Author/s:
BATTERBURY, SIMON

Title:
Perceptions of climate variability and dairy farmer adaptations in Corangamite Shire, Victoria, Australia

Date:
2014-01-01

Citation:
Elgin-Stuczynski, IR; Batterbury, S, Perceptions of climate variability and dairy farmer adaptations in Corangamite Shire, Victoria, Australia, INTERNATIONAL JOURNAL OF CLIMATE CHANGE STRATEGIES AND MANAGEMENT, 2014, 6 (1), pp. 85 - 107 (23)

Persistent Link:
http://hdl.handle.net/11343/45244

Draft version of

Elgin-Stuczynski I and Batterbury SPJ. 2014. Perceptions of climate variability and dairy farmer adaptations in Corangamite Shire, Victoria, Australia. *International Journal of Climate Change Strategies and Management* 6(1): 85-107.

Perceptions of climate variability and dairy farmer adaptations in Corangamite Shire, Victoria, Australia

Elgin-Stuczynski I. and Batterbury SPJ.

Abstract

Purpose: The article surveys dairy farmers' lay knowledge of climate change and the adaptation strategies they have implemented to respond to climatic and economic drivers. Dairy farming is highly dependent on climate. The case study is in Western Victoria, Australia, part of a major dairy farming region that contributes 26% of national milk production and 86% of the country's dairy exports.

Design: This study utilised a survey and semi-structured interviews in Corangamite Shire, to document dairy farmers' perceptions of climate change and the adaptation strategies they have implemented, compared to meteorological data on past climate variability.

Findings: Farmers in this region perceive a change in rainfall and temperature broadly in line with meteorological records. Those that have experienced a greater degree of climate vulnerability were found to perceive it more accurately. Almost all respondents had already made changes to their dairy businesses, but in doing so only a small percentage were responding directly to seasonal variability or longer term changes (9% and 15% respectively); the majority said they were responding to changing economic conditions in the industry.

Originality/value: A primary survey of dairy farming adds to knowledge of how climate changes are perceived, and how they are adapted to in a region heavily reliant on rainfall for its prime economic activity.

Key words: Climate variability, farmer perceptions, adaptation, dairy farming, Corangamite Shire, Australia

Acknowledgements

We would like to thank all the survey respondents for their kind participation, and three reviewers. For assistance with survey distribution; Murray Goulburn Cooperative Co. Ltd, Warrnambool Cheese and Butter, and West Vic Dairy. For data and advice; Stephen Commadeur at Australian Agribusiness Group, and Helen Chenoweth and Graeme Anderson at the Victorian Department of Primary Industries.

1. Introduction

In the local authority district known as Corangamite Shire, Victoria, south-east Australia (Figure 1), the success of dairy farming is intrinsically linked to the economic and social well-being of the region (WestVic Dairy, 2010). Some 22% of the Shire's population work in dairying, and it contributes to Victoria's dairy exports that were valued at AU $1.96 billion in 2010-2011 (DPI, 2012). Corangamite is a region of 4404 km^2 with a population of approximately 16,000 (ABS, 2011)

Most dairy farms in Corangamite Shire are not irrigated, and pasture quality relies on adequate precipitation, which increases from north to south (Figure 2) (Phelps et.al., 2012). Projections from the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BoM) suggest that temperatures are expected to rise by approximately one degree Celsius by 2030 across this region, whilst precipitation is expected to decline by 5% (Watterson et.al., 2007). Such expected changes in the climate could have significant negative impacts upon all agricultural enterprises, in terms of production and profitability (DeVoil et. al., 2006; Hayman et. al., 2008; Howden and Jones, 2001; Jones & Hennessey 2000; Luo et. al, 2007; White et. al., 2003). There have also been significant calls for dairying to reduce its carbon emissions and the issue is significant, but our focus here is on how the dairying community has already adapted to an uncertain climate. Future adaptations to climate risks must involve managing fluctuations in rainfall and temperature, and general climatic uncertainty that may exceed historical patterns (Bryant et. al., 2000; Bradshaw, et.al. 2004; Buys et.al. 2012; Howden et. al., 2007; Muller et. al., 2011).

This article explores the current relationship between dairying and climate in the region. We explain how dairy farmers perceive recent (post-2001) variations in the climate within which they operate. Meteorological observations are compared with participants' responses on how *they* perceive climate is changing. A second aim is to ask how farmers have adapted their material practices deriving from these perceptions, where information came from to make these decisions, and their perceived degree of success.

We conclude with a simplified framework for understanding agricultural adaptation to climate change in this industry.

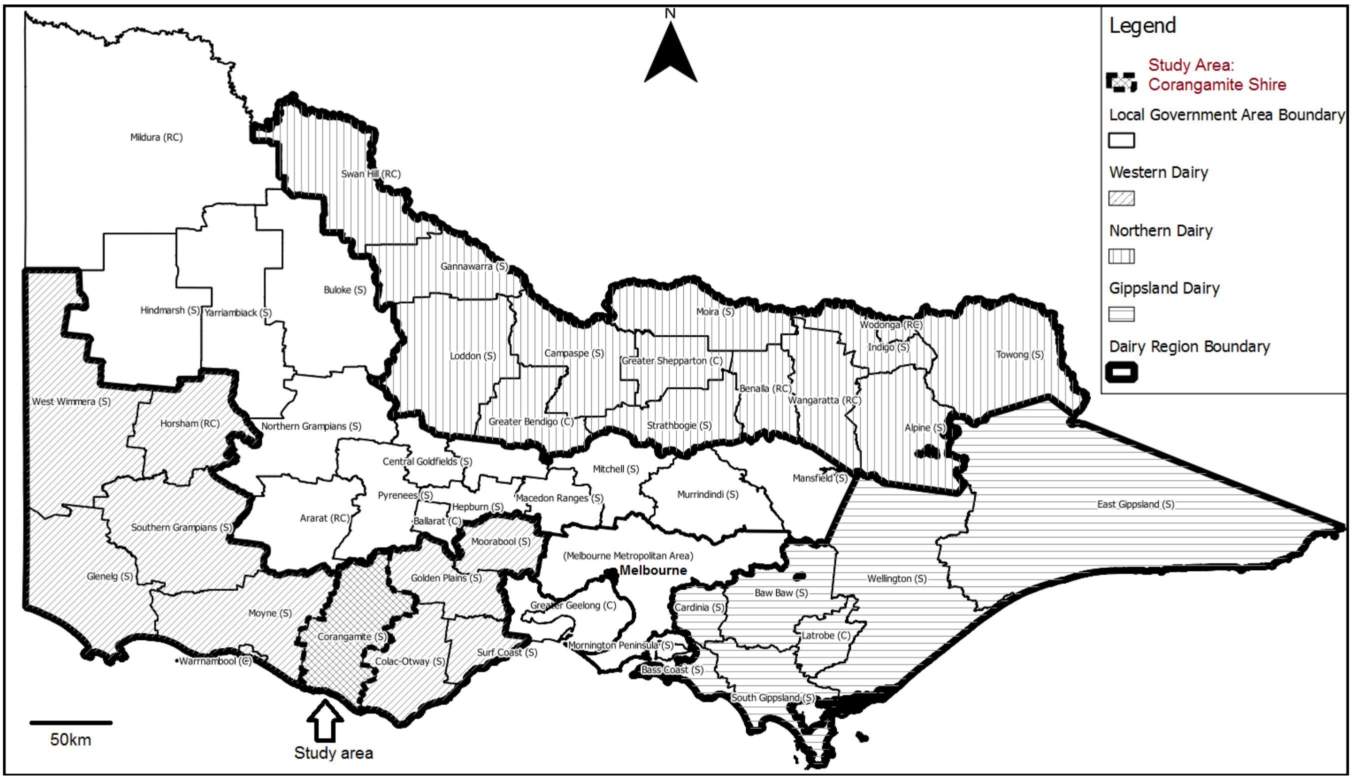


Figure 1: Victorian Dairy farming regions. Corangamite Shire is identified within the larger Western Victoria dairy region.

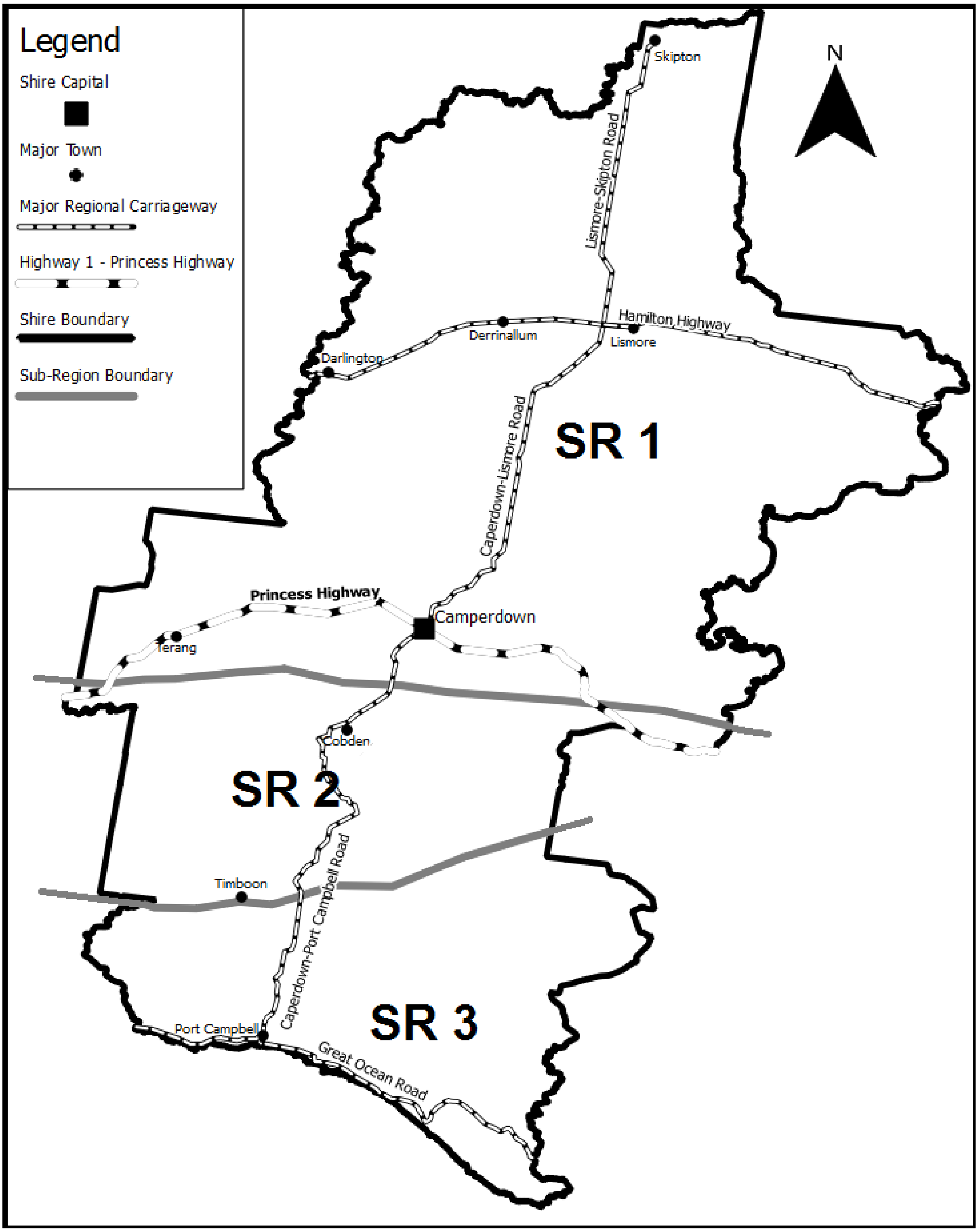


Figure 2: Corangamite Shire and the study's three sub-regions..

2. Climate change and variability in the region

The Australian agricultural sector has always had to adapt and adjust its practices to a harsh, highly variable and unforgiving climate (Stokes and Howden, 2011). There is current evidence that anthropogenic climate change is already impacting negatively on the agricultural sector, and a robust debate about future trends (Hughes, 2003; IPCC, 2007).

In south-west Victoria, Watterson et.al. (2007) expect a 1-1.5^{o}C temperature increase by 2070 and a 5-10% decline in annual precipitation. The Forest Fire Danger Index (FFDI), a function of weather patterns and vegetation condition, has already increased over the reference period from 1973-2007 at both stations in closest proximity to the Corangamite Shire: Melbourne (VIC) and Mount Gambier (SA). The expected number of FFDI days of very high and extreme danger is projected to increase under all emission scenarios produced for the years 2020 and 2050 at the Melbourne site (Hennessey et.al. 2005).

The region suffers periodic “agricultural drought”, most recently in the mid 2000s (BoM, 1967; CSIRO, 2007; Mpelasoka, et. al., 2008). Burke et.al. (2006), using the Palmer Drought Severity Index, suggests that whilst the incidence of drought did not increase in relative terms over the 1952-1998 period in south-west Victoria, there is a greater likelihood of drought incidence over the period 2000-2046, with a sharper increase thereafter. Projections by Mpelasoka et. al. (2008) suggest that under various climate models and under low emission scenarios the incidence of drought in south-west Victoria would remain steady or decrease, whilst under high emission scenarios drought would increase (by 0-20%) by 2030.

It is also expected that climate variability will increase in future (Hennessey et.al. 2008). The Rural Industries Research and Development Corporation (RIRDC) expects that Victoria will face some of the highest increases in seasonal variability in Australia, expected to present as increased incidence of drought and flood events (Barber, 2009).

Dairy Australia (2007), the national services and representative body for the dairy industry, list seven expected impacts that future expected climate change could have in the region. These are:

- Higher pasture growth in winter due to warmer temperatures and fewer frosts, but:

- Reduced pasture growth overall due to lower annual water availability[1]
- Earlier harvest and sowing times for summer crops due to earlier warmer temperatures
- Longer growing seasons that will favour perennial and/or drought tolerant pasture species
- Increased water stress due to declining precipitation which may in turn reduce water for dairy wash-down[2]
- Increased heat-stress for livestock due to warmer temperatures
- Higher temperature and lower rainfall to increase the competitiveness of C4 pasture species at the expense of C3 species.[3]

Combined, these impacts are expected to have a significant impact. Across Victoria, a 5% contraction in dairy production by 2030 is estimated (and 10% by 2050) in the event of no major adaptation actions being taken (Gunasekera et.al. 2007, based on models by Cline 2007).

4. How farmers adapt to climate change and variability

Climate stimuli vary significantly on a regional scale, but, also on a local scale across individual farms and landscapes (Bryant et.al. 1997). Adaptation to local conditions, therefore, are tailored, although our surveys demonstrate some commonalities. Variation can be explained by the intrinsic heterogeneity in managerial acumen, entrepreneurial capabilities, family circumstances, decision making styles, personal and community values and the strength of professional networks (Bryant et. al., 2000; Risbey et. al, 1999). Some farmers and their workforce are more aware than others of change, and thus more willing to progress alterations to dairying practices.

Risbey et. al. (1999) propose a ‘bottom-up’ method of investigating agricultural adaptation to climate variability and change, with a strong focus on farmer perception of climate variability and individual adaptation and decision-making. Their study is appealing, and has been taken up by other authors (Smit & Skinner 2002, Smit &

[1] The contradictory nature of these expected impacts reflects their uncertainty in climate predictions. The CSIRO (2007d) states that there is a -43 to +20% uncertainty range in run-off projection and a +/-8% uncertainty range in expected precipitation changes.
[2] Not all farmers only use surface run-off. Some have bores or town water to supplement it.
[3] C4 grasses have better water use efficiency, especially under warmer conditions, than C3 counterparts. C4 grasses are better adapted to drier conditions, however are not as nutritious as C3 species, nor can they support similar density of cows/hectare as C3 grasses.

Wandel 2006). They interrogate what adaptation decisions farmers have *actually* made in response to a changing climate. This is part of a long tradition of research in geography, anthropology and other disciplines based on fieldwork in farming systems, and monitoring of farmer behaviour in response to climatic and economic stimuli (Batterbury and Mortimore 2013; Mertz et. al., 2009; Mortimore, 1989, p. 4-6; Smit et. al., 2000).

Risbey et. al. (1999) suggest that whilst farmers are aware of macro-scale change, most on-farm decisions are made in response to micro-level changes like a decline in on-farm rainfall. [5] Short-term responses, like buying in extra water for livestock, are termed *tactical* responses. Longer term changes are *strategic*; resulting in an observable change in farm operation beyond a single season (Smit et. al. 1996).

WIDCORP (2009), Schwartz et. al. (2011) and Kiem et.al. (2010) investigated whether Victorian farmers perceive changes in the climate, and how they have implemented changes in their businesses. The latter study found farmers possess a great adaptive ability due to their innate inclination for experimentation, although the farmers deemed most financially and socially vulnerable were also the least likely to alter their production systems. Farmers were primarily focussed on economic adaptations to enable them to 'hold on', and the majority were not adapting their business to a future shaped by an increasingly changing climate, only considering the short-term (Hogan et.al. 2011). Victoria has recently experienced drought-to-flood conditions which have compounded difficulties for the sector (Rickards 2012) resulting in some strategic adaptations - altering crop varieties, or looking for more off-farm income sources. Ironically, effective adaptation to drought, which has included buying farmland in wetter regions as a form of security, was found to have reduced adaptive capacity to extreme wet periods that have occurred over the last five years.

A focus on individual adaptation strategies, the focus of our surveys, does not suggest that collective or cooperative adaptive actions are absent . In Corangamite,

[5] Macro-scale changes in this context include change to El Nino or La Nina conditions (as a result of change in the Southern oscillation index) or a drop in milk price (due to strengthening of the Australian Dollar).

farmers do cooperate, for example on stream fencing, but the region is dominated by private dairying concerns. Bryant et.al. (2000) suggest that farmers with weak social networks struggle to implement adaptations that require group co-operation (such as drainage schemes).

5. Research Methods and locations

Against this complex range of climatic factors affecting the dairying sector, we conducted a mixed-methods study in 2012, utilising a mail-out and online survey to 80 farmers in Corangamite Shire, supplemented with 10 semi structured interviews. Participants were selected based upon the criteria of location, age, and herd size. All were reliant on dairying for more than 90% of their income. The survey questions, first piloted and refined, were divided into five themes: demographics, perceptions, management practices, climate change and the role of government, adapted from Risbey et. al. (1999). Interviews followed the same five themes. The majority of interviews (80%) were conducted with both heads of households.

We compared the sample with Australian Bureau of Statistics (ABS) data on dairy farming in Corangamite Shire (ABS, 2008) and a recent Dairying for Tomorrow survey of current dairy farming practices[7]. Three sub-regions of the Shire were defined (SR1, SR2, SR3), based upon average annual rainfall isohyets (figure 2). Results were tabulated using descriptive statistics and adaptation strategies were classified and compared to the literature.

Northern reaches of the Shire (SR1) are drier than those in the far south east (SR3), whilst average temperature is fairly similar across the Shire. Almost all dairying is concentrated in the wetter regions to the south of the main transport artery the Princes Highway, which dissects SR1. Pasture yields vary from approximately 15 t dry matter per hectare per year in the Otway (SR3), to about 6 t DM/ha/y in the north of SR1. Modelling by research teams suggests the prevalent ryegrass pasture can sustain temperature increases of up to 2^{o}C warming with adequate productivity (Cullen et al 2012)

[7] The 'Dairying for Tomorrow' survey was conducted on behalf of Dairy Australia (2012) on all major Australian dairy regions, one of which is West Vic Dairy.

In line with an aging demographic running dairy farms in rural Victoria, over a third of the survey and interview participants have spent more than 25 years on their current farm, with over 60% having resided at least a decade (Table 1). Almost 75% of survey respondents have been dairy farmers for over 25 years and despite the presence of multi-generational dairy households there is significant purchase and sale of agricultural land in the Shire, reflecting the changing fortunes of the sector and the intentions of its participants. A farm herd size of between 200 and 499 cows was the most common (slightly above the national average; Nettle and Lamb 2010). Very few participants ran herds larger or smaller than this. Milk is sold to several major dairy companies, and then prepared and packaged by the dairy.

Time on current property (years)	**Survey Sample (% by time on farm)**	**SR1 (%)**	**SR2 (%)**	**SR3 (%)**	**Interview Sample (%)**
0-5	4	-	6	-	-
5-10	9	25	6	3	-
10-20	13	31	3	17	20
20-40	50	31	52	60	70
40+	24	13	33	20	10
Total surveys (+interviews) . 5 more had unknown postcodes.		14(+4)	31(+4)	30(+2)	

Table 1: Time on current property; distribution of survey and interview respondents. Source: 2012 Corangamite Shire Dairy Farmers Survey.

Climatic data, reported here in summary form, included monthly temperature and rainfall data, aggregated into annual and seasonal datasets and then graphed as 10 and 30 year moving averages[8]. Other environmental data, including a heat stress index, was collected but is not reported in this article.

6. Results and discussion

We first explore the links between farmer perceptions of changing seasonal conditions, compared to the meteorological record. The second sub-section will

[8] As used by the Bureau of Meteorology, see: http://www.bom.gov.au/climate/cdo/about/about-stats.shtml

establish how farmers are actually adjusting their businesses to their perceptions of climate variability and change.

Assessing farmer's perceptions of climate variability and change

How farmers perceive a change in signal, in this case climate stimuli, plays a significant role in how they may then adjust their farming to adapt to this change (Risbey et. al., 1999). Some 36% of farmers surveyed perceived a change in rainfall over the past decade. Conversely 38% stated that they had not noticed a change, with the remainder undecided on the issue (Figure 3). Across the three sub-regions, SR2 respondents showed the best detection of changing rainfall patterns (52% of those surveyed), followed closely by SR1 (43%). Only 30% of SR3 respondents, living in the wettest region, thought that it had become drier over the last 10 years. According to two SR3 farmers:

> **Interviewer:** In your time on this property, 10 years, have you noticed changes in rainfall?
> **Respondent IC6:** I think we've seen a cycle, a series of wet years, a series of dry years and now a series of wet years again. We haven't seen too many extremes, nothing outside of normal.
>
> **Interviewer:** Have you noticed any change in rainfall pattern…as opposed to natural variation?
> **IC4:** I don't consider anything to be out of the ordinary…we're just in a good rainfall area.

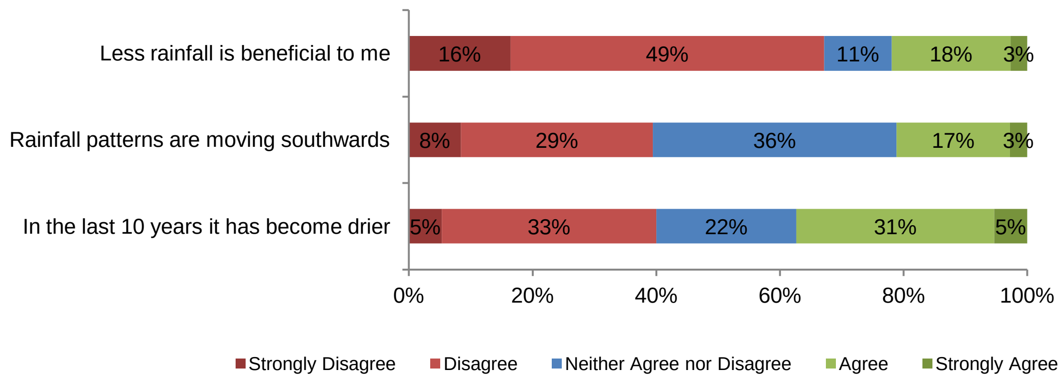


Figure 3: Rainfall signal detection and evaluation for whole survey sample. Source: 2012 Corangamite Shire Dairy Farmers Survey.

This can be compared against those in the drier northern regions who were more inclined to notice a change:

> **Interviewer:** Have you noticed much change in the rainfall patterns?
> **IC5:** Yes. In the last 10 years we've had a heap of failed autumns. Autumn has become a disaster, it never used to be, you could bank on autumn. Now it is just hot and dry. My first 10 years it was never like that…It just stays dry, Autumn is a nice time of the year, but you can't farm off no moisture. We've had two good ones in 12 years.

The meteorological record indicates decreasing rainfall, with 10 of the 14 rain stations showing a fall in the 30-year average annual rainfall since 2001 (Figures 4 and 5, which distinguish between northern drier and southern wetter locations). Of these 10 stations (Figure 6), 8 also displayed a rainfall total wholly below the long-term average over the past decade, with six of these by greater than one standard deviation below the mean. The stations that fall in the northern half of the shire and in SR1 have displayed a lower degree of variation from the mean over the past decade (Figure 5). All bar one station show a negative rainfall trend over the past decade, linked particularly to declining autumn rainfall (the date shows a significant drop in autum rainfall totals since 1991). In the SR2 and SR3 stations a decline in spring and winter rainfall has occurred.

Coupled with the fact that the northern regions have lower net rainfall than the south, it comes as no surprise that SR1 respondents perceived a drop in rainfall over time (Figure 7). In SR2, where rainfall declined by less than in SR1, fewer respondents thought that rainfall patterns were moving southwards and thus becoming drier . Farmers' perceptions in SR1 (and SR2) appear to be in accordance with the meteorological data. But in SR3, where rainfall is much higher, the majority of farmers were unable to detect the fall in average rainfall in recent years. Mortimore (1989, p. 50) suggests that under similar drought conditions in Africa, farmers in relatively more marginal regions have a greater need to react to changes compared to those in less variable ones, even if the losses incurred across both regions are proportionally similar.

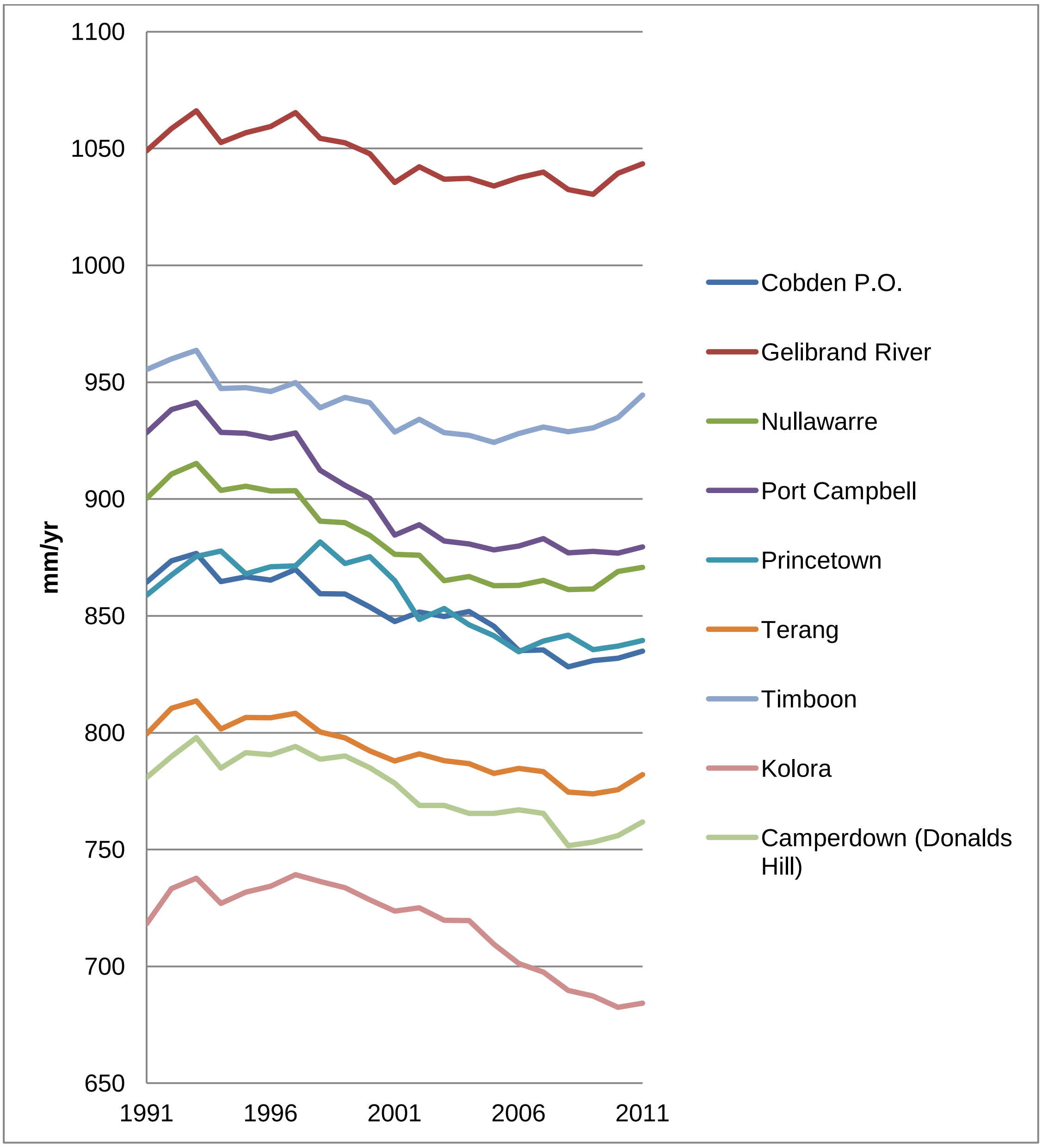


Figure 4: 30-year averaged annual rainfall from southern Corangamite Shire (SR3) recording stations from period 1991-2011. Y-axis units: millimetres (mm). Source:BoM (2012)

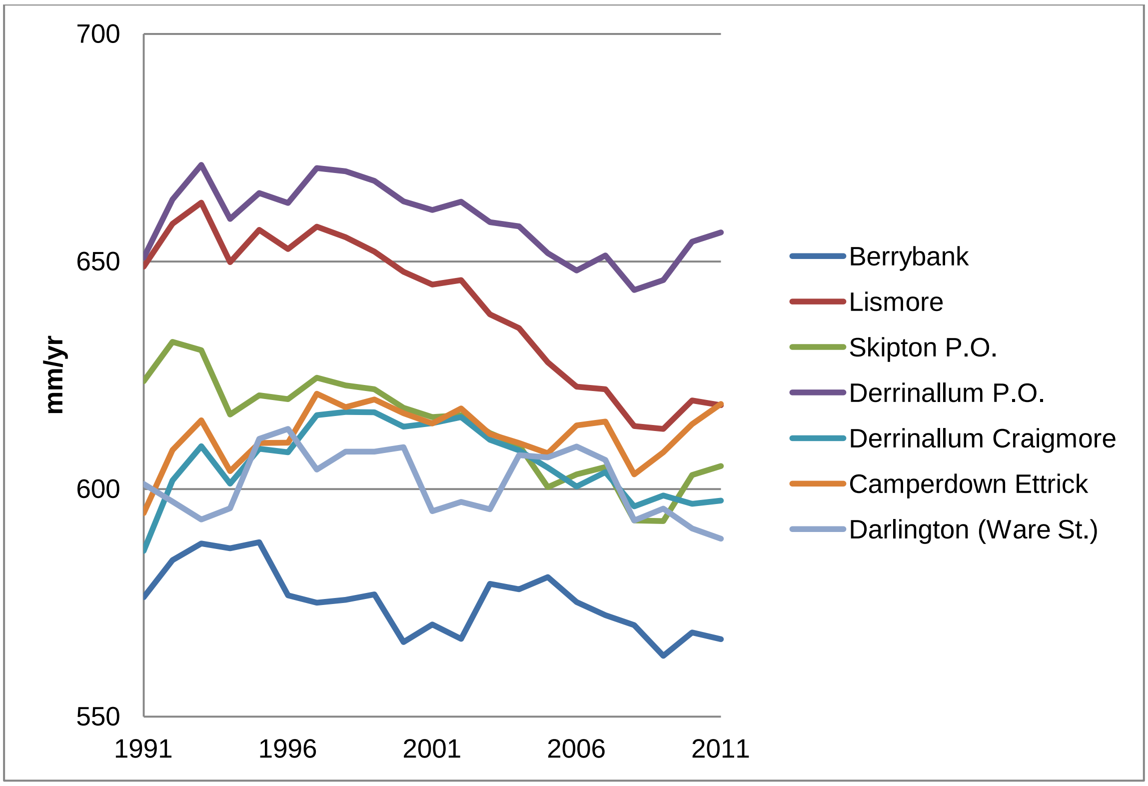


Figure 5: 30-year averaged annual rainfall from northern Corangamite Shire (SR 1) recording stations from period 1991-2011. Y-axis units: millimetres (mm**).** Source: BoM (2012)

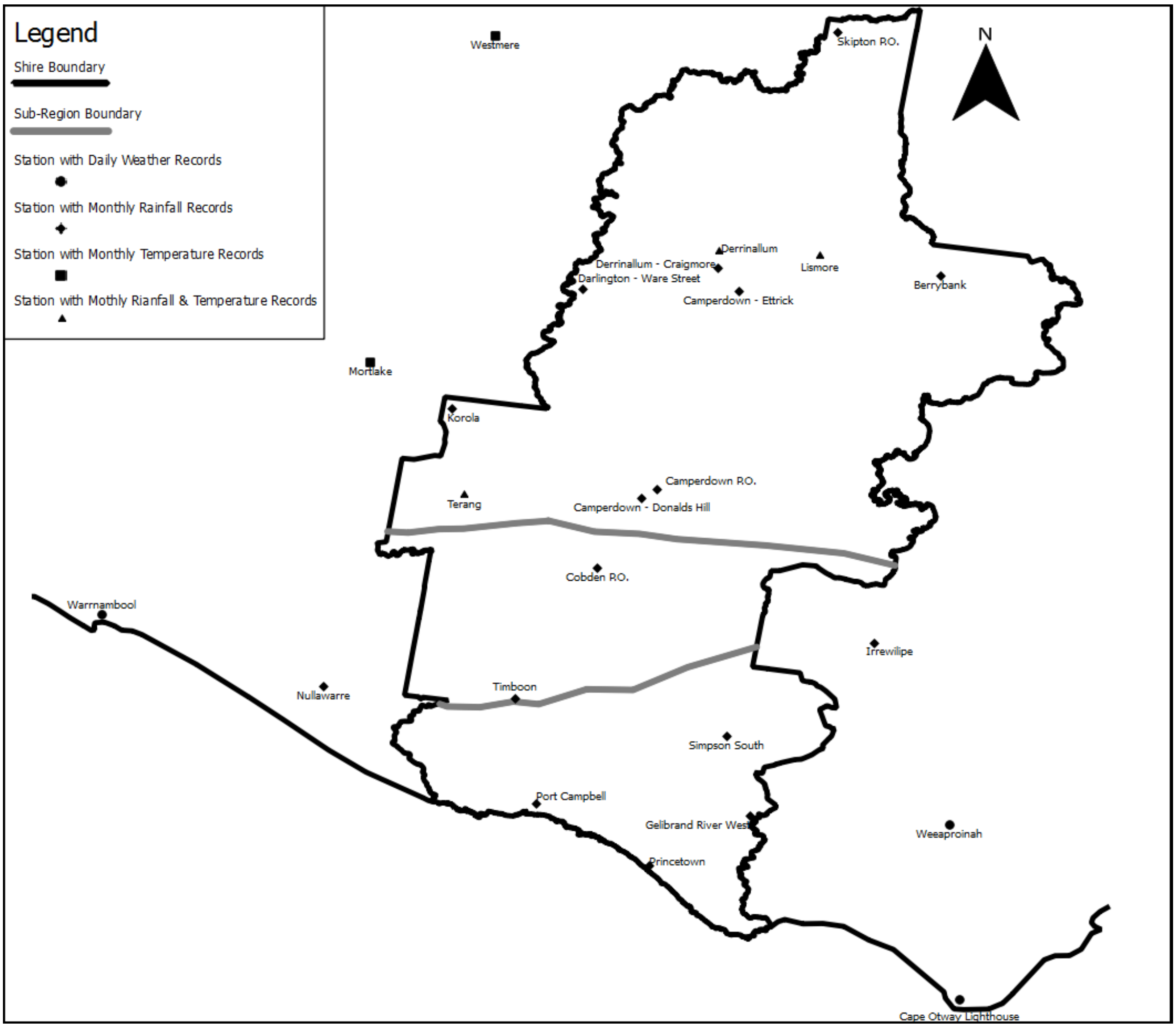


Figure 6. Location of raingauge stations shown in Figures 5 and 6.

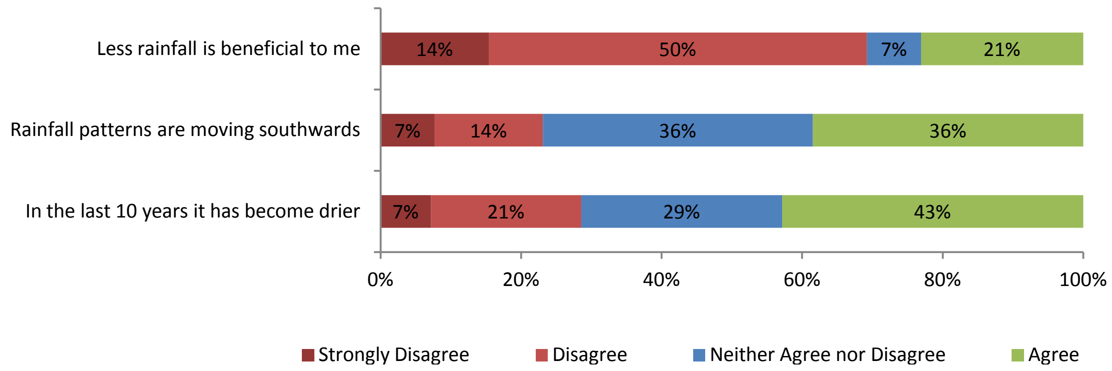


Figure 7: Rainfall signal detection and evaluation for sub-region 1. Source: 2012 Corangamite Shire Dairy Farmers Survey.

Turning to termerature, mean annual maximum and mean annual minimum temperature in Corangamite Shire increased between 1891-2011, with the difference between maximum and minimum growing over time (Figures 8, 9, showing combined datasets). Over this period maximum temperature has risen by a little over one degree.

Farmer perceptions of these temperature changes were not always accurate (Figure 10). Approximately 40% of all respondents across the Shire stated that temperature patterns have not changed in the past decade, whilst 29% correctly stated that they have increased (Figure 6). Those in the north were more inclined to state the change than their southern counterparts. Of interest are the 89% of respondents who believed that were temperatures to increase, this would be negative for their operations. In fact farmers struggled to perceive if temperature has increased in all regions:

> **Interviewer:** Have you noticed any change in temperature patterns?
> **IC5:** Hard to say if it is getting hotter, I don't know about that.
> **Interviewer:** As far as temperatures go, have you seen at all any changes?
> **IC1:** No, no, it has been cold in July for the last 35 years.
>
> **Interviewer:** Have you noticed any change in [temperature] patterns?
> **IC2:** I think climate change is taking place basically over 100 years or more, so it is very hard for me to pick it up from just normal variation in the seasons.

Farmers are finding it difficult to differentiate between change in the signal (increasing temperature) and noise (temperature variation). This is expected, as temperatures have risen by only a small amount over the past 25 years.

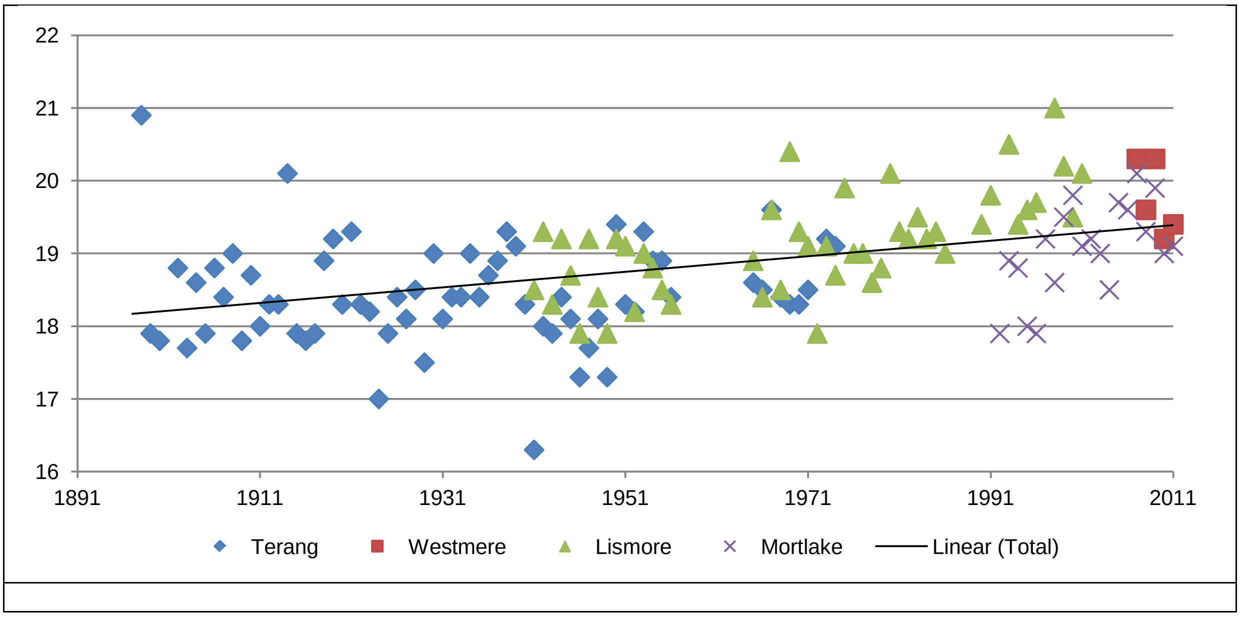


Figure 8: Mean annual maximum temperature 1891-2011 from four different points in Corangamite Shire. Y-axis units : ^{o}C. BoM (2012)

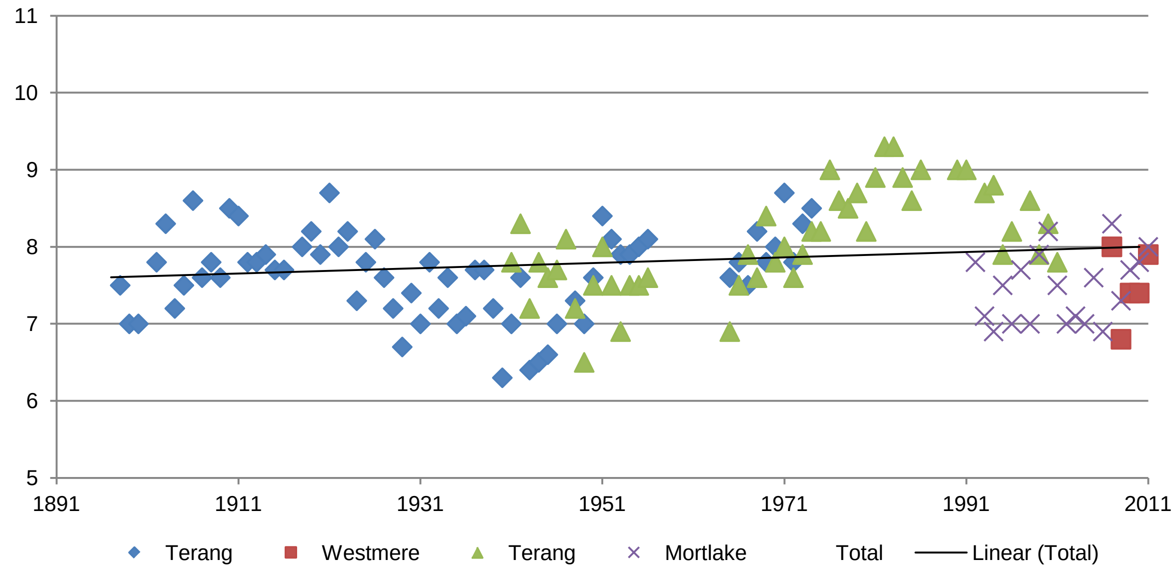


Figure 9: Mean annual minimum temperature 1891-2011 from four different points in Corangamite Shire. Y-axis units: ^{o}C. BoM (2012)

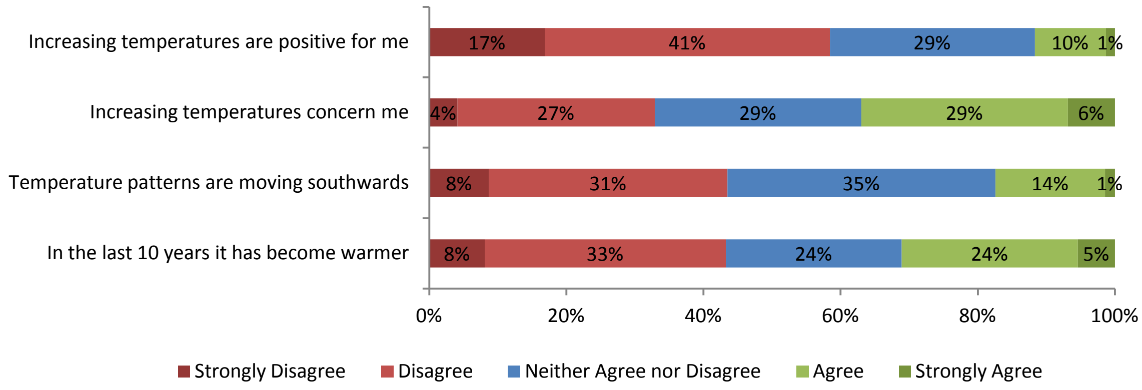


Figure 10 : Temperature signal detection and evaluation for whole survey sample. Source: 2012 Corangamite Shire Dairy Farmers Survey.

Some 20% of individuals agreed that fire risk and the incidence of drought had increased over the past 10 years, whilst 31% said that extreme weather events have become more frequent since 2001 (Figure 11). The most northern region (SR1) had the greatest proportion of respondents who detected an increase in the incidence of extreme weather events, followed by the central SR2 and the southerly SR3.

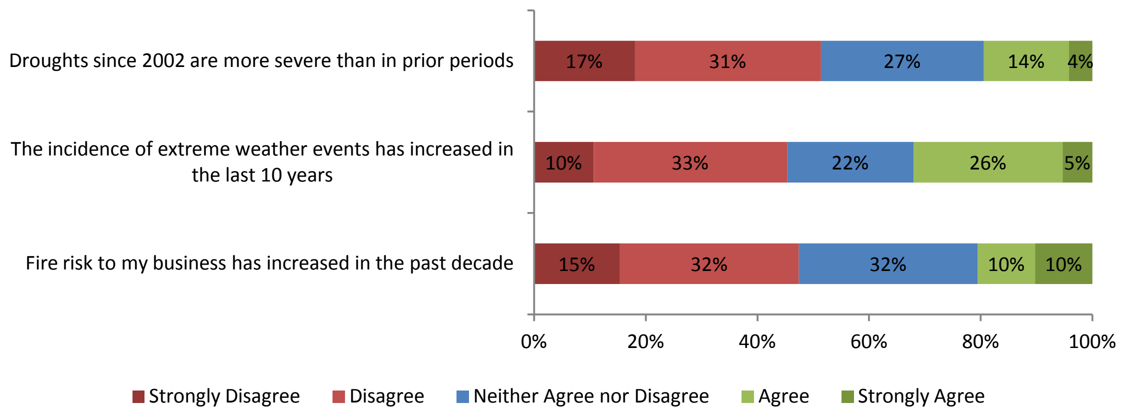
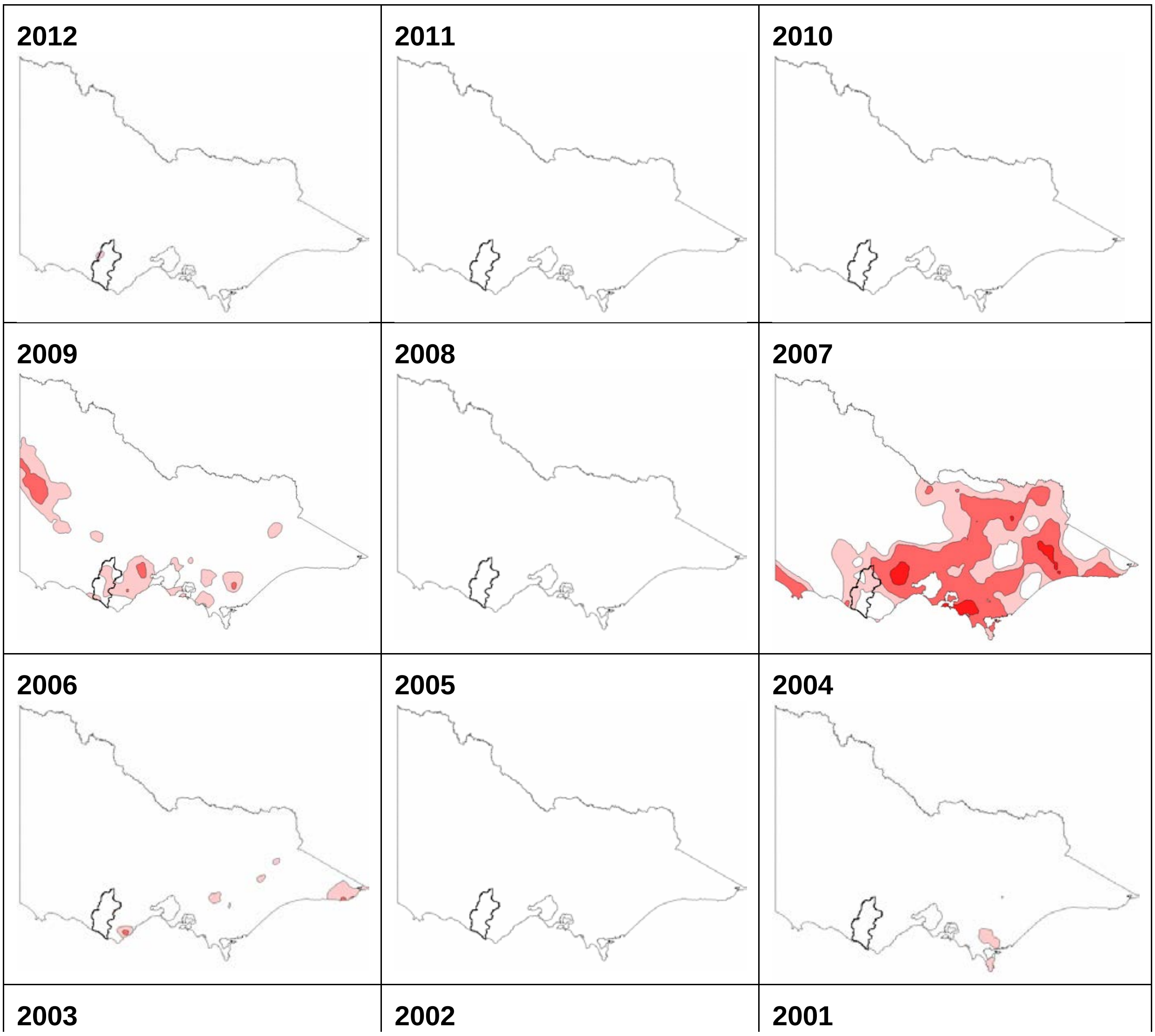


Figure 11: Extreme weather signal detection for whole survey sample. Source: 2012 Corangamite Shire Dairy Farmers Survey

The drought that affected much of eastern Australia through the early to late 2000s was particularly hard for farming families. Corangamite Shire was not as badly affected as some northern regions of Victoria (Figure 12). Eastern Victoria escaped the worst of the effects of a crippling 2003 drought (ABC 2002) but in 2007 and

2009 the dairy farming region recorded a serious deficiency in rainfall affecting livestock and pasture. The dates of serious droughts in Victoria since 1900 are shown in Table 2. The perception is that drought management strategies have improved significantly over the past 50 years, reducing farmers' vulnerability. This was supported by farmer IC7 in SR1, who had farmed through the droughts of the 1960s until the present:

> IC7: I saw the 1970's [as being] very wet, I haven't seen anything as wet as that since…I don't think that there is anything new in droughts, there are fences through all the dried up lakes. I remember the drought of '68, I haven't seen anything as dry as that since. But we can shift fodder now to here for a cost…you couldn't do that in '68…we're better at drought management now.



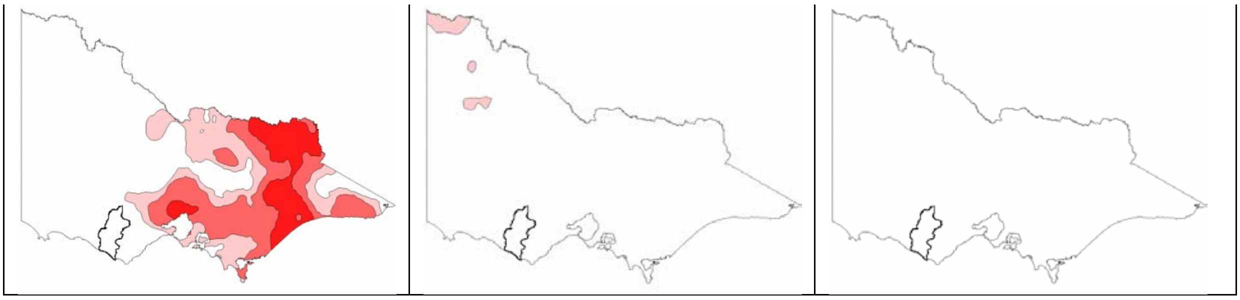


Figure 12: Incidence of 1 October to 31 March drought in Victoria, 2001-2012 (BoM, 2012). Corangamite Shire is illustrated by black outline in south-west. Pink: serious deficiency in rainfall (less than 10th percentile). Light red: severe deficiency in rainfall (less than 5th percentile). Solid red: lowest rainfall on record.

Serious rainfall deficiency	Severe rainfall deficiency	Lowest rainfall on record
1997, 1983, 1982, 1964, 1951, 1943, 1934, 1922, 1909, 1901	1985, 1968, 1944, 1942, 1936, 1921, 1920, 1915, 1912	1939, 1926

Table 2: Years when there was a 1 October to 31 March drought in Corangamite Shire from 1900-2000, by category (BoM, 2012). Serious and Severe deficiency are equivalent to less than 10th and 5th percentile rainfall respectively.

Younger farmers were more inclined to perceive a change in temperature and rainfall patterns in accord with rainfall data, and similar findings have been noticed in other locations (Diggs, 1991; Leviston et. al. 2011; Nyanga et. al., 2011). Those with smaller holdings had more accurate perception of a change in temperature: perhaps because they need to be more 'in-tune' with seasonal shifts to ensure optimal pasture production at minimal cost (Nyanga et. al., 2011). For them, buying in fodder in the event of failed pastures could negate any profit.

Assessing farmers' adaptations to climate change and variability

A major challenge for all research on climate adaptation is differentiating between adjustments implemented by farmers in response to changing seasonal variability or climate variability, and adjustments implemented to adapt to other drivers of change. Of course the latter adjustments may, as a by-product, increase the resilience of the farm to seasonal variability (Belliveau et. al., 2006). This difference is illustrated by two farmers, IC5 and IC6 - both changed their pasture mix from annual to perennial species over the past decade. In IC5's case this was to increase the farm's resilience to seasonal rainfall variability, whilst for IC6 it was due to the increasing cost of buying grain and feed supplements:[9]

> **Researcher:** Do you see your new pasture regime as being more resilient to weather variability?
> **IC5:** Yes, definitely, and we are counting that into [why we changed], we haven't got everything right...but we have learnt a lot on what pastures do best here…and the last 8 months have been the driest on record here…

> **Researcher:** With regards to pasture growth and pasture management, have you had to change what pasture you grow or the type of pastures you grow?
> **IC6:** We try and stay up to date with the pastures…they bring out new species all the time. We try and use them…we can grow more grass, and cut back on the grain bill, because the price has gone up.

Farmers were questioned on what adjustments they have made to their dairy business over the past decade In total, 23 adjustment options were documented over three categories. To overcome the difficulty in distinguishing the reasons behind these, all adjustment scenarios presented in a survey checklist were those that had been previously suggested by industry peak bodies, the Victorian DPI, other Australian state bodies, and in the literature.[10]

Almost all (94%) of farmers surveyed stated that they had made a physical adjustment to their business in the past decade. Some 79% implemented new practices (Fig and table) , 86% altered an existing practice (Fig and table) .The most common new action taken was the use of seasonal forecasting technology as an aid for what pastures to sow, and when to sow them (Figure 14). This was particularly visible among SR2 farmers (Table 3). These findings are in line with other surveys conducted in Victoria by WIDCORP (2008) and Schwartz et. al. (2011). There were

[9] As all feed for cattle may not be sourced all year-round from on-farm pastures, farmers often used feed supplements, such as grain, to make up a shortfall in feed and to provide cows with an incentive to come to the milking shed.
[10] Increasing temperature, reduced rainfall (primarily autumn), increasing incidence of days of high potential heat stress.

also notable changes in the pasture species grown on-farm, and in the adoption of more sustainable water use practices.

Changing pasture mix (in terms of species and varieties) was the second most common adjustment, and was often aided by agricultural extension advice. The decision by farmers to alter their pasture species mix is an adaptive adjustment to reduced rainfall and increased temperatures and the northern farmers led this change (Table 3).

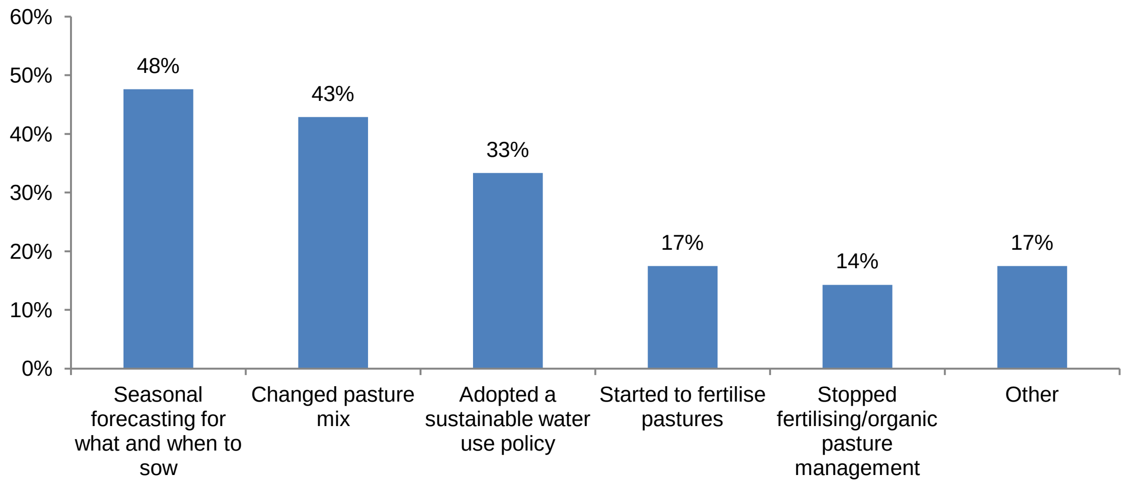


Figure 14: *New* management practices implemented by survey sample. Source: 2012 Corangamite Shire Dairy Farmers Survey.

Region / *Proportion of sample (%)*	**Sub-region 1**	**Sub-region 2**	**Sub-region 3**
Seasonal forecasting for what and when to sow	42	52	44
Changed pasture species mix	50	43	36
Adopted a sustainable water use policy	33	33	36
Started to fertilise pastures	33	24	8
Stopped fertilising/organic pasture management	17	10	16
Other	25	19	16

Table 3: *New* management practices implemented, by those who implemented new management practices over the last 10 years, Separated by sub-region. Source: 2012 Corangamite Shire Dairy Farmers Survey, Q3.1.

Figure 15 shows greater detail on the adjustments made by a subset of the sample who self-identified as altering their existing practices. Improving the efficiency of water used in the twice-daily 'wash-down' of the dairy is important since between 5,000 and 25,000 litres is used per wash, taking 1 to 2 hours per day (Dairy Research and Development Corporation, 2003). Some respondents, not really distinguished by zone, have installed new reticulating effluent ponds, using the sediment as nutrient rich irrigation water for pasture. Such a strategy was implemented by IC2 to increase the fertiliser load on nutrient poor sandy fields and resulted in an increase in pasture growth:

> **Interviewer:** Would you reticulate [the effluent run-off] through an irrigation system?
> **IC2:** Yeah, we actually have, because we are fairly high on the farm, we have a manure pond at the highest point of the farm. The back of the farm is more sandy, and needs extra fertiliser, and we use those areas for irrigation for effluent.

IC2 constructed an effluent water recycling system on economic grounds:

> **Interviewer:** And has this [effluent water recycling system] been a beneficial change for your property?
> **IC2:** Definitely. We have a reduce reliance on fertiliser, and buying fertiliser, the growth in those paddocks has improved substantially, so we don't have to buy in as much fertiliser and we do find that some of those paddocks they take off earlier in the autumn, so in a way we don't start that far behind.
> **Interviewer:** So this is more of an economic decision?
> **IC2:** Yes.

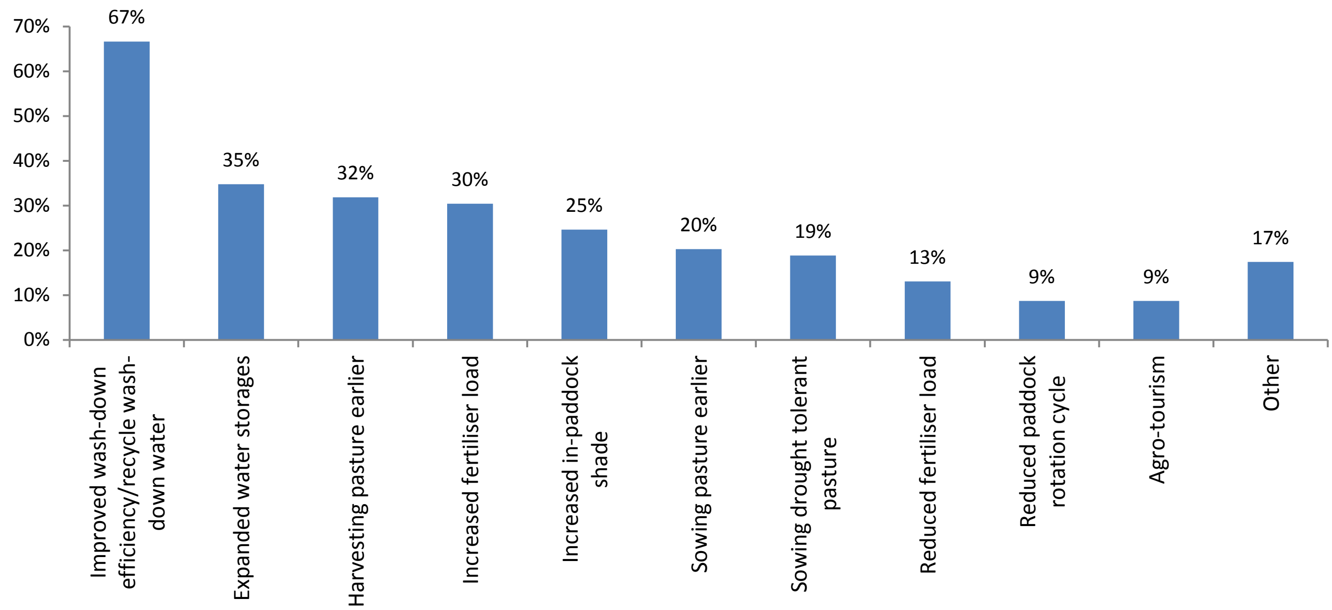


Figure 15: Changes implemented in *existing* management practices by subset of survey sample who changed their management practices. Source: 2012 Corangamite Shire Dairy Farmers Survey.

Region / *Proportion of sample (%)*	**Sub-region 1**	**Sub-region 2**	**Sub-region 3**
Improved wash-down efficiency/recycle wash-down water	69	67	67
Expanded water storages	46	33	33
Harvesting pasture earlier	31	41	25
Increased fertiliser load	31	41	21
Increased in-paddock shade	15	33	25
Sowing pasture earlier	15	30	8
Sowing drought tolerant pasture	15	30	13
Reduced fertiliser load	0	19	13
Reduced paddock rotation cycle	8	4	13
Agro-tourism	8	7	4
Other	31	19	13

Table 4: Changes implemented in existing management practices by those who changed management practices. Source: 2012 Corangamite Shire Dairy Farmers Survey; Q3.2.

The northern and drier sub-region was the most likely to expand water storages, in line with their increased perception of a decline in rainfall over the past decade (Table 4). The majority (80%) of farmers who did this were aged between 35 and 54. Such an outcome is expected due to the very high capital outlay required:[11]

[11] High capital cost means that farmers want to see a long term return on investment. At 35, farmers can have 30 years to get the return on investment, but at 65 this is unlikely.

Interviewer: Have you had to bolster your water storages?

IC7: We put in a couple of good sized dams for water storage, and we have probably utilised the ones we had more than previous managers. We have a bigger supply of water now than we previously had.

The adjustments nominated by participants *have* adapted businesses to expected future climate scenarios, but it is clear that these decisions are being made as a reactionary response primarily to fluctuation in economic, not climatic stimuli (Smit et. al., 2000) (Figure 16). For example: reduced profit occurs if milk production declines. Milk production has itself declined due to poor pasture production. Pasture production is poor due to seasonal conditions outside of the current pastures' optimal growing conditions. To increase milk production the farmer alters the pasture species, the altered pasture species produced more nutritional value under current seasonal conditions, higher quality pasture raises milk production, and higher milk production increases profit. The farmer is most likely to state that a *change in pasture mix* was implemented, with the reason behind this being because it *made good financial sense*, however the underlying reason for this change was in part a variation in climate. Inherent farmer scepticism in the region towards environmentalist claims about global warming and its political ramifications could account for this; however in the drier SR1 there was more recognition of climate variability (Figure 16).

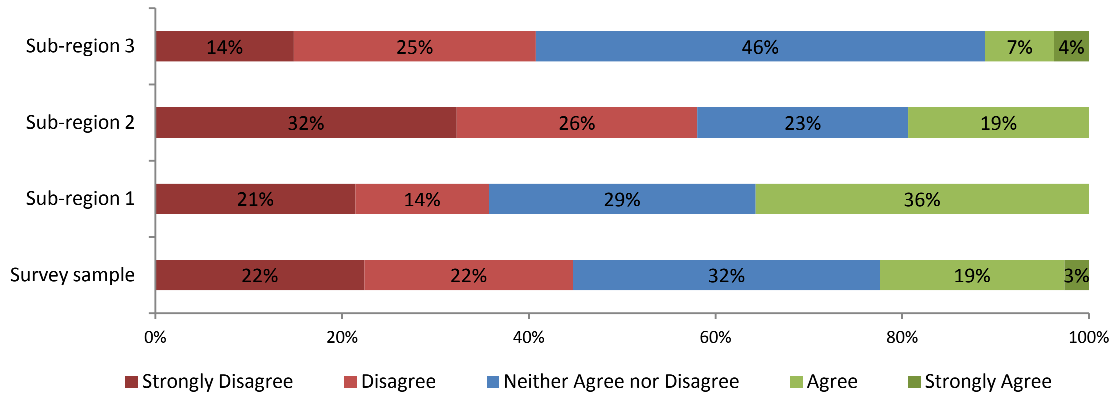


Figure 16: The degree to which changing seasonal variability is noted as a factor in changing farming practices, by those who made a change to their practices. Source: 2012 Corangamite Shire Dairy Farmers Survey.

)

Respondents IC5 in SR1 shifted their pasture management from a monoculture to a mix of pasture varieties across their farm. This adjustment reduced costs and improved herd health. However IC5 also noticed a change in the seasonal variability:

> **Interviewer:** Have you noticed any change in the weather patterns?
> **IC5:** Less reliable, more fluctuation. Hard to say if it is getting hotter, I don't know about that. But we've had really dry, really hot, really wet, really cold, really windy. It is more all over the place.
> **Interviewer:** Is that something which has become worse in your experience?
> **IC5:** In the last 10 years we have had a lot of failed autumns, autumn is a disaster…in my first 10 to 15 years it wasn't like that.

The adjustment was implemented as a response to the economic stimuli of the increasing cost of fertiliser. But utility per unit of water has increased, thereby adapting to the expected future climate scenario. Again, a business decision can have adaptive benefits. The rainfall data for the region certainly confirms a decline in autumn rainfall in SR1.

Smit and Skinner (2002) posit that adaptation is seldom made in response to single factors, and that the decision to adjust a business is usually iterative and dynamic. This is supported by this study. The nature of experimentation and iterative response to climate variability needs to figure more in studies that link perceptions of climate to climate adaptation (Batterbury and Mortimore 2013; WIDCORP, 2009). In response to a survey question on 'how was [adjustment X] informed?', there is evidence of shared discussion and efforts**;**

> **IC1:** Just word of mouth and observing the demo dairy and reading magazines that comes out from [my milk collection co-operative].

> **IC2**: We're in a discussion group, so we actually are in a group with a whole lot of other famers and we rotate visiting farms and quite often we have new things that they have tried out, or recommendations.

> **IC3:** I am in a local discussion group, and that information [was] readily available.

The two predominant reasons for why a change was *not* implemented were; financial limitations, and a perception that the farm was already in good working order. Financial restrictions and access to capital have played a major part in curtailing farm adjustments in Australia (WIDCORP, 2009) and internationally (Iglesias et. al., 2007; Dyszynski, 2010; Maddison, 2007; Nyanga et. al., 2009; World Bank, 2007, p. 200). The majority of the farmers who did not change their farming approach were in the 35-44 age bracket, were farm owners, and less likely than the average to perceive climate change as a threat. Hogan et. al. (2011) categorise similar farmers in Australia as ‘comfortable non-adaptors’, farmers who did not see climate change as a threat, could continue to cope with changes, and were unlikely to seek information about adjustment options. Farmers who stated that their farm worked fine and that there was no need to adapt, may be categorised in this way. Nettle and Lamb (2010) reinforce the fact that Victorian dairy farmers hold varying worldviews in relation to environmental threats and their stewardship obligations.

The final step in our study was the gathering of retrospective feedback from farmers who have made an adjustment to their business, to see if the adaptations implemented have been effective (Risbey et. al., 1999). There was a general consensus that change has increased profits, increased efficiency and was of benefit to their businesses. And yet, a low proportion of the sample population deemed changing seasonal variability to be major factor in altering their business. Fortunately following Risbey et. al. (1999) it would be expected that the majority of farmers who adjusted their business over the past decade will have added the adaptation strategy that they implemented into their future repertoire. It is to be expected that these strategies will play a part in future adaptation to changing seasonal variability and climate change, even if adaptation to climate variability is less conscious than to financial viability (Figure 17).

We are in agreement with anthropologist Paul Richards (2010) who says, following Durkheim, that "much of what farmers and farm labourers do (as opposed to what science or regulatory authority tells them to do) is based on practical contingencies… or it relates to unavoidable social responsibilities to dependants or a wider community group." (Richards, 2010, p. 10). The practical contingencies for dairying households include making a living, and so this structures perception of, and responses to, climate variability (Figure 17). In drier regions, the struggle is more acute, and awareness of climate variability is greater.

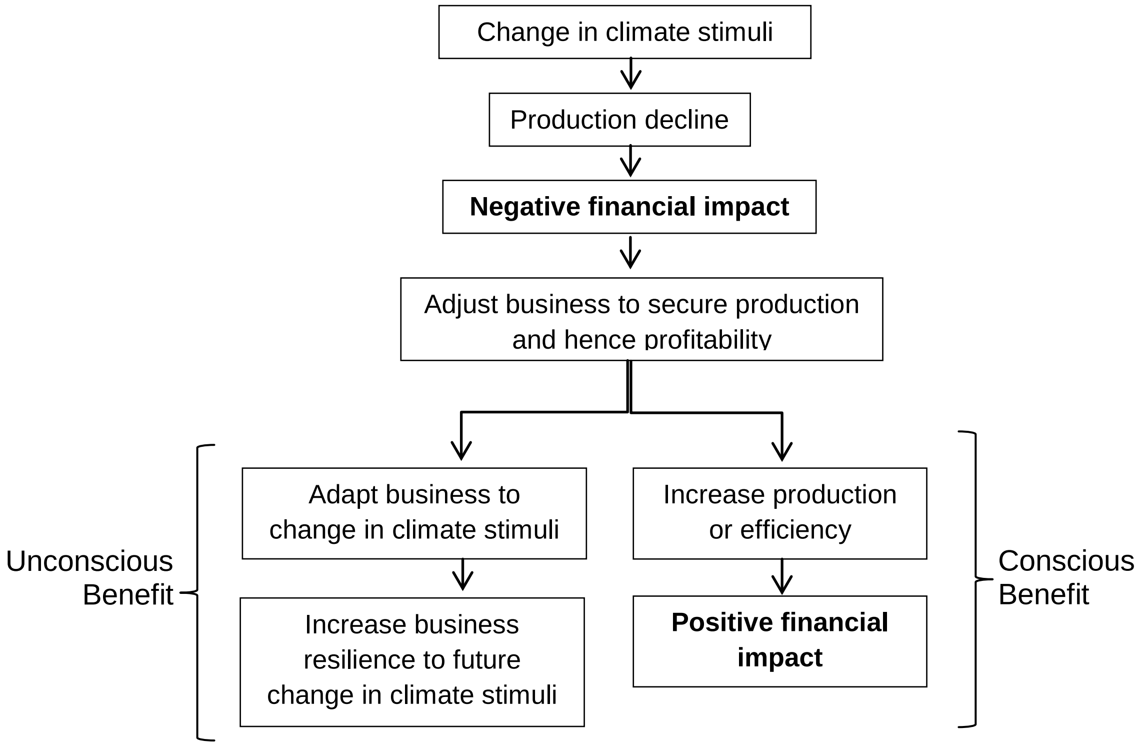


Figure 17: Agricultural adaptation to climate change occurring as a result of adaptation to economic stimuli.

7. Conclusions

Corangamite Shire dairy farmers' perceptions of seasonal variability were found to be broadly in line within the meteorological record. Northern (dry) region farmers were more able to correctly perceive a change in rainfall signal, and were more inclined to state that temperatures have changed, in comparison to their southern region (wetter) counterparts. Farmers struggled to perceive a change in the incidence of extreme weather events. Younger farmers were more likely to perceive a change in temperature and rainfall over the last decade. Those with smaller holdings were more inclined to notice a change in temperature than major landholders. Hypothetically, these farmers must maximise pasture growth at minimal cost, and should pastures fail their smaller profit margins and inability to mitigate climate risk can result in a more immediate and unsustainable loss of income.

The majority of farmers in the survey stated that they have made an adjustment to their business over the past decade; a lesser percentage had initiated entirely new practices like purchasing weather forecasts. Although farmers were aware of changes in climate variability, the majority stated that economic stimuli were the underlying reason for the changes they implemented on-farm. The majority did not make a *strategic* decision to adjust to changing climate variability, however the *tactical* actions they carried out could be effective against it. Consequently many of those dairy farmers in Corangamite Shire surveyed have adapted their businesses to climate variability as a result of their adaptation to economic stimuli.

Farmers in our survey acted in accordance with their perceptions of climate variability and change. Although adjustment is occurring in line with their perceptions, economic stimuli played the dominant role in influencing adaptive behaviour. The major, conservative adjustment identified was water recycling and re-use in the dairy. A greater connection still needs to be made between climate variability, climate change, and the real long-term economics of dairying.

References

ABC (2002), *Farmers face worst drought in 100 years*. Australian Broadcasting Corporation. Available at: http://www.abc.net.au/7.30/content/2002/s720415.htm

ABS (2008), Dairy farming key statistics by LGA. Prepared by The Workplace Research Centre for Dairy Australia. Australian Bureau of Statistics. Available at: http://www.censusdata.abs.gov.au

ABS (2011), Corangamite (S) (Local Government Area) People. Australian Bureau of Statistics. Available at: http://www.censusdata.abs.gov.au

Batterbury, S.P.J. and Mortimore, M.J. (2013), "Adapting to drought in the West African Sahel". In *S*. Boulter, J. Palutikof, D. Karoly, and D. Guitart (Eds) *Natural Disasters and Adaptation to Climate Change*. Cambridge University Press, Cambridge.

Belliveau, S., Bradshaw, B., Smit, B., Ried, S., Ramsey, D., Tarlton, M., and B. Sawyer. (2006), "Farm-level adaptation to multiple risks: climate change and other concerns". *Department of Geography Occasional paper No. 27.* University of Guelph, Canada.

BoM (1967), "Rainfall deciles as Drought Indicators", *Bulletin No. 48*. Bureau of Meteorology, Melbourne, VIC.

BoM, (2012), *Climate Data Online*. Bureau of Meteorology, Melbourne. http://www.bom.gov.au/climate/data/ Accessed July 1, 2012.

Bradshaw, B., Dolan, H., Smit, B. (2004), "Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies".*Climatic Change*, 67: 119-141.

Bryant, C.R., Singh, B., Thomassin, P., Laurie, B. (1997), "Vulnérabilités et adaptation aux changements climatiques au Québec au niveau de la ferme: leçons tirées de la gestion du risque et de l'adaptation à la variabilité climatique par les agriculteurs". *Resources Naturelles Canada*.

Bryant, C.R., Smit, B., Brklacich, M., Johnston, T.R., Smithers, J., Chiotti, Q., and B. Singh. (2000), "Adaptation in Canadian agriculture to climate variability and change. *Climatic Change*, 45:181-201.

Burke, E.J., Brown, S.J., Christidis, N. (2006), "Modeling the recent evolution of global drought and projections for the 21st century with the Hadley Centre climate model".*Journal of Hydrometeorology*, 7:1113-1125.

Buys, L., Miller, E., van Megan, K. (2012), "Conceptualising climate change in rural Australia: community perceptions, attitudes and (in)actions". *Journal of Regional Environmental Change*, 12:237-248.

Cline, W.R. (2007), Global Warming and Agriculture: Impact Estimates by Country. Centre for Global Development and Peterson Institute for International Economics, Washington, DC.

CSIRO (2007), "Chapter 5 Regional climate change projections (drought, wind, fire weather)". In: *Climate change in Australia: Technical Report*. CSIRO, Canberra.

Cullen B.R., R.J. Eckard and Rawnsley R.P. (2012), "Resistance of pasture production to projected climate changes in south-eastern Australia". *Crop & Pasture Science* 63: 77–86

Dairy Australia (2007), "What does climate change mean for dairy in Western Victoria?". Dairy Australia, Melbourne, VIC.

Dairy Research and Development Corporation (2003),Chapter 6 – Cleaning Up, in: *CowTime – Guidelines for milk harvesting*. DRDC, Melbourne, Victoria.

deVoil, P., Rossing, W.A.H., Hammer, G.L. (2006), "Exploring profit – sustainability trade-offs in cropping systems using evolutionary algorithms". *Environmental Modelling & Software*, 21(9):1368-1374.

Diggs, D.M. (1991), "Drought experience and perception of climatic change among Great Plains farmers". *Great Plains Research*, 1(1): 114-132

DPI, 2012: Fravel, S., Ridley, L. (2012), Victorian food and fibre export performance: 2010-11 Financial Year. Department of Primary Industries, Melbourne, VIC.

DSE (2008), Climate change in the Corangamite region. Department of Sustainability and Environment, Melbourne, VIC.

Dyszynski, J. (2010), UNEP AdaptCost briefing note: economics of climate impacts and adaptation in Africa's agricultural sector. Stockholm Environmental Institute, Oxford, Oxfordshire.

Gunasekera, D., Yeaon, K., Tulloh, C., Ford, M. (2007), "Climate change: impacts on Australian agriculture". *Australian Commodities*, 14(4):657-676.

Hayman, P., Rebbeck, M., Bellotti, B. (2008), Managing the Risk of Climate Change in the South East Region. Prepared for: *ARC Linkage Grant, June 2008*

Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R., Ricketts, J. (2005), Climate change impacts on fire-weather in south-east Australia. *CSIRO Marine and Atmospheric Research*, Aspendale, VIC.

Hennessy, K., Fawcett, R., Kirono, D., Mpelasoka, F., Jones, D., Bathols, J., Whetton, P., Stafford Smith, M., Howden, M., Mitchel, C., Plummer, N. (2008). An assessment of the impact of climate change on the nature and frequency of exceptional climatic events. Bureau of Meteorology Climate and Ocean Services, Melbourne and CSIRO Climate Adaptation Flagship, Aspendale, VIC.

Hogan A., A. Bode, H. Berry. (2011), Farmer health and adaptive capacity in the face of climate change and variability. Part 2: Contexts, personal attributes and behaviors. International Journal of Environmental Research in Public Health. 8(10): 4055–4068.

Howden, M., Jones, R. (2001), Costs and benefits of CO_2 increase and climate change on the Australian wheat industry. *Report to the Australian Greenhouse Office*, p. 25.

Hughes, L. (2003), Climate change and Australia, trends, projections and impacts.*Australian Ecology*, 28:423-443

Iglesias, A., Avis, K., Benzie, M., Fisher, P., Harley, M., Hodgson, N., Horrocks, L., Moneo, M. (2007), Adaptation to climate change in the agricultural sector.*AEA Energy and Environment*, Dicot, Oxfordshire.

IPCC (2007), Understanding and Attributing Climate Change. In Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.

Jones, R.N., Hennessy, K.J.. (2000), Climate change impacts in the Hunter Valley: A risk assessment of heat stress affecting dairy cattle. *CSIRO Atmospheric Research*, Aspendale, VIC, Australia.

Kiem, A.S., Askew, L.E, Sherval, M., Verdon-Kidd, D.C., Clifton, C., Austin, E., McGuirk, P.M., Berry, H. (2010), *Drought and the Future of Rural Communities: Drought impacts and adaptation in regional Victoria, Australia*. Report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia

Leviston, Z., Leitch, A., Greenhill, M., Leonard, R., & Walker, I. (2011), Australians' views of climate change. CSIRO Report. Canberra, Australian Capital Territory.

Luo, Q., Bellotti, W., Williams, M., Cooper, I., Bryan, B. (2007), "Risk analysis of possible impacts of climate change on South Australian wheat production". *Climatic Change*, 85:89-101.

Maddison D. (2006), The perception of and adaptation to climate change in Africa. *CEEPA Discussion Pape*r No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Mertz, O., Mbow, C., Reenberg, A., Diouf, A. (2009), "Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel". *Environmental Management*, 43:804-816.

Mortimore, M.J. (1989), *Adapting to drought: farmers, famines and desertification in West Africa.* Cambridge University Press, Cambridge.

Mpelasoka, F., Hennessy, K., Jones, R., Bates, B. (2008), "Comparison of suitable drought indices for climate change impacts assessment over Australia towards resource management". *International Journal of Climatology*, 28:1283-1292.

Müller, C., Cramer, W., Hare, W.L., Lotze-Campen, H. (2011), "Climate Change risks for African agriculture". *Proceedings of the National Academy of Sciences of the United States of America*, 108 (11): 4313-4315.

Nettle, R. and G. Lamb. (2010), "Water security: how can extension work with farming worldviews?" *Extension Farming Systems Journal* 6 (1):12-21.

Nyanga, P.H., Johnsen, F.H., Aune, J.B., Kalinda, T.H. (2011), "Smallholders farmers' perceptions of climate change and conservation agriculture: evidence from Zambia". *Journal of Sustainable Development*, 4(4):73-85.

Phelps, C., Watson, P, Watson, D. (2012). *Dairying for tomorrow: Survey of natural resource management on dairy farms*. Dairy Australia, Melbourne, VIC.

Richards, P. (2010), *A Green Revolution from Below? Science and Technology for Global Food Security and Poverty Alleviation*. Retirement address. Wageningen University, the Netherlands.

Rickards, L. (2012), *Critical Breaking Point: the effects of climate variability, change and other pressures on farm households*. Report for the Birchip Cropping Group and the Sustainable Agriculture Initiative Platform Australia.

Barber, M. (2009), *Managing the risks of climate variability in Australian agriculture: decision-making in agriculture under conditions of uncertainty*. Rural Industries Research and Development Corporation, Barton, ACT.

Hogan, A., Berry, H.L., Ng, S.P., Bode, A. (2011), *Decisions made by farmers that relate to climate change*. Rural Industries Research and Development Corporation, Barton, ACT.

Risbey, J., Kandlikar, M., Dowlatabadi, H., Graetz, D. (1999), "Scale, context, and decision making in Agricultural adaptation to climate variability and change". *Mitigation and Adaptation Strategies for Global Change*, 4:137-165

Schwartz, I., Greymore, M., Brownell, B. (2011), The Victorian Farmer Survey on Climate Change, 2011. Victorian Department of Primary Industries, Melbourne.

Smit, B., Burton, I., Klein, R.J.T, Wandel, J. (2000), "An anatomy of adaptation to climate change and variability". *Climatic change*, 45:223-251.

Smit, B., McNabb, D., Smithers, J. (1996), "Agricultural adaptation to climatic variation". *Climatic Change*, 33:7-29.

Smit, B., Skinner, M.W. (2002), "Adaptation options in agriculture to climate change: a typology". *Mitigation and adaptation strategies for global change,* 7:85-114.

Smit, B., and J. Wandel. (2006), "Adaptation, adaptive capacity and vulnerability". *Global Environmental Change* 16: 282–292.

Stokes, S., Howden, M. (2011), "Adapting agriculture to climate change"*.* In: *Climate change: science and solutions for Australia* CSIRO, Canberra.

Watterson, I, Whetton, P, Moise, A, Timbal, B, Power, S, Arblaster, J, and McInnes, K. (2007) Chapter 5 - Regional climate change projection (temperature and precipitation). In: *Climate change in Australia: technical report*. CSIRO, Canberra.

World Bank (2007), "Focus F: Adaptation to and mitigation of climate change in agriculture". in: *World Development Report 2008: Agriculture for Development*. The World Bank, Washington, DC.

WIDCORP, (2009), "Understanding farmer knowledge and attitudes to climate change, climate variability and greenhouse gas emissions". Water In Drylands Collaborative Research Program. Victoria Department of Primary Industries, Melbourne.

WestVic Dairy (2010), *Dairy News*, 156:1.

White, N., Sutherst, R.W., Hall, N., Whish-Wilson, P. (2003), "The vulnerability of the Australian Beef Industry to impacts of the cattle tick (*Boophilusmicroplus*) under climate change". *Climatic Change*, 61(1-2):157-19