmental Change Part A*, 15(2), pp.125–138.
- Næss, L.O. et al., 2006. Data and processes linking vulnerability assessment to adaptation decision-making on climate change in Norway. *Global Environmental Change*, 16(2), pp.221–233.
- Nagy, C., 2001. *Agriculture energy use of adaptation options to climate change*, Saskatoon, SK.
- Nairn, J.A. & Beanland, S., 1989. Geological setting of the 1987 Edgecumbe earthquake, New Zealand. *New Zealand Journal of Geology and Geophysics*, 32(1), pp.1-13.
- Narayan, K.A. et al., 2003. Effects of groundwater pumping on saltwater intrusion in the lower Burdekin Delta, North Queensland. In A. D. Post, ed. *MODSIM 2003 International Congress on modelling and simulation*. Perth, Australia: Modelling and Simulation Society of Australia and New Zealand, pp. 206-211.
- Nelson, D.R., 2011. Adaptation and resilience: responding to a changing climate. *Wiley Interdisciplinary Reviews: Climate Change*, 2(1), pp.113-120.
- Nelson, R., Kokic, P. & Meinke, H., 2007. From rainfall to farm incomes—transforming advice for Australian drought policy. II. Forecasting farm incomes. *Australian Journal of Agricultural Research*, 58(10), pp.1004-1012.
- Nelson, R., Kokic, P., Crimp, S., Martin, P., et al., 2010b. The vulnerability of Australian rural communities to climate variability and change: Part II—Integrating impacts with adaptive capacity. *Environmental Science & Policy*, 13(1), pp.18–27.
- Nelson, R., Kokic, P., Crimp, S., Meinke, H., et al., 2010a. The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability. *Environmental Science & Policy*, 13(1), pp.8-17.
- Nelson, V. et al., 2002. Uncertain predictions, invisible impacts, and the need to mainstream gender in climate change adaptations. *Gender and Development*, pp.51–59.

- Nepstad, D.C., Stickler, C.M. & Almeida, O.T., 2006. Globalization of the Amazon Soy and Beef Industries: Opportunities for Conservation. *Conservation Biology*, 20(6), pp.1595-1603.
- Neudoerffer, R.C. & Waltner-Toews, D., 2007. Community-Based Watershed Management as an Agricultural Adaptation to Climatic Extremes in the Canadian Prairies. In E. Wall, B. Smit, & J. Wandel, eds. *Farming in a changing climate: agricultural adaptation in Canada*. Vancouver, Canada: UBC Press, pp. 187-199.
- Newton, P.C.D. et al., 2006. Impacts of Elevated CO₂ on a Grassland Grazed by Sheep: the New Zealand FACE Experiment. In J. Nösberger et al., eds. *Managed Ecosystems and CO₂*. Berlin/Heidelberg: Springer-Verlag, pp. 157-171.
- Nicholls, R. J. et al., 2010. Sea-level rise and its possible impacts given a “beyond 4°C world” in the twenty-first century. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1934), pp.161-181.
- Nicholls, R. J., 2004. Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. *Global Environmental Change*, 14(1), pp.69-86.
- Nicholls, R. J. & Hoozemans, F.M.J., 2005. Global vulnerability analysis. In M. Schwartz, ed. *Encyclopedia of Coastal Science*. Netherlands: Kluwer, pp. 486-491.
- Nicholls, R.J., Hoozemans, F.M. J. & Marchand, M., 1999. Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. *Global Environmental Change*, 9(Supplement 1), p.S69-S87.
- Nie, Z.N., Ward, G.N. & Michael, A.T., 2001. Impact of pugging by dairy cows on pastures and indicators of pugging damage to pasture soil in south-western Victoria. *Aust. J. Agric. Res.*, 52(1), pp.37-43.
- Nordhaus, W.D., 1991. The Cost of Slowing Climate Change: a Survey. *The Energy Journal*, 12(1), pp.37-66.
- Norman, R., 2009. Palm kernel addiction threatens economic sabotage. *Green Party of Aotearoa New Zealand*. Available at: <http://www.greens.org.nz/press-releases/palm-kernel-addiction-threatens-economic-sabotage> [Accessed July 28, 2011].
- NWASCO (National Water and Soil Conservation Organisation), 1975. *New Zealand Land Resource Inventory Worksheets*, Wellington N.Z.: Water and Soil Division, Ministry of Works and Development.
- NZIER, 2009. *The economic impact of the New Zealand wine industry: a report to New Zealand winegrowers*, Wellington, N.Z.: New Zealand Institute of Economic Research.

- O'Brien, K. & Leichenko, R.M., 2000. Double exposure: assessing the impacts of climate change within the context of economic globalization. *Global Environmental Change, Part A: Human and Policy Dimensions*, 10(3), pp.221–232.
- O'Brien, K. & Wolf, J., 2010. A values-based approach to vulnerability and adaptation to climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 1(2), pp.232-242.
- O'Brien, K., Eriksen, S., et al., 2004. *What's in a word? Conflicting interpretations of vulnerability in climate change research*, Oslo, Norway: CICERO (Center for International Climate and Environmental Research).
- O'Brien, K. et al., 2006. Questioning complacency: Climate change impacts, vulnerability, and adaptation in Norway. *Ambio*, 35(2), pp.50-56.
- O'Brien, K. et al., 2007. Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, 7, pp.73-88.
- O'Brien, K., Leichenko, R., et al., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change Part A*, 14(4), pp.303–313.
- O'Gorman, P.A. & Schneider, T., 2009. The physical basis for increases in precipitation extremes in simulations of 21st-century climate change. *Proceedings of the National Academy of Sciences*, 106(35), p.14773.
- O'Keefe, P., Westgate, Ken & Wisner, Ben, 1976. Taking the naturalness out of natural disasters. *Nature*, 260(5552), pp.566-567.
- O'Neill, R., 2011. Rising kiwi bites into fruit exporters' pockets. *Sunday Star Times*. Available at: <http://www.stuff.co.nz/business/5331241/Rising-kiwi-bites-into-fruit-exporters-pockets/> [Accessed May 26, 2011].
- Oliver-Smith, A. & Hoffman, S.M., 1999. *The angry earth: disaster in anthropological perspective*, New York:Routledge.
- Olmstead, C.W., 1970. The phenomena, functioning units and systems of agriculture. *Geographia Polonica*, 19, pp.31-41.
- Olsson, P. & Folke, Carl, 2001. Local Ecological Knowledge and Institutional Dynamics for Ecosystem Management: A Study of Lake Racken Watershed, Sweden. *Ecosystems*, 4(2), pp.85-104.
- Opara, L.U. & Mazaud, F., 2001. Food traceability from field to plate. *Outlook on Agriculture*, 30(4), pp.239-247.
- Oreskes, N., 2004. The scientific consensus on climatic change. *Science*, 306(5702), p.1686.

- Orlove, B.S., 2005. Human adaptation to climate change: a review of three historical cases and some general perspectives. *Environmental Science & Policy*, 8(6), pp.589-600.
- Orlove, B.S. & Guillet, D.W., 1985. Theoretical and methodological considerations on the study of mountain peoples: Reflections on the idea of subsistence type and the role of history in human ecology. *Mountain Research and Development*, pp.3–18.
- Osbahr, H. et al., 2010. Evaluating successful livelihood adaptation to climate variability and change in southern Africa. *Ecology and Society*, 15(2), p.27.
- Paavola, J., 2008. Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science & Policy*, 11(7), pp.642-654.
- Pahl-Wostl, C., 2002. Participative and Stakeholder-Based Policy Design, Evaluation and Modeling Process. *Integrated Assessment*, 3(1), pp.3-14.
- Pailly, O. et al., 1990. La qualité gustative du kiwi. In 9^o coll. *Sur les recherches fruitières: "La maîtrise de la qualité des fruits frais."* INRA. Avignon, France, pp. 85-101.
- Pailly, O., Habib, R. & Delecolle, R., 1995. Effect of soil and climate conditions on soluble solids evolution during maturation of kiwifruit. *New Zealand Journal of Crop and Horticultural Science*, 23(2), p.145.
- Pall, P. et al., 2011. Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, 470(7334), pp.382-385.
- Pande, T.N. et al., 2000. Pasture damage and regrowth from cattle treading. In *Proceedings of the New Zealand Grassland Association 2000*. New Zealand Grassland Association 62nd Conference. Invercargill, NZ, pp. 155-160.
- Pant, K.P., 2009. Effects of agriculture on climate change: a cross country study of factors affecting carbon emissions. *The Journal of Agriculture and Environment*, 10, pp.72-88.
- Park, G., 2002. "Swamps which might doubtless Easily be drained". Swampdrainage and its impact on the indigenous. In E. Pawson & Brooking, eds. *Environmental Histories of New Zealand*. Melbourne: Oxford University Press, pp. 151-165.
- Park, P., 1999. People, Knowledge, and Change in Participatory Research. *Management Learning*, 30(2), pp.141 -157.
- Parker, W.J. & Holmes, C.W., 1997. How much must the average farm produce in 2010 in order to maintain its present level of net income? *Dairyfarming Annual*, 49, pp.25-33.
- Parmesan, C. & Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, 421(6918), pp.37–42.

- Parry, M., Rosenzweig, Cynthia & Livermore, Matthew, 2005. Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1463), pp.2125 -2138.
- Parry, M.L. & Carter, T.R., 1989. Assessing the effects of climatic change on agriculture and forestry. *Carbon dioxide and other greenhouse gases: climatic and associated impacts. Proc., symposium, CEC, Brussels, 1986*, pp.256-269.
- Parry, M.L. & Carter, T.R., 1998. *Climate Impact and Adaptation Assessment*, London: Earthscan.
- Parry, M.L. et al. eds., 2007. *Climate Change 2007: impacts, adaptation and vulnerability : contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press.
- Parry, M.L., Lowe, J. & Hanson, C., 2009. Overshoot, adapt and recover. *Nature*, 458(7242), pp.1102-1103.
- Parry, M. L. et al., 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14(1), pp.53-67.
- Patt, A.G., Daze, A. & Suarez, P., 2009. Gender and climate change vulnerability: what's the problem, what's the solution? In M. Ruth & M. E. Ibararán, eds. *Distributional impacts of climate change and disasters: concepts and cases*. London: Edward Elgar Publishing, pp. 82-104.
- Patterson, K., Burdon, J. & Lallu, N., 2003. 'Hort16a' Kiwifruit: Progress and Issues with Commercialisation. *Acta Horticulturae*, (610), pp.267-274.
- Patterson, M.G. et al., 2006. Climate change impacts on regional development and sustainability: an analysis of New Zealand regions. In M. Ruth, ed. *Smart Growth and Climate Change: Regional Development, Infrastructure and Adaptation*. Northampton, MA, USA: Edward Elgar, pp. 82-108.
- Pearce, H.G., Mullan, A.B. & Salinger, M.J., 2005. *Impact of climate change on long-term fire danger*, Wellington, N.Z.
- Pearce, L., 2005. The value of public participation during a hazard, impact, risk and vulnerability (HIRV) analysis. *Mitigation and Adaptation Strategies for Global Change*, 10(3), pp.411-441.
- Pearce, T., Ford, J.D., et al., 2010. Climate change and mining in Canada. *Mitigation and Adaptation Strategies for Global Change*, 16(3), pp.347-368.
- Pearce, T., Smit, B., et al., 2010. Inuit vulnerability and adaptive capacity to climate change in Ulukhaktok, Northwest Territories, Canada. *Polar Record*, 46(02), pp.157-177.

- Pearce, T.D. et al., 2009. Community collaboration and climate change research in the Canadian Arctic. *Polar Research*, 28(1), pp.10–27.
- Pearson, L.J. et al., 2011. Interpretive review of conceptual frameworks and research models that inform Australia's agricultural vulnerability to climate change. *Environmental Modelling & Software*, 26(2), pp.113-123.
- Pelling, M., 2003. *The Vulnerability of Cities: Natural Disasters and Social Resilience*, London: Earthscan.
- Pelling, M. et al., 2008. Shadow spaces for social learning: a relational understanding of adaptive capacity to climate change within organisations. *Environment and Planning A*, 40(4), pp.867–884.
- Pennington, J.A. et al., 1985. Sexual Activity of Holstein Cows: Seasonal Effects. *Journal of Dairy Science*, 68(11), pp.3023-3030.
- Perch-Nielsen, S.L., 2009. The vulnerability of beach tourism to climate change—an index approach. *Climatic Change*, 100(3-4), pp.579-606.
- Perkins, J. & Jamison, R., 2008. History, Ethics and Intensification in Agriculture. In P. B. Thompson, ed. *The Ethics of Intensification: Agricultural Development and Cultural Change*. Berlin, Heidelberg: Springer, pp. 59-83.
- Perry, A.L. et al., 2005. Climate Change and Distribution Shifts in Marine Fishes. *Science*, 308(5730), pp.1912 -1915.
- Pielke Jr, R. et al., 2007. Lifting the taboo on adaptation. *Nature*, 445(8), pp.597-598.
- Pielke Jr, R.A., 2008. Climate predictions and observations. *Natural Geosciences*, 1, p.206.
- Plummer, R. & Armitage, D., 2010. Integrating Perspectives on Adaptive Capacity and Environmental Governance. In D. Armitage & R. Plummer, eds. *Adaptive Capacity and Environmental Governance*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 1-19.
- Polsky, C., Neff, R. & Yarnal, B., 2007. Building comparable global change vulnerability assessments: The vulnerability scoping diagram. *Global Environmental Change*, 17(3-4), pp.472-485.
- Porter, J.H., Parry, M. L. & Carter, T. R., 1991. The potential effects of climatic change on agricultural insect pests. *Agricultural and Forest Meteorology*, 57(1-3), pp.221-240.
- Pouliotte, J., Smit, B. & Westerhoff, L., 2009. Adaptation and development: Livelihoods and climate change in Subarnabad, Bangladesh. *Climate and Development*, 1(1), pp.31-46.
- Prache, S. et al., 2005. Traceability of animal feeding diet in the meat and milk of small ruminants. *Small Ruminant Research*, 59(2-3), pp.157-168.

- Prestidge, R.A. & Potter, R.P., 1990. *The Impact of Climate Change on Pests, Diseases, Weeds and Beneficial Organisms Present in New Zealand Agricultural and Horticultural Systems*, Wellington: Ministry for the Environment.
- Prno, J. et al., 2011. Community vulnerability to climate change in the context of other exposure-sensitivities in Kugluktuk, Nunavut. *Polar Research*, 30.
- Proctor, J.D., 1998. The meaning of global environmental change: Retheorizing culture in human dimensions research. *Global Environmental Change*, 8(3), pp.227-248.
- Pullar, W.A., 1985. *Soils and land use of Rangitaiki Plains, North Island, New Zealand*, Lower Hutt, NZ: New Zealand Soil Bureau, Dept. of Scientific and Industrial Research. Available at: <http://www.getcited.org/pub/102507397> [Accessed July 3, 2011].
- Pullar, W.A. & Patel, R.N., 1972. Identification of Tree Stumps and Driftwood Associated With Tephra Layers in Alluvium, Peat, and Dune Sands. *New Zealand Journal of Botany*, 10, pp.605-614.
- Pullar, W.A. & Selby, M.J., 1971. Coastal progradation of Rangitaiki Plains, New Zealand. *New Zealand Journal of Science*, 14, pp.419-434.
- Radhakrishnan, M., Waisel, Y. & Sternberg, M., 2006. Kikuyu Grass: A Valuable Salt-Tolerant Fodder Grass. *Communications in Soil Science and Plant Analysis*, 37(9-10), pp.1269-1279.
- Rahmstorf, S. et al., 2007. Recent Climate Observations Compared to Projections. *Science*, 316(5825), p.709.
- Ramanathan, V. & Feng, Y., 2008. On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead. *Proceedings of the National Academy of Sciences*, 105(38), pp.14245-14250.
- Ransom, E. & Bain, C., 2011. Gendering Agricultural Aid. *Gender & Society*, 25(1), pp.48-74.
- Rao, S., 2011. Work and Empowerment: Women and Agriculture in South India. *Journal of Development Studies*, 47(2), pp.294-315.
- Rappaport, R.A., 1977. Maladaptation in social systems. In J. Friedman, ed. *Evolution of social systems*. London, UK: Duckworth.
- Rasmussen, K. et al., 2010. Prospects for climate change on three Polynesian outliers in Solomon Islands: Exposure, sensitivity and adaptive capacity. *Geografisk Tidsskrift: Danish Journal of Geography*, 111(1), p.43.
- Reid, S. et al., 2007. Vulnerability and adaptation to climate risks in Ontario agriculture. *Mitigation and Adaptation Strategies for Global Change*, 12(4), pp.609-637.

- Reidsma, P. et al., 2010. Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses. *European Journal of Agronomy*, 32(1), pp.91-102.
- Reilly, J., 2011. Climate Change Adaptation in the Agricultural Sector. In James D. Ford & L. Berrang-Ford, eds. *Climate Change Adaptation in Developed Nations*. Dordrecht: Springer Netherlands, pp. 347-357.
- Reilly, J. & Schimmelpfennig, D., 1999. Agricultural Impact Assessment, Vulnerability, and the Scope for Adaptation. *Climatic Change*, 43(4), pp.745-788.
- Reisinger, A. et al., 2011. The Role of Local Government in Adapting to Climate Change: Lessons from New Zealand. In James D. Ford & L. Berrang-Ford, eds. *Climate Change Adaptation in Developed Nations*. Dordrecht: Springer Netherlands, pp. 303-319.
- Rennie, R., 2009. Analyst warns of dairy debt tsunami. *The New Zealand Farmers Weekly*. Available at: <http://www.nzfarmersweekly.co.nz/article/7645.html> [Accessed July 21, 2011].
- Rennie, R., 2007. Palm kernel discontent simmers. *The New Zealand Farmers Weekly*. Available at: <http://www.nzfarmersweekly.co.nz/article/6834.html> [Accessed July 28, 2011].
- Ribot, J.C., 1995. The causal structure of vulnerability: Its application to climate impact analysis. *GeoJournal*, 35(2), pp.119–122.
- Richardson, A.C. et al., 2004. High growing temperatures reduce fruit carbohydrate and vitamin C in kiwifruit. *Plant, Cell & Environment*, 27(4), pp.423-435.
- Riden, C., 2007. Why restructure Fonterra? *The New Zealand Farmers Weekly*. Available at: <http://www.nzfarmersweekly.co.nz/article/7110.html> [Accessed July 21, 2011].
- Rijske, W.C., 1993. *Soils of Whakatane County, North Island, New Zealand*, Landcare Research.
- Rijske, W.C. & Guinto, D.F., 2010. *Soils of the Bay of Plenty Volume 3: Eastern Bay of Plenty*, Whakatane, N.Z.: Environment Bay of Plenty.
- Risbey, J. et al., 1999. Scale, context, and decision making in agricultural adaptation to climate variability and change. *Mitigation and Adaptation Strategies for Global Change*, 4(2), pp.137–165.
- Rittel, H.W. & Webber, M.M., 1973. Dilemmas in a general theory of planning. *Policy sciences*, 4(2), pp.155–169.
- Rivers, M.J. et al., 1997. *Change and Diversity: Opportunities for and Constraints on Rural Women in New Zealand*, Wellington, N.Z.: Ministry of Agriculture and Forestry.

- Robards, M.D. et al., 2011. The importance of social drivers in the resilient provision of ecosystem services. *Global Environmental Change*, 21(2), pp.522-529.
- Robertson, N., Perkins, H.C. & Taylor, N., 2008. Multiple Job Holding: Interpreting Economic, Labour Market and Social Change in Rural Communities. *Sociologia Ruralis*, 48(4), pp.331-350.
- Rodriguez, D. et al., 2011. The intrinsic plasticity of farm businesses and their resilience to change. An Australian example. *Field Crops Research*, In Press.
- Rogers, F.M. & Shoemaker, F.F., 1971. *Communication of Innovations*, New York, NY: The Free Press.
- Romieu, E. et al., 2010. Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications. *Sustainability Science*, 5(2), pp.159-170.
- Roncoli, C., 2006. Ethnographic and participatory approaches to research on farmers' responses to climate predictions. *Climate Research*, 33(1), p.81.
- Root, T.L. et al., 2003. Fingerprints of global warming on wild animals and plants. *Nature*, 421(6918), pp.57-60.
- Rosenberg, N.J., 1986. Adaptations to Adversity: Agriculture, Climate, and the Great Plains of North America. *Great Plains Quarterly*, 6, pp.202-217.
- Rosenberg, N.J. & Scott, M.J., 1994. Implications of policies to prevent climate change for future food security. *Global Environmental Change*, 4(1), pp.49-62.
- Rosenzweig, C. & Parry, M.L., 1994. Potential impact of climate change on world food supply. *Nature*, 367(6459), pp.133-138.
- Rosenzweig, C. et al., 2001. Climate change and extreme weather events: Implications for food production, plant diseases, and pests. *Global Change Human Health*, 2, pp.90-104.
- Rosenzweig, C. et al., 2008. Attributing physical and biological impacts to anthropogenic climate change. *Nature*, 453(7193), pp.353-357.
- Rosin, C., 2008. The conventions of agri-environmental practice in New Zealand: farmers, retail driven audit schemes and a new spirit of farming. *GeoJournal*, 73(1), pp.45-54.
- Ross, D.J. et al., 1996. Elevated CO₂ effects on carbon and nitrogen cycling in grass/clover turves of a Psammaquent soil. *Plant and soil*, 182(2), pp.185-198.
- Rudel, T.K. et al., 2009. Agricultural intensification and changes in cultivated areas, 1970-2005. *Proceedings of the National Academy of Sciences*, 106(49), pp.20675-20680.

- Rumball, P.J., 1991. Performance of several subtropical grasses in Northland hill pastures. *New Zealand Journal of Agricultural Research*, 34, pp.375-382.
- Rutherford, H., 2011. In-debt farmers face more pain. *Stuff.co.nz*. Available at: <http://www.stuff.co.nz/business/farming/5139450/In-debt-farmers-face-more-pain> [Accessed June 23, 2011].
- Sale, P.R. & Lyford, P.B., 1990. Cultural, management and harvesting practices for kiwifruit in New Zealand. In I. J. Warrington & C. G. Weston, eds. *Kiwifruit: science and management*. Auckland, N.Z.: Ray Richards Publisher and New Zealand Society for Horticultural Science, pp. 247-296.
- Salinger, M.J., 2005a. Climate variability and change: past, present and future—an overview. *Climatic Change*, 70(1), pp.9–29.
- Salinger, M.J., 2005b. Increasing climate variability and change: reducing the vulnerability. *Increasing Climate Variability and Change*, pp.1–3.
- Salinger, M.J. et al., 2004. Atmospheric circulation and precipitation. In *Freshwaters of New Zealand*. NZ Hydrological Society and Limnological Society of New Zealand, pp. 2.1-2.18.
- Salinger, M.J., Renwick, J.A. & Mullan, A.B., 2001. Interdecadal Pacific Oscillation and South Pacific climate. *International Journal of Climatology*, 21(14), pp.1705-1721.
- Salinger, M.J., Stigter, C.J. & Das, H.P., 2000. Agrometeorological adaptation strategies to increasing climate variability and climate change. *Agricultural and Forest Meteorology*, 103(1-2), pp.167-184.
- Sandrey, R. & Reynolds, R. eds., 1990. *Farming without subsidies: New Zealand's recent experience*, Wellington, N.Z.: GP Books.
- Santos, S.L. & Chess, C., 2003. Evaluating citizen advisory boards: The importance of theory and respondent-based criteria and practical implications. *Risk Analysis*, 23(2), pp.269-279.
- Sarewitz, D. & Pielke, J., 2007. The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science & Policy*, 10(1), pp.5-16.
- Sauchyn, D.J., Kennedy, S.D. & Stroich, J., 2005. Drought, climate change and the risk of desertification on the Canadian Plains. *Prairie Forum*, 30(1), pp.143-156.
- Saunders, C., Barber, A. & Taylor, G., 2006. *Food miles – comparative energy/emissions performance of New Zealand's agriculture industry*, Lincoln, N.Z.: Agribusiness and Economics Research Unit, Lincoln University. Available at: http://researcharchive.lincoln.ac.nz/dspace/bitstream/10182/125/1/aeru_rr_285.pdf.

- Schamel, G. & Anderson, K., 2003. Wine Quality and Varietal, Regional and Winery Reputations: Hedonic Prices for Australia and New Zealand. *Economic Record*, 79(246), pp.357-369.
- Schellnhuber, H.J., 2009. 'Opening Address', 2009 Meeting International Human Dimensions Programme on Global Environmental Change (IHDP), Bonn, Germany, 26-30 April.
- Schimmelpfennig, D. & Yohe, G., 1999. Vulnerability of crops to climate change: A practical method of indexing. *Global Environmental Change and Agriculture: Assessing the Impacts*, pp.193-217.
- Schipper, E.L., 2006. Conceptual History of Adaptation in the UNFCCC Process. *Review of European Community & International Environmental Law*, 15(1), pp.82-92.
- Schmidhuber, J. & Tubiello, F. N., 2007. Global food security under climate change. *Proceedings of the National Academy of Sciences*, 104(50), p.19703.
- Schneider, S., Easterling, W.E. & Mearns, L.O., 2000. Adaptation: sensitivity to natural variability, agent assumptions and dynamic climate changes. *Climatic Change*, 45(1), pp.203-221.
- Schneider, S., 2009. The worst-case scenario. *Nature*, 458(7242), pp.1104-1105.
- Schröter, D., Polsky, C. & Patt, A.G., 2005. Assessing vulnerabilities to the effects of global change: an eight step approach. *Mitigation and Adaptation Strategies for Global Change*, 10(4), pp.573-595.
- Schubert, S.D. et al., 2008. Potential Predictability of Long-Term Drought and Pluvial Conditions in the U.S. Great Plains. *Journal of Climate*, 21(4), pp.802-816.
- Schultz, H.R. & Stoll, M., 2010. Some critical issues in environmental physiology of grapevines: future challenges and current limitations. *Australian Journal of Grape and Wine Research*, 16, pp.4-24.
- Schwartz, B. & Sharpe, K.E., 2006. Practical Wisdom: Aristotle meets Positive Psychology. *Journal of Happiness Studies*, 7(3), pp.377-395.
- Schweiger, O. et al., 2010. Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination. *Biological Reviews*, p.no-no.
- Scott, A., 2008. Hiding our light under the No. 8 wire. *Science New Zealand*. Available at: http://www.sciencenewzealand.org/opinion/hiding_our_light_under_the_no_8_wire [Accessed July 16, 2011].
- Scott, D. et al., 2006. Climate change and the sustainability of ski-based tourism in eastern North America: A reassessment. *Journal of Sustainable Tourism*, 14(4), pp.376-398.

- Scott, J.C., 1998. *Seeing Like a State*, Yale University Press.
- Sen, A., 1981. *Poverty and famines*, London: Clarendon Press.
- Seo, S.N., 2006. A geographically scaled analysis of adaptation to climate change with spatial models using agricultural systems in Africa. *The Journal of Agricultural Science*, 1(-1), pp.1–13.
- Settele, J. et al., 2010. Climate change impacts on biodiversity: a short introduction with special emphasis on the ALARM approach for the assessment of multiple risks. *BIORISK – Biodiversity and Ecosystem Risk Assessment*, 5, pp.3-29.
- Shafiee, S. & Topal, E., 2010. A long-term view of worldwide fossil fuel prices. *Applied Energy*, 87(3), pp.988-1000.
- Shaw, A. et al., 2009. Making local futures tangible--Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. *Global Environmental Change*, 19(4), pp.447-463.
- Sherval, M. & Askew, L.E., 2011. Experiencing “drought and more”: local responses from rural Victoria, Australia. *Population and Environment*. In press.
- Shove, E., 2010. Beyond the ABC: climate change policy and theories of social change. *Environment and Planning A*, 42(6), pp.1273–1285.
- Shrestha, A., Bhattarai, B. & Leduc, B., 2008. Case Study: Gender and Climate Change in the Hindu Kush Himalayas of Nepal. *Development*, pp.1-18.
- Sillmann, J. & Roeckner, E., 2007. Indices for extreme events in projections of anthropogenic climate change. *Climatic Change*, 86(1-2), pp.83-104.
- Silva, J.A., Eriksen, Siri & Ombe, Z.A., 2010. Double exposure in Mozambique’s Limpopo River Basin. *Geographical Journal*, 176(1), pp.6-24.
- Simonet, G., 2010. The concept of adaptation: interdisciplinary scope and involvement in climate change. *Sapiens*, 3(1), pp.1-9.
- Sivakumar, M.V.K. & Motha, R.P., 2007. *Managing Weather and Climate Risks in Agriculture* 1st ed., Springer.
- Smit, B., 1994. Climate, compensation and adaptation. In J. McCulloch & D. Etkin, eds. *Proceedings of a Workshop on Improving Responses to Atmospheric Extremes: The role of insurance and compensation*. Toronto: Environment Canada/The Climate Institute, pp. 2.29-2.37.

- Smit, B. & Pilifosova, O., 2001. Adaptation to climate change in the context of sustainable development and equity. In J. J. McCarthy et al., eds. *Climate Change 2001: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, pp. 877-912.
- Smit, B. & Pilifosova, O., 2003. From Adaptation to Adaptive Capacity and Vulnerability Reduction. In J.B. Smith, R.J.T. Klein, & S. Huq, eds. *Climate Change, Adaptive Capacity and Development*. London: Imperial College Press, pp. 9-28.
- Smit, B. & Skinner, M.W., 2002. Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change*, 7(1), pp.85–114.
- Smit, B. & Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3), pp.282-292.
- Smit, B. et al., 2000. An anatomy of adaptation to climate change and variability. *Climatic Change*, 45(1), pp.223-251.
- Smit, B. et al., 2010. Introduction to the CAVIAR Project and Framework. In Grete K. Hovelsrud & Barry Smit, eds. *Community Adaptation and Vulnerability in Arctic Regions*. Dordrecht: Springer Netherlands, pp. 1-22.
- Smit, B., McNabb, D. & Smithers, J., 1996. Agricultural adaptation to climatic variation. *Climatic Change*, 33(1), pp.7-29.
- Smit, B., 1991. Decisions in Agriculture in the Face of Uncertainty: The Role of Climate Impact Assessment. In P. Dzikowski, ed. *Changing Climate in Relation to Sustainable Agriculture*. Fredericton, Canada: ECA/CSAM, pp. 33-42.
- Smith, B.L. & Towers, N.R., 2002. Mycotoxicoses of grazing animals in New Zealand. *New Zealand Veterinary Journal*, 50(3), pp.28-34.
- Smith, J.B. et al., 2009. Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) “reasons for concern.” *Proceedings of the National Academy of Sciences*, 106(11), pp.4133 -4137.
- Smith, J.B., Klein, R.J.T. & Huq, S., 2003. *Climate change, adaptive capacity and development*, Imperial College Press.
- Smith, K. & Petley, D.N., 2009. *Environmental Hazards: Assessing Risk and Reducing Disaster*, Taylor & Francis.
- Smith, K., Barrett, C.B. & Box, P.W., 2000. Participatory risk mapping for targeting research and assistance: With an example from East African pastoralists. *World Development*, 28(11), pp.1945-1959.

- Smith, L.C. et al., 2008. The effectiveness of dicyandiamide in reducing nitrous oxide emissions from a cattle-grazed, winter forage crop in Southland, New Zealand. *Aust. J. Exp. Agric.*, 48(2), pp.160-164.
- Smith, M.S. et al., 2011. Rethinking adaptation for a 4° C world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1934), p.196.
- Smith, N., 2009. Will fertiliser scarcity harm farm economy? *New Zealand Herald*. Available at: <http://www.stuff.co.nz/business/blogs/nick-smith/2513708/Will-fertiliser-scarcity-harm-farm-economy> [Accessed July 17, 2011].
- Smith, P. & Oleson, J.E., 2010. Synergies Between the Mitigation of, and Adaptation to, Climate Change in Agriculture. *The Journal of Agricultural Science*, 148(Special Issue 05), pp.543-552.
- Smith, W. & Montgomery, H., 2004. Revolution or evolution? New Zealand agriculture since 1984. *GeoJournal*, 59(2), pp.107–118.
- Smith, W. & Saunders, L., 1995. Agricultural policy reforms and sustainable land management: A New Zealand case study. *Australian Geographer*, 26(2), pp.112-117.
- Smith, W. & Saunders, L., 1996. Agricultural Sustainability: the cost of the 1984 agricultural reforms. *New Zealand Geographer*, 52(1), pp.21-28.
- Smith, W., Montgomery, H. & Rhodes, T., 2007. North Island hill country farmers? management response to issues of sustainability. *New Zealand Geographer*, 63(1), pp.30-42.
- Smithers, J. & Blay-Palmer, A., 2001. Technology innovation as a strategy for climate adaptation in agriculture. *Applied Geography*, 21(2), pp.175-197.
- Smithers, J. & Smit, B., 1997. Human adaptation to climatic variability and change. *Global Environmental Change*, 7(2), pp.129–146.
- Solomon, S. et al., 2009. Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences*, 106(6), pp.1704 -1709.
- Spedding, C.R.W., 1988. *An Introduction to Agricultural Systems* 2nd ed., Barking: Elsevier Applied Sciences.
- Statistics New Zealand, 2007. Agriculture, horticulture, and forestry. Available at: <http://www.stats.govt.nz/agriculture> [Accessed February 6, 2011].
- Statistics New Zealand, 2006. *Research Report on Regional Gross Domestic Product*, Wellington N.Z.: Statistics New Zealand. Available at: <http://www.stats.govt.nz/agriculture> [Accessed June 1, 2011].

- Stern, N., 2006. *The Economics of Climate Change: The Stern Review*, Cambridge: Cambridge University Press.
- Stockdale, C., 1995. Maize silage as a supplement for pasture-fed dairy cows in early and late lactation. *Aust. J. Exp. Agric.*, 35(1), pp.19-26.
- Stone, R.C. & Meinke, H., 2006. Weather, Climate, and Farmers: An Overview. *Meteorological Applications*, 13(Supplement S1), pp.7-20.
- Stott, P.A. et al., 2006. Transient Climate Simulations with the HadGEM1 Climate Model: Causes of Past Warming and Future Climate Change. *Journal of Climate*, 19(12), pp.2763-2782.
- Stringer, L.C. et al., 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy*, 12(7), pp.748-765.
- Stroombergen, A. et al., 2006. The relationship between New Zealand's climate, energy, and the economy to 2025. *Kotuitui: New Zealand Journal of Social Sciences Online*, 1(2), pp.139-160.
- Subak, S., 2000. Climate change adaptation in the U.K. water industry: Managers' perceptions of past variability and future scenarios. *Water Resources Management*, 14(2), pp.137-156.
- Sutherland, K. et al., 2005. Vulnerability in Samoa. *Tiempo*, 54, pp.11-15.
- Sydneysmith, R. et al., 2010. Vulnerability and Adaptive Capacity in Arctic Communities. In Derek Armitage & R. Plummer, eds. *Adaptive Capacity and Environmental Governance*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 133-156.
- Syigna, L. et al., 2004. *Climate change in Norway: Analysis of economic and social impacts and adaptations*, Oslo: CICERO (Center for International Climate and Environmental Research). Available at: <http://www.cicero.uio.no/media/3290.pdf>.
- Tait, A.B. et al., 2008. An initial assessment of the potential effects of climate change on New Zealand agriculture. *New Zealand Science Review*, 65(3), pp.50-56.
- Tait, A.B., Renwick, J.A. & Stroombergen, A.H., 2005. The economic implications of climate-induced variations in milk production. *New Zealand Journal of Agricultural Research*, 48(2), pp.213-225.
- Tao, F. et al., 2009. Modelling the impacts of weather and climate variability on crop productivity over a large area: A new super-ensemble-based probabilistic projection. *Agricultural and Forest Meteorology*, 149(8), pp.1266-1278.
- Tarleton, M. & Ramsay, D., 2008. Farm-Level Adaptation to Multiple Risks: Climate Change and Other Concerns. *Journal of Rural and Community Development*, 3(2), pp.47-63.

- Tate, A.B., 2001. Global warming's impact on wine. *J. Wine Res.*, 12, pp.95-109.
- Teather, E.K., 1996. Farm women in Canada, New Zealand and Australia redefine their rurality. *Journal of Rural Studies*, 12(1), pp.1-14.
- Teather, E.K., 1998. The double bind: Being female and being rural: A comparative study of Australia, New Zealand and Canada. *Rural Society*, 8(3), pp.209-221.
- Tebaldi, Claudia et al., 2006. Going to the Extremes. *Climatic Change*, 79(3-4), pp.185-211.
- Terry, G., 2009. No climate justice without gender justice: an overview of the issues. *Gender & Development*, 17(1), pp.5-18.
- Thomalla, F. et al., 2006. Reducing hazard vulnerability: Towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, 30(1), pp.39-48.
- Thomas, D. S. G. et al., 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change*, 83(3), pp.301-322.
- Thorpe, H., 2010. Scrap ETS on stock: ruminants don't cause climate change. *Straight Furrow*, p.7.
- Thywissen, K., 2006. *Components of Risk*, United Nations University-Institute for Environment and Human Security (UNU-EHS). Available at: <http://www.ehs.unu.edu/file/get/4042> [Accessed July 8, 2011].
- Tingem, M. & Rivington, M., 2008. Adaptation for crop agriculture to climate change in Cameroon: Turning on the heat. *Mitigation and Adaptation Strategies for Global Change*, 14(2), pp.153-168.
- Tipples, R. et al., 2002. *Future dairy farming employment in New Zealand: An application of the Human Capability Framework*, Lincoln, N.Z.: Agriculture and Life Sciences Division, Lincoln University.
- Tittonell, P. et al., 2005. Exploring diversity in soil fertility management of smallholder farms in western Kenya: I. Heterogeneity at region and farm scale. *Agriculture, Ecosystems & Environment*, 110(3-4), pp.149-165.
- Tobin, G.A. & Montz, B.E., 1997. *Natural Hazards: Explanation and Integration* 1st ed., The Guilford Press.
- Tol, R.S.J., Fankhauser, S. & Smith, J.B., 1998. The scope for adaptation to climate change: What can we learn from the impact literature? *Global Environmental Change*, 8(2), pp.109-123.
- Tol, R.S.J. & Yohe, G.W., 2007. The weakest link hypothesis for adaptive capacity: An empirical test. *Global Environmental Change*, 17(2), pp.218-227.

- Tompkins, E.L. & Adger, W.N., 2004. Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society*, 9(2). Available at: <http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-27444437760&partner=40&rel=R5.0.4>.
- Tompkins, E.L., Few, R. & Brown, K., 2008. Scenario-based stakeholder engagement: Incorporating stakeholders preferences into coastal planning for climate change. *Journal of Environmental Management*, 88(4), pp.1580-1592.
- Tompkins, E.L. & Adger, W.N., 2005. Defining response capacity to enhance climate change policy. *Environmental Science & Policy*, 8(6), pp.562-571.
- Trainor, S.F. et al., 2007. Arctic Climate Impacts: Environmental Injustice in Canada and the United States. *Local Environment*, 12(6), pp.627-643.
- Trauger, A., 2004. “Because they can do the work”: women farmers in sustainable agriculture in Pennsylvania, USA. *Gender, Place and Culture: A Journal of Feminist Geography*, 11(2), pp.289-307.
- Trauger, A. et al., 2009. “Our market is our community”: women farmers and civic agriculture in Pennsylvania, USA. *Agriculture and Human Values*, 27(1), pp.43-55.
- Troeh, F.R. & Thompson, L.M., 2005. *Soils and soil fertility*, New York, NY: Wiley-Blackwell.
- Tschakert, P., 2007. Views from the vulnerable: Understanding climatic and other stressors in the Sahel. *Global Environmental Change*, 17(3-4), pp.381-396.
- Tubiello, F.N., Soussana, J.-F. & Howden, S.M., 2007. Crop and pasture response to climate change. *Proceedings of the National Academy of Sciences*, 104(50), pp.19686 -19690.
- Tucker, C.B. et al., 2007. Effects of shelter and body condition on the behaviour and physiology of dairy cattle in winter. *Applied Animal Behaviour Science*, 105(1-3), pp.1-13.
- Turner, B.L., 2010. Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science? *Global Environmental Change*, 20(4), pp.570-576.
- Turner, B.L., Kasperson, R. E, et al., 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), p.8074.
- Turner, B.L. et al., 1990. Two types of global environmental change: Definitional and spatial-scale issues in their human dimensions. *Global Environmental Change*, 1(1), pp.14-22.
- Turner, B.L., Matson, P.A., et al., 2003. Illustrating the coupled human–environment system for vulnerability analysis: three case studies. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), p.8080.

- Tyler, N.J.C. et al., 2007. Saami reindeer pastoralism under climate change: Applying a generalized framework for vulnerability studies to a sub-arctic social-ecological system. *Global Environmental Change*, 17(2), pp.191-206.
- Ummenhofer, C.C. & England, M.H., 2007. Interannual Extremes in New Zealand Precipitation Linked to Modes of Southern Hemisphere Climate Variability. *Journal of Climate*, 20(21), pp.5418-5440.
- Usmar, K., 2009. Getting all flushed about Hi-Cane. Available at: <http://www.sunlive.co.nz/news/3457-getting-all-flushed-about-hicane.html> [Accessed July 15, 2011].
- Vaccari, D.A., 2009. Phosphorus: A Looming Crisis. *Scientific American*, 300(6), pp.54-59.
- Valentine, G., 1997. Tell me about...: using interviews as a research methodology. In *Methods in human geography*. London, UK: Longman.
- Varley, A. ed., 1994. *Disasters, development and environment*, Chichester: John Wiley.
- Vásquez-León, M., 2009. Hispanic Farmers and Farmworkers: Social Networks, Institutional Exclusion, and Climate Vulnerability in Southeastern Arizona. *American Anthropologist*, 111(3), pp.289-301.
- Vásquez-León, M., West, C.T. & Finan, T.J., 2003. A comparative assessment of climate vulnerability: Agriculture and ranching on both sides of the US-Mexico border. *Global Environmental Change*, 13(3), pp.159-173.
- Vedwan, N. & Rhoades, R.E., 2001. Climate change in the Western Himalayas of India: a study of local perception and response. *Climate Research*, 19(2), pp.109–117.
- Verkerk, G., 2003. Pasture-based dairying: challenges and rewards for New Zealand producers. *Theriogenology*, 59(2), pp.553-561.
- Vincent, K., 2007. Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change*, 17(1), pp.12–24.
- Vogel, C. & O'Brien, K., 2004. Vulnerability and global environmental change : rhetoric and reality. *Aviso: an information bulletin on global environmental change and human security*, 13.
- Vogel, C. et al., 2007. Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships. *Global Environmental Change*, 17(3-4), pp.349-364.
- de Vries, J., 1985. Analysis of Historical Climate-Society Interaction. In R.W. Kates, J. H. Ausubel, & M. Berberian, eds. *Climate Impact Assessment, Studies of the Interaction of Climate and Society*. New York: Wiley, pp. 273-291.

- Walker, B. et al., 2006. A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society*, 11(1), p.13.
- Walker, B. et al., 2004. Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society*, 9(2). Available at: <http://www.ecologyandsociety.org/vol9/iss2/art5> [Accessed July 5, 2011].
- Wall, E. & Marzall, K., 2006. Adaptive capacity for climate change in Canadian rural communities. *Local Environment*, 11(4), pp.373-397.
- Wall, E. & Smit, B., 2005. Climate Change Adaptation in Light of Sustainable Agriculture. *Journal of Sustainable Agriculture*, 27(1), pp.113-123.
- Wall, E., Smit, B. & Wandel, J. eds., 2007. *Farming in a changing climate: agricultural adaptation in Canada*, UBC Press.
- Walther, G.R. et al., 2002. Ecological responses to recent climate change. *Nature*, 416(6879), pp.389–395.
- Wandel, J. & Marchildon, G.P., 2010. Institutional Fit and Interplay in a Dryland Agricultural Social–Ecological System in Alberta, Canada. In Derek Armitage & R. Plummer, eds. *Adaptive Capacity and Environmental Governance*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 179-195.
- Wandel, J. & Smit, B., 2000. Agricultural risk management in light of climate variability and change. *Agricultural and Environmental Sustainability in the New Countryside*, pp.30-39.
- Wandel, J., Wall, S.E. & Smit, B., 2007. Process-Based Approach. In E. Wall, Barry Smit, & J. Wandel, eds. *Farming in a changing climate: agricultural adaptation in Canada*. Vancouver, Canada: UBC Press, pp. 42-50.
- Wandel, J., Young, G. & Smit, Barry, 2009. The 2001–2002 Drought: Vulnerability and adaptation in Alberta’s special areas. *Prairie Forum*, 34(1), pp.211-234.
- Warrick, R.A. et al., 1996. Integrated model systems for national assessments of the effects of climate change: Applications in New Zealand and Bangladesh. *Water, Air, & Soil Pollution*, 92(1), pp.215-227.
- Washburn, S.P. et al., 2002. Reproduction, Mastitis, and Body Condition of Seasonally Calved Holstein and Jersey Cows in Confinement or Pasture Systems. *Journal of Dairy Science*, 85(1), pp.105-111.
- Watts, M.J. & Bohle, H.G., 1993a. Hunger, famine and the space of vulnerability. *GeoJournal*, 30(2), pp.117-125.
- Watts, M.J. & Bohle, H.G., 1993b. The space of vulnerability: the causal structure of hunger and famine. *Progress in Human Geography*, 17(1), pp.43 -67.

- Wedderburn, M.E. et al., 2010. Root growth patterns of perennial ryegrasses under well-watered and drought conditions. *New Zealand Journal of Agricultural Research*, 53(4), pp.377-388.
- Wenger, R.B., 2000. An Assessment of Ecosystem Risks in the St. Croix National Scenic Riverway. *Environmental Management*, 25(6), pp.599-611.
- Werner, A.D. & Simmons, C.T., 2009. Impact of Sea-Level Rise on Sea Water Intrusion in Coastal Aquifers. *Ground Water*, 47(2), pp.197-204.
- West, J.W., 2003. Effects of heat-stress on production in dairy cattle. *Journal of Dairy Science*, 86(6), pp.2131-2144.
- Westerhoff, L., 2010. "Planning for Today": The Nature and Emergence of Adaptation Measures in Italy. In E. Carina H. Keskitalo, ed. *Developing Adaptation Policy and Practice in Europe: Multi-level Governance of Climate Change*. Dordrecht: Springer Netherlands, pp. 233-270.
- Westerhoff, L. & Smit, B., 2008. The rains are disappointing us: dynamic vulnerability and adaptation to multiple stressors in the Afram Plains, Ghana. *Mitigation and Adaptation Strategies for Global Change*, 14(4), pp.317-337.
- Westerhoff, L., Keskitalo, E. C. H. & Juhola, S., 2011. Capacities across scales: local to national adaptation policy in four European countries. *Climate Policy*, 11(4), pp.1071-1085.
- Whakatane District Council, 2009. *Long Term Council Community Plan 2009-2019*, Whakatane, N.Z.: Whakatane District Council.
- Wheaton, E.E. & Maciver, D.C., 1999. A framework and key questions for adapting to climate variability and change. *Mitigation and Adaptation Strategies for Global Change*, 4(3-4), pp.215-225.
- White, P.A., 2005. *Future use of groundwater resources in the Bay of Plenty Region*, Taupo, N.Z.: Geological and Nuclear Sciences.
- White, T.A., Campbell, Bruce D. & Kemp, P.D., 1997. Invasion of temperate grassland by a subtropical annual grass across an experimental matrix of water stress and disturbance. *Journal of Vegetation Science*, 8(6), pp.847-854.
- White, T.A., Snow, V.O. & King, W.M., 2010. Intensification of New Zealand beef farming systems. *Agricultural Systems*, 103(1), pp.21-35.
- Wilbanks, T. J, 2007. Scale and sustainability. *Climate Policy*, 7(4), pp.278–287.
- Wilbanks, T.J. & Kates, Robert W., 2010. Beyond Adapting to Climate Change: Embedding Adaptation in Responses to Multiple Threats and Stresses. *Annals of the Association of American Geographers*, 100(4), pp.719-728.

- Wilbanks, T.J. & Kates, R.W., 1999. Global change in local places: How scale matters. *Climatic Change*, 43(3), pp.601-628.
- Wilhelmi, O.V. & Hayden, M.H., 2010. Connecting people and place: a new framework for reducing urban vulnerability to extreme heat. *Environmental Research Letters*, 5, p.014021.
- Wilhelmi, O.V. & Wilhite, D.A., 2002. Assessing vulnerability to agricultural drought: A Nebraska case study. *Natural Hazards*, 25(1), pp.37-58.
- Williams, W.M., Easton, H.S. & Jones, C.S., 2007. Future options and targets for pasture plant breeding in New Zealand. *New Zealand Journal of Agricultural Research*, 50(2), pp.223-248.
- Williamson, P., 1985. Sheep Farming in the New Zealand Bush. *Whakatane & District Historical Society: Historical Review*, 33(2), pp.106-117.
- Williamson, T., Hesseln, H. & Johnston, M., 2010. Adaptive capacity deficits and adaptive capacity of economic systems in climate change vulnerability assessment. *Forest Policy and Economics*, In Press, Corrected Proof. Available at: <http://www.sciencedirect.com/science/article/pii/S1389934110000523>.
- Willis, B., 2003. Enlargement, concentration and centralisation in the New Zealand dairy industry. *Geography*, 89(1), pp.83-88.
- Wilson, D.R. & Salinger, M.J., 1994. Climatic risk for sweet corn production in Canterbury, New Zealand. *New Zealand Journal of Crop and Horticultural Science*, 22(1), pp.57-64.
- Wilson, J. & Tipples, R., 2008. *Employment trends in dairy farming in New Zealand, 1991 - 2006*, Lincoln, N.Z.: Agriculture and Life Sciences Division, Lincoln University. Available at: <http://researcharchive.lincoln.ac.nz/dspace/handle/10182/574>.
- Wilson, O., 1995. Rural restructuring and agriculture-rural economy linkages: A New Zealand study. *Journal of Rural Studies*, 11(4), pp.417-431.
- Wilson, O., 1994. "They Changed the Rules": Farm Family Responses to Agricultural Deregulation in Southland, New Zealand. *New Zealand Geographer*, 50(1), pp.3-13.
- Winder, G.M., 2009. Grassland revolutions in New Zealand: Disaggregating a national story. *New Zealand Geographer*, 65(3), pp.187-200.
- Wisner, B., 2004. Assessment of capability and vulnerability. In G. Bankoff, G. Ferks, & D. Hilhorst, eds. *Mapping Vulnerability: Disasters, Development, and People*. London: Earthscan, pp. 183–193.
- Wisner, B. et al., 2004. *At Risk: Natural hazards, people's vulnerability and disasters*, London: Routledge.

- Wisner, B., O'Keefe, Phil & Westgate, Ken, 1977. Global systems and local disasters: The untapped power of peoples' science. *Disasters*, 1(1), pp.47-57.
- Woods, R. & Howard-Williams, C., 2004. Advances in freshwater sciences and management in New Zealand. In J. Harding et al., eds. *Freshwaters of New Zealand*. Wellington, N.Z.: New Zealand Hydrological Society & New Zealand Limnological Society.
- Woodward, T., 2007. *Variation in "Hayward" kiwifruit quality characteristics*. Unpublished MPhil. Hamilton, NZ: University of Waikato.
- Wratt, D., 2002. Climate change New Zealand: Impacts, vulnerability and adaptation. *Pacific Ecologist*, 1, pp.9-14.
- Wratt, D. & Matthews, W.A., 1992. *Submission for Funding from Output Class 33: Atmosphere and Climate Research*, Wellington N.Z.: Ministry for Research, Science and Technology.
- Wratt, D. et al., 2006. Climate for crops: integrating climate data with information about soils and crop requirements to reduce risks in agricultural decision-making. *Meteorological Applications*, 13(04), p.305.
- Wreford, A. & Adger, W. Neil, 2010. Adaptation in agriculture: historic effects of heat waves and droughts on UK agriculture. *International Journal of Agricultural Sustainability*, 8(4), pp.278-289.
- Yin, R., 2009. *Case Study Research*, California: Sage Publications.
- Yohe, G., 2000. Assessing the role of adaptation in evaluating vulnerability to climate change. *Climatic Change*, 46(3), pp.371-390.
- Yohe, G. & Tol, R.S.J., 2002. Indicators for social and economic coping capacity - Moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12(1), pp.25-40.
- Yohe, G. et al., 2003. Assessing Vulnerability in the Context of Changing Socioeconomic Conditions: A Study of Egypt. In Joel B. Smith, Richard J. T. Klein, & Saleemul Huq, eds. *Climate change, adaptive capacity and development*. London: Imperial College Press.
- Young, G. et al., 2009. Vulnerability and adaptation in a dryland community of the Elqui Valley, Chile. *Climatic Change*, 98(1-2), pp.245-276.
- Young, K.R. & Lipton, J.K., 2006. Adaptive governance and climate change in the tropical highlands of Western South America. *Climatic Change*, 78(1), pp.63-102.
- Young, O. R., 2010. Institutional dynamics: Resilience, vulnerability and adaptation in environmental and resource regimes. *Global Environmental Change*, 20(3), pp.378-385.

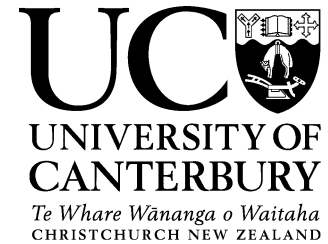
- Young, O. R. et al., 2006. The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change*, 16(3), pp.304-316.
- Zhou, H. et al., 2009. Resilience to natural hazards: a geographic perspective. *Natural Hazards*, 53(1), pp.21-41.
- Ziervogel, G., Bharwani, S. & Downing, T.E., 2006. Adapting to climate variability: Pumpkins, people and policy. *Natural Resources Forum*, 30(4), pp.294-305.

Appendix A

College of Science

Department of Geography

Tel: +64 3 3667001, Fax: + 64 364 2907



Nicholas Cradock-Henry, PhD Candidate
Department of Geography
University of Canterbury
Private Bag 4800
Christchurch 8130
nicholas.cradock@pg.canterbury.ac.nz

The research is required as part of an accepted PhD program in the Dept. of Geography at the University of Canterbury assessing the vulnerability of stakeholder producers in the Bay of Plenty region to climate variability and change, in the context of other, multiple sources of risk.

The need for research that will improve farm-level adaptation to climate change is well recognized. To assist farmers in adapting to climatic variability and extremes it is necessary to understand farmers' awareness and experiences, how they are affected by climatic conditions, the adaptive strategies available to them, and the constraints and opportunities for enhancing their adaptive capacity. The proposed research aims to identify the vulnerabilities and adaptive capacities of agricultural producers in the Rangitaiki Plain, Bay of Plenty, NZ, in order to contribute to the development of effective strategies to assist farmers in adapting to climatic variability.

This research has been designed to document the decisions, forces, and processes that influence decision-making at the farm-level, and to identify those that represent measures or strategies to adapt to climate risks. Interviews are being used to document farmers' management decisions and the forces and pressures that motivate or underlie them.

A diverse range of dairy farmers and horticulturalists in the Eastern Bay are being sought to participate in a short interview about agricultural risks. The research seeks participants that broadly represent the main types of Rangitaiki Plains farms and farmers with regards to farm size, farm type and location, and I would be greatly interested in your participation and if you know of anyone else that might be interested, could you please forward this information on and have them contact me at Nicholas.cradock@pg.canterbury.ac.nz.

Climate risks and agricultural adaptation in the Eastern Bay of Plenty

Sample Interview Questions

This interview is part of a PhD research project at the Department of Geography, University of Canterbury, in which I am exploring agricultural adaptations to risk in the Eastern Bay of Plenty. Agricultural producers in the BoP are exposed to a range of risks: climatic risks, financial risk, and other environmental risks such as earthquakes. I am interested in understanding the range of risks agricultural producers and stakeholders in the Bay of Plenty are exposed to; and how those risks have been managed.

I am planning to schedule interviews for late-February - April 2008, and would be greatly interested in your participation. The following is a rough guide to the sort of information that would be covered in the interview. Interviews will be transcribed and copies made available to you, no real names or identifying information will be used. If you have any questions about the research project, the interview, or would like to participate, please don't hesitate to contact me.

Nicholas (Nick) Cradock-Henry
Dept. of Geography, University of Canterbury

email nicholas.cradock@pg.canterbury.ac.nz

Thank you.

What sort of farming operation do you have? Can you describe it in general terms (location, size, type, length of time on farm, etc.)

What are the sorts of risks that you are both currently exposed to, and have been exposed to, over the farm's history? And what have made years "good" in terms of agricultural production?
How did you manage or adapt to those conditions?

Has the climate in the Bay of Plenty changed over the last 25-30 years? There are a number of measures to deal with weather related risks. What are some of the adaptations, or changes you've made in response to climatic risks?