Climate change impacts and adaptation responses for South-West Victoria’s primary industries

A DPI VCCAP Discussion Paper

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1. INTRODUCTION

Climate change adaptation can be defined as actions taken to cope with a changing climate. Adaptation aims at cost-effectively reducing the risk and damage or exploiting potential benefits from current and future harmful climate change impacts. Adaptation can encompass national or regional strategies, practical steps taken at community level or actions by individuals. Adaptation measures can be anticipatory or reactive and applies to natural as well as to human systems (Commission of the European Communities 2007).

There is widespread acknowledgement that climate change has already occurred, that future change is almost inevitable, and that we will have to adapt to these changes (IPCC 2007). The 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report concluded that the Australian agriculture sector is particularly vulnerable to future climate change. This vulnerability could negatively impact on the amount and quality of agricultural produce, the reliability of production and on the natural resource base on which agriculture depends (IPCC 2007). To address these vulnerabilities high levels of adaptation are required.

To understand what the most appropriate adaptations may be, improved knowledge of the likely impacts of climate change and the available adaptation options is required.

The Department of Primary Industries (DPI) Victorian Climate Change Adaptation Program (VCCAP) has recognised that climate change adaptation is complex and influenced by a wide range of biophysical and socio-economic factors. To address the multifaceted nature of climate change adaptation, DPI VCCAP has incorporated six interdependent, multidisciplinary themes aimed at providing an integrated understanding of climate change impacts and adaptation.

This paper combines knowledge developed by the DPI VCCAP project with complementary information to explore the likely impacts of climate change on Victoria’s primary industries as well as likely adaptation options. In the following sections, research into the biophysical impacts of climate change, particularly in the study area of South-West Victoria, including groundwater, agriculture, grains, pasture-based industries and forestry are explored. This is followed an exploration of socio-economic elements including adaptive capacity, stakeholder engagement, communication and policy research as methods of supporting adaptation.

1.1. SOUTH–WEST VICTORIA – THE STUDY AREA

The study area of South-West Victoria includes the Glenelg Hopkins and Corangamite Catchment Management Authority regions (Figure 1).

![Figure 1: The DPI VCCAP study area](Sposito et al. 2010b)
South-West Victoria was selected as the pilot region because it:

- has an agricultural industry production worth over $2 billion annually that is the biggest employer in most parts of the region (Liu and Fitzsimons 2009);
- includes a wide range of farming systems including dairy, grains, broadacre livestock grazing and forestry (Liu and Fitzsimons 2009);
- contains irrigation and dryland systems;
- has a clear rainfall gradient from north to south, but also a clear drying signal in rainfall patterns, consistent with climate change predictions (CSIRO 2007);
- is undergoing enterprise and land use change, partly due to expansion of dryland grain crops, blue gum plantations and amenity land use and decreases in dryland pasture and native vegetation (Liu and Fitzsimons 2009);
- contains the South West Climate Change Forum (SWCCF), a regional stakeholder reference with whom VCCAP could work with.

2. PROJECTED CLIMATE CHANGES AND IMPACTS

Overall, the future climate of South-West Victoria is expected to be hotter, drier and more variable than it is today. However, in comparison to many other parts of the State, the regional climate is expected to remain moderate (Cullen et al. 2009; Anwar et al. 2007 and 2008).

Under the A1FI climate scenario, (an IPCC scenario based on a fossil fuel intensive future that we are currently tracking at) (Rahmstorf et al. 2007), it is estimated that the region's average annual temperature may increase by 0.8°C by 2030 (Figure 2), while 2070 may be 2.4°C warmer. Winters will probably warm slightly less than the other seasons (0.6°C-0.7°C) as much of the warming is expected to occur in summer. The frequency of hot days (>30°C) is expected to increase from 21 to 40 in Corangamite and from 31 to 52 in Glenelg-Hopkins region by 2030 (The State of Victoria 2008a; The State of Victoria 2008b). A reduction in the region's total average annual rainfall of around 4% is anticipated by 2030 under the A1FI scenario, with the largest rainfall reductions occurring in
winter and spring. In Corangamite, annual rainfall is expected to decrease by approximately 73mm (Christy et al. 2009a). Rainfall patterns will probably become more erratic and unpredictable, with fewer rain-days, more frequent and intense droughts and increased summer rainfall (Cullen et al. 2009; The State of Victoria 2008a; The State of Victoria 2008b).

An increase in high intensity rainfall events may contribute to increased soil erosion, particularly if high intensity rainfall events occur in combination with longer, drier seasons (Cullen et al. 2009).

To put these changes into perspective, in 2070, under the A1FI scenario, (i) Ballarat’s climate will probably resemble present day Maldon, (ii) Warrnambool’s temperature may resemble present day Horsham, with annual rainfall similar to present day Hamilton and (iii) Hamilton’s temperature will likely be similar to present day Horsham, with annual rainfall similar to present day Ararat (The State of Victoria 2008a; The State of Victoria 2008b).

2.1. WATER RESOURCES

The average annual runoff into the Barwon River, Moorabool River and Lake Corangamite is anticipated to decrease by between 10% and 50% by 2030 (A1FI scenario). Average annual runoff into the Hopkins and Glenelg Rivers is expected to decrease by between 10% and more than 50% (The State of Victoria 2008a; The State of Victoria 2008b).

These significant reductions in catchment yield would impact on all land uses associated with diversion and/or the storage of surface runoff. The implication for agriculture, particularly irrigated agriculture may be an increase in the proportion of years when no water is available for agricultural diversion.

More frequent, prolonged dry periods could exhaust on-farm water supplies, threatening the viability of livestock enterprises.

Groundwater accounts for 43% of the water used in western Victoria, supplying water for towns, industry, stock and irrigation. Many farms and communities are without direct access to alternative water supplies. Portland, Heywood, Port Campbell, Port Fairy and Timboon rely on groundwater as their only reliable source of water. While in Horsham, Hamilton and Warrnambool groundwater is relied upon for part of their supply, particularly in times of drought (Department of Sustainability and Environment 2009).

Groundwater is already being placed under considerable stress. Hekmeijer and Gill (2008) found that in 2007, groundwater in Corangamite had declined up to 10 metres, while in Glenelg Hopkins, groundwater had fallen to the lowest level since monitoring commenced in the 1980s. These results are concerning as even under favourable circumstances it can take a great many years for groundwater to recover (Christy et al.)

Figure 3: Corangamite CMA difference in potentiometric surface under current land management (historic climate data minus predicted climate change data) (2050) (Christy et al. 2009a)
2009a). Reductions are expected to continue as groundwater recharge declines in South-West Victoria. This will probably be due to reduced rainfall and more water efficient farming practices that reduce drainage below the root zone. Application of the Catchment Analysis Tool (CAT) to the Corangamite catchment indicates that the amount of water entering aquifers may decrease by up to 21% (24 mm/year) under the 2050 A1FI scenario. The impact of this reduction would vary across the catchment, with upper landscapes experiencing the most significant reductions due to their high hydraulic gradient (Figure 3). On a more positive note, with less water entering the watertable, dryland salinity and nitrate leaching processes would probably decrease (Christy et al. 2009a).

Information uncertainty exists. Further research on the changes in climate and land use on regional water sources is necessary. The incentive for private investment in such research is likely to be small, as it is difficult for private investors to capture the full benefits (Alston and Pardy 1996).

2.2. LAND USE PRESSURE

The impact of climate change on agriculture is expected to be less damaging to South-West Victoria than other parts of the State. Temperatures are expected to remain moderate while rainfall is anticipated to remain adequate in the medium term, particularly in the region’s south (Cullen et al. 2009; Anwar et al. 2007 and 2008). These factors are expected to make the region more attractive to agricultural producers in northern Victoria, who may experience more negative production impacts due to climate change.

This, in combination with growth in the renewable energy and amenity land use sectors is likely to put pressures on regional land use and resources (Soste, 2009; Liu and Fitzsimons 2009; Barr, 2005). Growth in these sectors could contribute to regional diversification that provides the agricultural sector with the ability to adjust their enterprise mix and remain flexible during difficult times (Liu and Fitzsimons 2009). However, such pressures could also cause an increase in the rate of return required for broadacre agriculture to remain economically viable and create more alternative income sources that reduce investment in agriculture (Nelson et al. 2010).

Effectively managing these pressures will be vital, as land and resource use pressures have the potential to constrain the growth of agricultural businesses and cause tension in the community. This has already occurred in South-West Victoria in response to the expansion of the region’s plantation forestry industry. The purchase of land in the region for forestry has caused land prices to rise above levels related to the value of the land for agricultural production, limiting farm growth and productivity gains and creating community outrage (Barr 2005). To effectively address these pressures integrated planning between local and state government entities will be necessary (Soste et al. 2009).

2.3. AGRICULTURE

Increasing atmospheric carbon dioxide ($CO_2$) concentrations are expected to have a slight positive effect on vegetative growth. This stimulates photosynthesis, improving the nutrient and water use efficiency of crops and other plants. However, DPI VCCAP suggests that the benefits of increased $CO_2$ atmospheric concentrations cannot be expected to match the results of current
Free Air CO$_2$ Enriched Experiments (FACE) because other climate change factors, such as higher temperatures and reduced water availability are likely to limit growth (O’Leary et al., 2010).

One of the most significant factors expected to influence production in South-West Victoria is the increased frequency of hot days. An increased frequency of hot (>35 °C) days can result in poor fertilisation if occurring around flowering time. Further, if prolonged periods of high temperature occur, crops will develop and mature more quickly. This reduces the time available for the plant to utilise scarce water resources, resulting in lower growth and yield (O’Leary et al., 2010).

Changing seasonal patterns are also expected to impact agricultural production. Warmer temperatures predicted earlier in the season may improve crop growth rates in winter and early spring, but would probably be followed by a progressive shortening of favourable conditions later in spring due to hotter temperatures and reduced rainfall (Cullen et al. 2009). Warmer temperatures during the season would accelerate plant growth stages, restricting the time available for the plant to accumulate radiation and nutrients. This would negatively affect yield and quality and cause earlier maturity and harvesting of fruits, silage and other crops (Stokes and Howden 2010).

To maximise the length of the growing season South-West Victoria farmers are likely to sow crops earlier and apply more nitrogen at sowing. Whilst this is an effective productivity response, it could act against greenhouse gas mitigation. Nitrogen fertiliser production is energy intensive and if nitrogen is applied on wet winter soils, significantly higher emissions of nitrous oxide (NO$_2$) would be produced (Cullen et al. 2009). Increases in the volume of nitrogen applied may also result in increases in the volume of nitrogen discharged into water sources (Stokes and Howden 2010).

Another factor for agriculture is increasingly variable weather. This could cause farmers to be more responsive to short-term weather forecasts and may lead to production becoming more opportunistic. However, farmers may not have sufficient knowledge to take advantage of these opportunities and the benefits of private investment in generating and disseminating such knowledge may be difficult to capture (Marsh and Pannel 2000; Sandall et al. 2010).

Farm level adaptations to gradual climate change could occur incrementally and on an as-needs basis. Initial on-farm adaptations could involve refinement of current farm system management and best management practices to match the changing climate. In the medium term, as the climate becomes drier and warmer, additional tactical farm system changes such as conversion from perennial to annual fodder will probably take place. In the longer term, there may be a requirement for more radical, strategic decisions such as changing enterprise.

Whether changing enterprise or making substantial changes in management practices, a key risk for farmers will be gaps in the knowledge and skills available to them in order to successfully make required transitions.
2.4. GRAINS

In 2005/06 grain accounted for 6% ($123 million) of South-West Victoria’s agricultural value. Grain production was mainly concentrated around Ararat, which had the highest gross value and production of wheat (105,171 tonnes) in the region (Liu and Fitzsimons 2009).

South-West Victoria’s grain industry has been steadily growing over the past decade. This is partly due to drying of the region’s climate as well as rising international prices, raised bed technology and the decline of the region’s wool industry (Liu and Fitzsimons 2009). These factors along with the flexibility, management ease and reduced risk that this annual crop provides, are all likely to have contributed to the growth of the industry in this region.

DPI VCCAP modelling of South-West Victoria’s grain industry shows that as rainfall declines in the region and temperatures get warmer, grain production in the region is likely to become significantly more favourable. Significant differences occurred between different climate models (e.g. CSIRO CCAM Mark 2 and Mark 3) reflecting some uncertainty in the IPCC A1FI climate outlook. Despite this uncertainty, clear trends are evident. Consistent gains in yield of around 10-20% should occur in all cultivar types (e.g. Silverstar, Chara or Mackellar), but only from later sowing times (July to August) (Figure 4). This is primarily due to more favourable growing conditions and reduced rainfall, that are expected to make the once waterlogged soils of South-West Victoria’s high rainfall zone more suitable for crop production and the semi-arid zones more marginal (O’Leary et al. 2009).

The results of economic modelling (using REMPlan) suggest that in response to improved wheat yields, the wheat industry will respond positively to the A1FI climate change scenario between 2010 and 2070 relative to their performance in 2005-06. However, this modelling indicates that after 2045, there are potential limits to adaptation. At this point productivity is expected to decline as climate change progresses and water availability and temperature become major constraints, culminating in negative impacts after 2070 (Liu et al. 2010).

Climate change may also impact grain quality parameters, particularly in cooler regions, such as South-West Victoria. The expected shortening of grain fill as well as increased CO₂ atmospheric concentrations could reduce the plants nitrogen demand leading to lower protein grain. This is a concern, as grain with low protein levels is generally limited to animal feed or biscuits, as it produces poor quality bread and noodle products, and hence achieves a lower price. To address this quality concern, grain producers may apply more nitrogen to their crop. However, fertilisers are expensive and grain producers will only adapt in this way if it is economically viable. To address these potential quality and yield issues there is great potential for the breeding of longer season types that mature before temperatures start to get too warm (Stokes and Howden 2010). However, the benefits of breeding such cultivars may be difficult for private investors to capture and may need government investment.

The overall adaptation potential for grain cropping systems is relatively high compared to many other agricultural industries. This is because cropping systems have high levels of management input at sub-annual time steps that provide the opportunity for implementing adaptation strategies (Stokes and Howden 2010). Where necessary and as occasional wetter seasons occur, raised bed technology can be used to prevent waterlogging. However, as
Figure 4: Effect of IPCC Scenario A1Fi downscaled by two models (CCAM Mark 2 and CCAM Mark 3) on percentage change in mean wheat grain yield from current climate, examining the impact of sowing time on a medium developing type (cv. Chara) (O’Leary et al. 2009)
the regional climate becomes drier, grain growers are likely to change their management practices and increase their use of reduced tillage techniques to prevent soil moisture loss and maximise water infiltration (O’Leary et al. 2009).

Adaptation strategies such as crop management practices, new varieties, altered rotations (i.e. more barley and mustards rather than pulse crops and canola in the dryer areas of the SW) and improved water management have been developed (Stokes and Howden 2010). These strategies may need to be modified or integrated in different ways on individual farms to ensure the adaptation potential for grain cropping systems is realised (Howden et al. 2008). Farmers may not have the knowledge to enable them to adequately modify or integrate these strategies and the benefits of private investment in generating and disseminating such knowledge may be difficult to capture.

2.5. PASTURE BASED INDUSTRIES

Pasture based industries dominate South-West Victoria’s landscape and are a significant contributor to the regional economy. In 2005-06 dairy contributed $694.5 million, beef cattle $375 million, sheep and lambs $216 million and wool $216 million – a total of about $1.5 billion. However the size of these industries is changing. Between 2000-01 and 2005-06 meat cattle numbers steadily increased 14% in response to growing demand for Australian beef. Dairy experienced a decline of 9% due to falling world dairy prices and the widespread drought. The number of sheep for wool or meat production reduced by 23% as the number of prime lambs sold increased by 16%, both directly reflecting changes in commodity prices (Liu and Fitzsimons 2009).

Anticipated reductions in rainfall, increased frequency of droughts and more extreme and variable weather patterns are expected to decrease pasture production and reliability in the future. Such events will probably cause an increase in plant mortality and a need to re-sow pastures more frequently (Sposito et al. 2008 and Stokes and Howden 2010). On a more positive note, expected warmer temperatures will decrease the incidence of frost (Stokes and Howden 2010).

Application of climate models (SGS Pasture Model and DairyMod) show that under a 2030 low climate change scenario, Hamilton and Terang are expected to see annual pasture production increases of up to 12%. However, under the 2070 high climate scenario (A1FI), declines of up to 15% are predicted for the same areas. These results reflect the warmer winter temperatures that are expected to stimulate winter and early spring growth rates, counteracted by a shortening of spring due to hotter temperatures and lower rainfall (Cullen et al. 2009). This forecast suggests a need to focus plant breeding on improving the heat and drought tolerance of species such as perennial ryegrass and deeper rooted fodders. Private investors are likely to under invest in such plant breeding if its benefits are difficult to capture (Alston and Pardy 1996).

Sposito and Benke’s (2010) application of land use suitability analysis (a semi-quantitative approach to map/assess regional agricultural land suitability) suggests that in the medium term (2050 A1FI) the northern areas of the South-West Victoria region will become more suitable for phalaris/sub-clover growth whilst the southern regional areas would be better suited for perennial ryegrass/sub-clover growth, while lucerne is unlikely to be significantly affected (Figure 5).

In a changing climate, tropical, deep rooted perennial C₄ pasture species such as kikuyu
and paspalum are expected to become more competitive during summer at the expense of $C_3$ species such as ryegrass and phalaris. This is because $C_4$ species can overcome some of the reduced spring growth by intercepting more of the available water through their deeper root depth. For example, under the A1FI 2070 scenario at Ellinbank, Victoria annual pasture production could be increased from 10.5 to 11.6 t DM/ha as a result of root depth increasing from 0.40 to 0.60mm (Cullen et al. 2009). Use of $C_4$ pasture species may address some of the issues associated with expected drier, hotter conditions and shortened phenological stages, however their lower forage quality and reduced growth rates in winter will need to be managed to prevent a reduction in animal performance (Cullen et al. 2009).

A warmer, dryer climate in South-West Victoria may have implications for how farmers integrate grain and other sources of fodder into their feed management systems. Pasture is currently the cheapest source of animal feed for beef, dairy and sheep producers, but in a climate affected future, the gap in costs between pasture and grain feed is expected to narrow. Reduced pasture productivity and reliability is likely to make farmers more dependent on cool season production, grain feeding and stored fodder. Changing feed systems in this way would represent a substantial change in farm management. Moreover, it is likely to require considerable customisation and flexibility. This may also represent a substantial change for service providers, who may need to generate and extend knowledge differently to meet farmers' needs (Stokes and Howden 2010).

Grazing animals will also be affected. More hot days (>30°C) and heat waves would reduce milk production, restrict animal reproduction, lower milk protein and fat content and create animal welfare concerns. These issues will particularly affect milking sheds, young stock mortality and animal transportation. Strategies such as increasing shade and changing milking times are likely to be used to address the issue (Little and Campbell 2008), but if energy and/or water are used to manage heat stress, additional greenhouse gas emissions would be produced (Cullen et al. 2009; Stokes and Howden 2010).
2.6. FORESTRY

The hardwood timber industry has experienced significant growth over the past decade in the Green Triangle (comprising South-West Victoria and south eastern South Australia). This region is Australia’s largest timber plantation, constituting 17% of Australia’s forest plantation area (Department for Transport Energy and Infrastructure 2009).

Harvesting of hardwood timber is expected to increase rapidly between 2009 and 2012, reaching up to 3.5 million tonnes per annum by 2012. As a result, the port of Portland is expected to become the largest blue gum woodchip port in Australia, handling approximately 3.5 million tonnes of blue gum woodchip per year, compared to 0.5 million tonnes currently (Department for Transport Energy and Infrastructure 2009).

According to land use suitability analysis, the land suitability in South-West Victoria for blue gums may increase by approximately 18% by 2050 under the SRES A1FI scenario (Figure 6) (Sposito and Benke 2010). However growth in this industry will be dependant on global markets.

In the longer term, warmer temperatures coupled with limited water resources may decrease tree growth rates and increase tree mortality. It is expected that as rainfall declines, so will groundwater levels under plantations. To examine the relationship between plantation forests and groundwater resources, research has been conducted by Christy et al. (2009a). This catchment modelling study shows that in a changing climate, plantation forest trees will access less groundwater.

Figure 6: Change in land suitability for blue gum production, years 2000-2050 SRES Scenario A1FI (Sposito and Benke 2010)
As a result, tree growth rates will probably decline and the impact of plantation forests on groundwater resources will lessen.

To address the issues of limited water supplies and warmer temperatures, forest managers may plant more drought tolerant species, plant trees at wider spacings or thin existing stands. Unfortunately, the ability of forest managers to adapt to climate change is quite limited once trees are planted (Stokes and Howden 2010).

3. SUPPORTING ADAPTATION

3.1. ADAPTIVE CAPACITY

Adaptive capacity is ‘the ability of a system (region or community) to cope and thrive in the face of change’ (IPCC 2007).

To assess the adaptive capacity of regions of South-West Victoria, DPI VCCAP has developed a regional adaptive capacity index (ACI). ACIs such as Nelson (2010) have been utilised to inform where adaptation is required at a national scale. DPI VCCAP has developed a regionally-focused ACI in collaboration with regional stakeholders to provide a local perspective of adaptation needs. This work has identified that stakeholders in South-West Victoria consistently believe that the most appropriate indicators of adaptive capacity focus on themes of education, socioeconomic status, demographic changes such as population growth, community involvement and human well-being (Fitzsimons, 2010b). Figure 7 depicts the adaptive capacity of the dairy industry in South-West Victoria as determined by participants involved in the ACI process (Fitzsimons et al. 2010c). The darker shades of red within the diagram reflect higher levels of adaptive capacity as determined by the weighting of 10 individual indicators. (Fitzsimons et al. 2010c).

Figure 7: Indication of adaptive capacity in South-West Victoria as suggested by regional dairy stakeholders (Bond and Fitzsimons 2010)
3.2. SOCIAL NETWORKS
The influence of social networks has increased significantly due to the rise of governance over government, and the acknowledgement of the role of networks in the management of complex ecological systems (Ansell 2008). This is particularly relevant to an issue as complex as climate change, as people seek information from trusted sources. Individuals and groups have the potential to enable the transfer of knowledge, experiences and information as well as facilitate the development and communication of adaptive responses (Tiller and Fitzsimons 2008). A DPI VCCAP social network analysis of South-West Victoria has found that trust, flexibility, and innovative ideas drive their regional networks (Bond and Fitzsimons 2010).

The South West Climate Change Forum (SWCCF) is a social network that has become an organisation of influence in the region, bridging government, industry and community spheres. The SWCCF is a community group made up of primary industry and planning groups that has been formed to help South-West Victoria’s primary producers adapt and prepare for changes in climate and climate variability (SWCCF 2008).

To maximise the effectiveness of DPI VCCAP, the program worked with the SWCCF to undertake project activities and access a range of relevant regional stakeholders already engaged in the climate change issue. By working alongside the SWCCF, it is understood that stakeholders were more willing and open to participate in DPI VCCAP events as the activities were supported by the Forum that they trusted (Clear Horizon 2010).

3.3. STAKEHOLDER ENGAGEMENT
While primary industries will need to adapt to biophysical changes in the future, they will also need to adapt to significant non-climate drivers. The global financial crisis, the value of the Australian dollar and the future availability of oil supplies being prime examples. Some of these non-climate factors will influence how we adapt to climate change and it is important for us to understand how stakeholders will respond to such influencers.

Working with those who are and will be affected by climate change has been an important part of DPI VCCAP. One piece of work that particularly engaged stakeholders was scenario development. This brought together regional stakeholders to develop three future scenarios for South-West Victoria. The scenarios were based on climate data and incorporate social, economic and environmental elements.

Scenario #1: Armageddon: This scenario is based on the A1FI emissions scenario. It includes themes such as high levels of global cooperation, growing strength in China and India and a strong global reliance on energy from fossil-fuels. In this scenario the climate is severe and gets worse quickly (Soste 2010b).

Scenario #2: Trade: This scenario is based on the mid range of the A2 emissions scenario. This scenario includes themes such as a divided world where regionalism dominates global relationships and trade. Energy conflicts rise and China’s growth fluctuates. In this scenario climate gets worse, but more slowly than A1FI (Soste 2010b).

Scenario #3: Australia Felix: This scenario is based in the mid range of the B1 emissions scenario. This scenario includes themes around high levels of global co-operation. There is moderate growth around the world. There is a major shift to renewable energy and climate change occurs slowly (Soste 2010b).
By engaging stakeholders in scenario formulation, assessment and strategy development, the complex interdependencies within agri-community systems and the nature of stakeholder needs and aspirations can be more holistically understood (Soste et al. 2010). Through this process, stakeholders developed a number of recommendations that aim to support regional adaptation. Common themes include a need to:

- improve regional leadership;
- integrate climate adaptation responses across government to ensure that the cross-sectoral nature of climate change is addressed;
- re-examine regional population forecasts and land use planning strategies with climate change in mind;
- assess implications of land use and population change for regional infrastructure, particularly water, transport and energy;
- develop plans to enhance regional biodiversity across public and private land (Soste and Chaffe 2009).

Participants sent the clear message that they wish to be engaged by government as an equal partner in adaptation planning for their region (Soste et al. 2010).

An independent evaluation of the program identified significant growth in participants’ understanding of climate change impacts and adaptation options for their region and other parts of the community and a greater understanding of system. There was also a strong correlation between this increased understanding and an increase in the participants confidence to manage change (Kelly 2010).

The use of processes such as scenario planning can bring the tacit knowing and experience of stakeholders to high-level, systemic adaptation planning in order to complement research. This can provide valuable guidance to policy formulation, especially with regard to complex issues such as climate change adaptation. These outputs illustrate that stakeholders can make a powerful contribution to high-level, systemic adaptation planning in complex, uncertain environments and that their ideas can often align with that of government (Soste et al. 2010).

3.4 COMMUNICATING CLIMATE

Understanding the audience, particularly when communicating information on complex and emotive issues such as climate change is extremely important. To inform climate communication so that it can effect greater change, DPI VCCAP has reviewed psychology and environmental communication literature.

Generally, issues that are perceived to be local, immediate and addressable have heightened levels of involvement and engagement (Lorenzoni et al. 2007). However climate change is rarely perceived this way. Climate change is often communicated at a global rather than a local scale and involves impacts which occur incrementally, affecting perceptions of immediacy. Strategies for addressing climate change are often unclear, particularly at the level of individual action (Lorenzoni et al. 2007). These factors often prevent people from experiencing feelings of personal or immediate harm and compound a lack of confidence in individual ability to affect the issue.

To address these barriers to engagement, communication ought to be structured to raise awareness and concern by personalising and explaining the issue, clarifying that climate change is unnatural,
unavoidable, based in fact and a valid threat (Sandman 2009).

Promoting climate change action may be facilitated by focusing on positive opportunities rather than costs and sacrifices. Messages that include win-win solutions, good business sense, labour efficiencies, cost savings and other benefits to the individual, no regrets actions and precautionary messages are all good communication themes (Gardner et al. 2009). Also, addressing the desired behaviour change in non-climate terms can avoid some of the sensitivities and issues associated with the topic.

Caution is required when communicating information about an issue as emotive as climate change. Messages that create fear or arouse feelings of helplessness or guilt, take pleasure in bad news, do not acknowledge alternative scientific views, or focus on too many issues at one time must be avoided. Such messages can shift people from apathy (where people are peripherally engaged and only undertake minor changes or express concern if prompted) to psychological denial (where denial is used as a coping mechanism to reduce experience of negative feelings) (Sandman et al. 2009). If this shift occurs, an anti-climate change sentiment may be induced.

The complexity of climate change can be a barrier to communication efforts. Visualisation of climate change data, models and scenarios is one technique that can assist in better communicating climate change topics. Geo-visualisation can provide a geographic context to information (data and models) through the use of maps and spatial viewers. Such information can be communicated in two dimensions (maps), three dimensions (by including elevation and object extrusion) and four dimensions (animation). Geo-visualisation can enable outcomes of social, economic and environmental analyses to be brought together with visual media to convey meaning to land managers, communities, industry, regional planners and policymakers (Pettit et al. 2010).

3.5. POLICY RESPONSES

Adaptation is challenging and maladaptation, ‘an adaptation that does not succeed in reducing vulnerability but increases it instead’ (IPCC, 2001, p. 990), can occur if decisions are not well informed. Generally, adaptations that increase greenhouse gas emissions, disproportionately burden the most vulnerable, have high opportunity cost, reduce incentives to adapt, or set paths that limit the choices available in the future need to be avoided if effective adaptation is to occur. Each of these potential maladaptations creates a line of investigation that diligent policy makers may need to consider in choosing policy responses to assist agricultural adaptation (Barnett and O'Neill 2010).

Effective adaptation policy will critically depend on:

1. the economic benefits and costs of climate change impacts and how these benefits and costs are distributed (Pannell 2008; Frankhauser et al. 2008; Sandall et al. 2010);

2. the technical feasibility of alternative policy instruments (Young et al. 1996; Gunningham et al. 1998; Kaine et al. 2007);

3. the responses of primary producers to alternative policy instruments (Kaine and Higson 2006; Murdoch et al. 2006; Kaine et al. 2010); and

4. the support that organisations will need to implement such instruments (Kaine 2010).
To help inform the development of effective policy responses DPI VCCAP has developed a Policy Choice Framework (PCF) to systematically and transparently account for these considerations (Sandall et al. 2009 and 2010).

For example, a number of instances in this paper have identified where the adaptation responses of farmers are likely to have flow-on effects, such as increasing greenhouse gas emissions. The PCF can be used to examine the nature of these effects and how they are distributed. This provides a basis for avoiding maladaptive policy responses and for suggesting feasible policy instruments to assist adaptation such as education, regulation, research and incentives. The PCF can then be used to consider the likely responses of farmers to such instruments, and the organisational support that will be required to implement them.

As with any change, there will be an ongoing need to generate and disseminate to farmers the knowledge and skills required to adapt to climate change. This need concerns farm management realms such as crop management, pasture management, feed management, nutrient management and heat stress management. In some instances, this need may be adequately met by private industry, but in others government investment will be required. In some cases, extension programs may need to change dramatically to meet the need. The PCF can be used to examine when government investment may be required and whether industry needs could be more effectively met by private service providers or by government agencies.

4. CONCLUSION

The DPI VCCAP project has developed a range of knowledge pertaining to climate change impacts and adaptation options. The project findings reflect its multi-disciplinary nature, which has facilitated the examination of climate change adaptation from biophysical and socio-economic perspectives.

This paper provides insights about how agricultural industries in South-West Victoria may adapt to climate change. However, adaptations will be dependant on a range of inter-relating factors. As climate changes in the future, it will be important that adaptation options are considered with respect to the short, medium and long term so that short term solutions do not confound long term adaptations. It will also be important that policy works across both mitigation and adaptation realms, so that maladaptations can be prevented.

We need to recognise that there are limits to adaptation. When climate change is gradual, adaptations can be prepared for. Significant and rapid climatic changes provide less opportunity for adaptation strategies to be planned and implemented.

Further research in the area of climate change adaptation in Australia will be required in order to inform decision making by government, industry and landholders.
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