Building Resilience in Farming and Agribusiness - Victorian Adaption Sustainability Partnerships

Literature review and gap analysis

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Important disclaimer:

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Summary

The key aim of this study is to provide an understanding for local government of how information and practice about climate change is received and utilised by farming and agribusiness. This review of the literature included around 150 sources of information derived from international peer-reviewed academic journals, conference papers, published and unpublished reports and websites.

From the earliest pastoral settlement the Wimmera has been noted for its soils and climate that have made it one of Australia's most productive grain growing regions. It is clear from the literature that agricultural production in the Wimmera will be affected by climate change and almost all predictions are that crop yields will become more variable, with an overall drop in production over the next few decades. A considerable number of surveys have been undertaken to understand the attitudes and perceptions of Australian farmers, including those in the Wimmera, to climate change. The research shows that rural communities - and broadacre farmers in particular - are generally conservative and sceptical of climate change, but actively engaged in adaptation to climate variability, where health and finances allow.

Current research is largely focused on adaptations to sustain and improve broadacre cropping and crop-livestock systems, through programs such as no-till farming, Grain and Graze, and ongoing research and development will continue to develop new crop varieties and cultivars. All efforts are being made to sustain the agricultural business as usual. Yet 'resilience thinking' suggests that sustaining the current broadacre agricultural systems will not be enough to maintain farm viability in the face of climate change and that adaptations are required to build resilience. These may include on-farm diversification, new agricultural ventures and developing new products from agricultural produce. Agricultural diversification into intensive industries such as feedlots, piggeries and poultry are being encouraged, based around the Wimmera Mallee Pipeline.

The single message that emerges from this review of all of the research and studies that have been conducted is that the consistent barrier to adaptation to climate change in agriculture is the inadequacy of information and knowledge transfer. Knowledge exchange between the expert and the practitioner needs considerable improvement in the Wimmera, to encourage adaptations that will build resilience in agriculture in the face of the predicted climate change. Information is best understood when it is up-to-date, credibly sourced, geographically relevant and thematically relevant. Above all, it must acknowledge the economic realities of farming and the practicalities of any suggested behaviour change.

The establishment of a knowledge exchange portal is recommended to improve relevant information availability and encourage adaptations that will build resilience in the current agricultural industries, and encourage the generation of new research ideas and projects with other collaborators. It is recommended that local governments in the region adopt an open data policy to unlock access to the spatial information they hold and make it interoperably visible to other web portals. Web-based tools can be constructed to facilitate easier discovery of data, such as climate change scenarios for a particular place in the Wimmera landscape, and overlay that with other datasets such as current or historic climatic data, soil data, groundwater data or terrain data, for example. Finally, the establishment of a 'smart farm' in the region is recommended to demonstrate the practical advantages of adopting new technologies. Such a venture would be suited to collaboration with the Regional Universities Network.

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Introduction

The Victorian Adaptation and Sustainability Partnership (VASP) assists the 79 local governments in Victoria work together with the State Government in raising the priority of climate change and sustainability within councils (DEPI 2014b; 2014d). The key objectives of the VASP program are to:

- strengthen relationships between and within state government, local government and communities,
- provide real and practical support to local governments working on climate change adaptation and sustainability,
- facilitate learning and knowledge sharing to improve the capacity and efficiency of government, and
- build the capacity of resource constrained councils.

In March 2014 the West Wimmera Shire Council was granted funding by the Victorian Department of Environment and Primary Industries (DEPI) under the VASP program to examine blockers to, and opportunities for, building resilience in farming communities and agri-business, and trial and evaluate some of those opportunities put into practice. The aim is to add value to existing networks, research and sustainability activities within the Wimmera farming communities. Specifically, the outcomes of the project are to:

- Strengthen existing networks.
- Provide a focus on sustainable agriculture.
- Deliver practical implementation of sustainable farming practices in the Wimmera and demonstration models for the farming and agri-business sectors.
- Improved information channels for entities providing services, information and innovation technologies suitable for farming and agri-business consumption.
- Bring Councils closer to our farming communities and agricultural industries.
- Promote ongoing change of practices beyond the life of the project.

This research report represents one of the key activities in achieving the desired outcomes, *viz:* a literature review and gap analysis to identify the blockers experienced by farmers and agribusiness in 1) sourcing and receiving sustainability information and services, and 2) implementing sustainable practices including the adoption of sustainable technologies.

The Centre for eResearch and Digital Innovation (CeRDI) at Federation University Australia (FedUni) was commissioned (18th July 2014) by the West Wimmera Shire Council to undertake this literature review and gap analysis, within a limited timeframe. Three tasks have been requested:

- Desktop study of current climate change and sustainability research, activities and networks in, or of benefit to, the farming community and agribusiness.
- Gap analysis of the practical knowledge exchange to farmers and the agribusiness sector by sustainability information, service and technology providers.
- Investigation of the blockers to and the opportunities for, effective information conduits for the farming community and the agribusiness sector.

Scope

This literature review and gap analysis is constrained in its scope according to the allocated time and budget. Accordingly, the breadth and depth of the review and analysis have been more narrowly focused on the agricultural industry in geographic area of the Wimmera, with an emphasis on building resilience in the face of changing climates. Although agriculture in the Wimmera is inextricably linked with a myriad of other social, economic and environmental issues, the limited scope did not allow for full exploration of all the connecting issues.

A number of relevant consulting reports, unpublished research reports and government reports (known as 'grey literature' (OG 2014)) were supplied by the project stakeholders at the commencement of the project. This grey literature has been supplemented by a limited number of papers published in peer-reviewed research journals sourced by the CeRDI team and the search for additional grey literature was very limited. The resulting brief desktop review does not include independent research to verify any of the grey literature, or collection of new data. To that extent it represents breadth rather than depth.

Around 150 relevant articles were accessed and used in this analysis. The 129 references used to compile this literature review comprise 56 papers from peer-reviewed international journals or published books, 7 papers from conferences or other journals, 51 reports and articles from the grey literature or industry newsletters and 15 from web pages.

Project website

A website has been established as a tool to inform the research team, project partners and stakeholders about this project. The site includes key project information and a knowledge hub providing access to documents and links to information about the Wimmera Region, climate impacts and building resilience in farming. An interactive climate impacts map on the website has been included to allow easy access to spatial climate change data for the Wimmera, as a guide to what may be available to assist in adaptation planning and community engagement in the future. The draft project website can be accessed at:

http://tism.cecc.com.au/clients/wra/

Contextual overview of the Wimmera

"The Wimmera" is a geographic area of north west Victoria first documented as a distinctive region by explorer Major Thomas Mitchell (Mitchell 1838). Historically, the boundaries of the Wimmera have been delineated for different purposes (WDA 2014), such as economic planning (CPA 1961), weather forecasting (BoM 2014b), bioregions (DEPI 2014a), statistical division (ABS 2014), football (WFL 2014) and catchment management (WCMA 2013). The Wimmera covers around 30,000 km^2, approximately ten percent (10%) of Victoria's area.

Physiography

In the physiography of Victoria, the Wimmera is generally identified as the plain to the north of the Western Highlands, south of the Mallee dunefields and west of the Loddon River floodplain to the South Australian border (Hills 1940). The landscape is characterised by the extensive plains of calcareous clay soils and natural vegetation of grassy woodlands of eucalypts and Buloke (Savannah), with Red Gum and Grey Box along the rivers. The drainage is also notable for the effluents and anabranches from the main rivers that do not flow to the sea, but terminate into lakes. As a result, the Wimmera has 2,676 wetlands (>1 hectare) which roughly equates to 25% of Victoria's individual non–flowing wetlands (WCMA 2013). Many of the wetlands are groundwater dependent (GWMW 2011).

In Victoria's Geomorphic Framework, the Wimmera falls within the North Western Dunefields and Plains (Joyce et al. 2003; DPI 2007), which occur in the western part of the Murray Basin that was submerged by seas during the late Neogene Period (six million years ago). The northern and western Wimmera were covered by the megalake Bungunnia around 2.5 million years ago, depositing lacustrine clays, while other parts of the Wimmera experienced fluvial deposition associated with the rivers. During the arid phases in the Pleistocene Period (around 500,000 years ago) much of the Wimmera was covered by windblown calcareous materials of variable clay content on which linear dunefields are prominent (the Woorinen Formation). In areas where more siliceous sand was available, the dunefields of the Big and Little Desert were formed (the Lowan Sand).

The single most important characteristic of the Wimmera is its soil. Deep grey calcareous clays, known as the 'Wimmera black soils', are very uniform over large areas. These clays are highly plastic, swelling in winter and cracking in summer which creates self-mulching soils with a loose-crumbed surface. The clays alternate with duplex red-brown loams to form a mosaic that is particularly suited to broad-acre agriculture, especially cereal growing.

Within the Wimmera Catchment Management Authority (CMA) boundaries, the annual average rainfall varies from around 1000mm in the Grampians (south) to 300mm across the north (WCMA 2013). The Mediterranean style temperate to semi-arid climate regularly alternates severe droughts and flooding rains, with both ends of the spectrum experienced in the past decade. The annual mean maximum temperatures range from 20^{o}C to 22^{o}C and the annual mean minimum temperatures from 8^{o}C to 9^{o}C (BoM 2014a).

The Wimmera lies in the Murray Darling Basin (MDB) Drainage Division, and represents 3% of the total area of the MDB (CSIRO 2007a; 2007b). The region uses 1% of surface water diverted for irrigation and urban use and less than 0.1% of the MDB groundwater resource. Significant groundwater resources exist at depth under the western portion of Wimmera where groundwater extraction is primarily for stock and domestic use, urban supply and limited irrigation. The West Wimmera Groundwater Management Area (GMA) management strategy suggests limited potential for further exploitation (GWMW 2011).

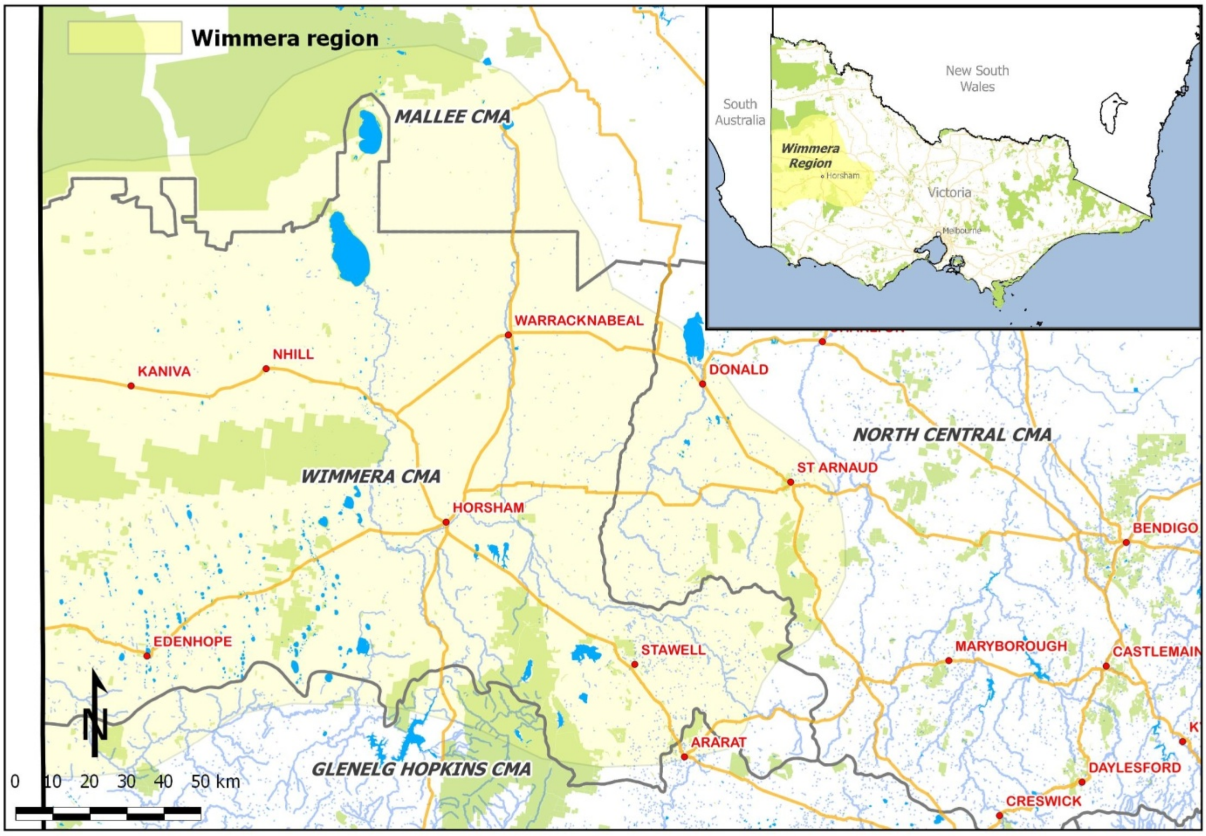

Figure 1. The Wimmera region

Population

Aboriginal Australians have inhabited the Wimmera for probably 40,000 years or more (Mulvaney and Kamminga 1999). Archaeological studies, ethno-historical accounts and oral histories indicate that throughout history the Grampians-Gariwerd landforms and region's rivers and lakes were consistently used by the indigenous Australian people (e.g. Bird et al. 1998; McNiven et al. 1999; Federal Court of Australia 2005), who also influenced the vegetation patterns through the use of fire (Pyne 1991; Morcom and Westbrooke 1998).

European settlement of the Wimmera occurred during the early 1840s, with pastoralists moving north from the south western Victorian plains (Gregory 1903). The regional migration and settlement is meticulously described by Powell (1970) who analysed the settlement of Western Victoria during the 1834-1891 period. After the squatters, the selectors who rushed to the Wimmera in the 1870s described excellent wheat yields averaging over 20 bushels per acre[1], oat yields of 25 bushels per acre and barley over 30 bushels per acre. More than half the selectors were of German origin, having moved from South Australia. Small holdings, isolation, uneven gilgai soils, nutrient (phosphate) depletion and crippling transport costs were limiting factors for the early agricultural enterprises. Deficient rainfall and clearing costs were additional limitations as the Wimmera agriculture spread north. In many areas collective action through congregations of ethnic or religious groups, the formation of cooperatives and harnessing family labour, was used to improve farm productivity.

[1] 1 bushel per acre ≈ 0.7 tonnes per hectare (wheat), 0.4 t/ha (oats) and 0.5 t/ha (barley)

The current population of the Wimmera is approximately 50,000 persons, with nearly one third in the City of Horsham and one third in settlements of <2000 people, or on farms (WCMA 2013). Overall population has been declining over the past three decades with a 40% decline in youth and a 30% increase in seniors. Over the past decade, population change in each municipality (except Horsham) has been generally falling (Figure 2).

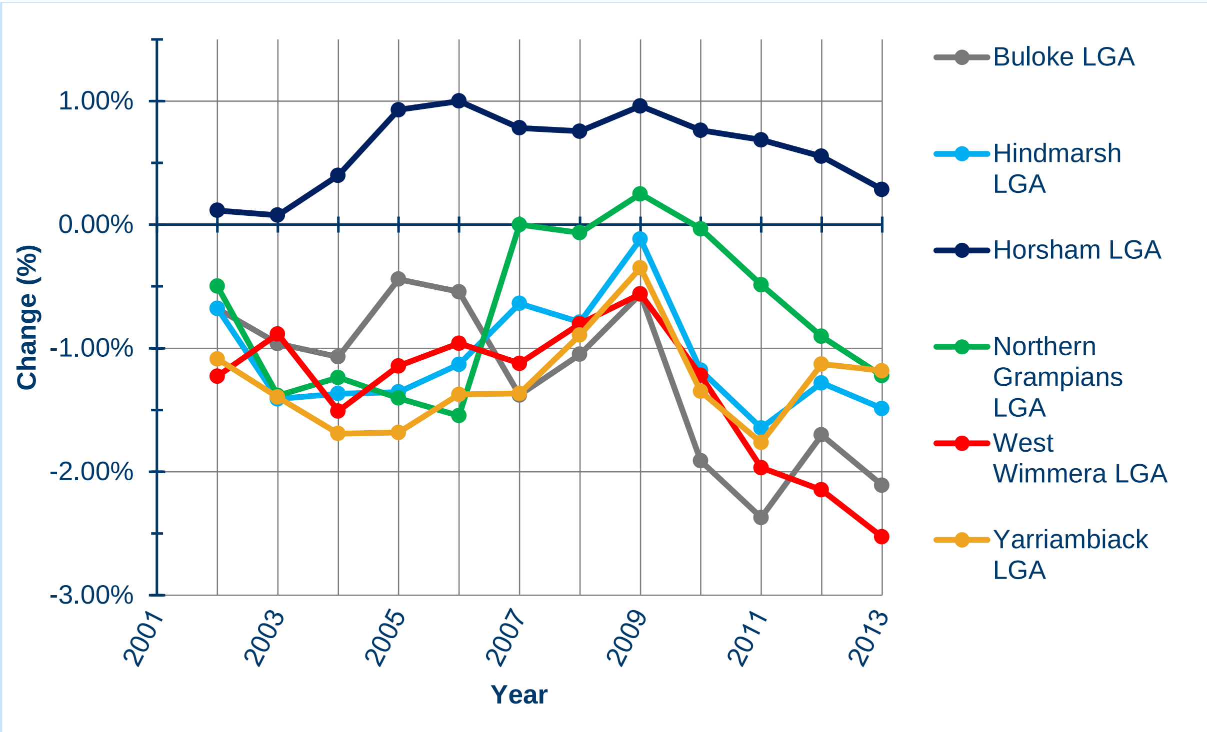

Figure 2. Population change, Wimmera area

Agriculture

Within the Wimmera Catchment Management Authority (WCMA) boundary, 84% of the land is privately owned (WCMA 2013), the vast majority of which is used for agriculture. Broadacre cropping of cereals, pulses and oilseeds is dominant in the central and northern Wimmera, and dryland livestock grazing in the South (DEPI 2014e). Agricultural production in the Wimmera has an annual total gross value greater than $900 million. The regional manufacturing industry is strongly linked to the agricultural sector, with around one-third of the region's manufacturing value added from the food production manufacturing sub-sector. In 2012 agriculture contributed to 20% of the region's employment and 30% of its Gross Value Added (GVA) (DEPI 2014e).

The average farm size is around 837 hectares, with 2,079 farms and over 1.74 million hectares of farmland (DEPI 2014e). The median age of farmers is 57 and 10% are 75 years or older (WCMA 2013). It is estimated that up to 50% of rural properties will change ownership in the next 10 years (Curtis and Mendham 2012). In the 2006 - 2011 period, 566 farming jobs were lost in region and the percentage change in agricultural jobs fell across all shires: Buloke -10.5%, Hindmarsh -10.1%, Horsham -12.7%, Northern Grampians -6.9%, West Wimmera -10.3% and Yarriambiack -16.9% (REMPLAN 2014). Yet, despite the falling employment in agriculture, the region is regarded as one of the more progressive agricultural communities, which is reflected in its strong social infrastructure and thriving community groups (Bourke 2014; DEPI 2014e).

Australian Premium White (APW) is the dominant wheat variety grown in the region, with barley (malting and feed) the second most prevalent crop. Canola is the major oilseed grown, and pulses include field peas, chickpeas, lentils, faba beans, broad beans, lupins and vetch (Table 1). Around 60% of all crop products are exported (Bourke 2014; DEPI 2014e).

Table 1 Wimmera harvest estimates, 2012-2013 (sourced from: Bourke 2014)

	Cropped area				
	2012		2013		Change
	hectares	%	hectares	%	%
Wimmera	1072565		1097194		+2.3
Commodity					
Wheat	352393	32.9	352393	32.1	0
Barley	320754	29.9	336792	30.7	+5
Oats*	33000	3.1	33000	3.0	0
Triticale	10910	1.0	10910	1.0	0
Canola	101850	9.5	101850	9.3	0
Lentils	58914	5.5	53023	4.8	-10
Chickpeas	49095	4.6	54005	4.9	+10
Faba beans	51823	4.8	54414	5.0	+5
Lupins	6546	0.6	6546	0.6	0
Field peas	26184	2.4	20947	1.9	-20
Vetch*	61096	5.7	73315	6.7	+20

* assume 25% is harvested

In the southern Wimmera, wool growing and sheep meat production together with some beef cattle are the dominant livestock industries. There are currently 6000 ha of irrigated cropping with the major enterprises being vines, pastures and orchards (CSIRO 2007b). Emerging industries include duck meat production, with Australia's largest duck meat processing facility at Nhill. Wimmera olive orchards produce significant quantities of olive oil and other olive products. Vineyards and wine production, herb production and goat meat production are a few of the niche agricultural businesses also reported in the Wimmera (DEPI 2014e).

Climate change predictions

The physical science behind climate change and the fact that greenhouse gas emissions from human activities are a key driver of climate change, is undisputed by climate scientists (Collins et al. 2007; Rosenzweig et al. 2008). The Earth's climate is a global system and climate changes are inextricably linked with many complex natural and anthropogenic drivers and feedbacks. Understanding climate science requires a systems-thinking approach (expansionism) rather than traditional analytical thinking (reductionism). Systems thinking is founded in the belief that the components of a system can be best understood in the context of the whole, rather than in isolation (Checkland 1981; Skyttner 2006). In other words, the only means to understand why a systematic process persists is to understand its relationship to the entirety of the system, including the components outside of the domain of science. For that reason it is regarded as an inexact science (Whitaker 2007).

Climate change predictions for the Wimmera are that it will get hotter and drier, with fewer rainy days over the next 50 years (DEPI 2014c). By 2070 Horsham can be expected to experience temperatures similar to the current day Wentworth, NSW and annual rainfall similar to the current day Nhill, Victoria. When compared to 1990, it is predicted that by 2030, average annual temperatures across the Wimmera will be around 0.8˚C warmer, with the greatest increases expected in summer (0.9˚C) (DSE 2008). The number of days over 30˚C is also expected to increase. Reduced average annual rainfall of 4% is expected, with the greatest reduction in spring rains (7%). Increases in potential evaporation and reductions in relative humidity are expected to contribute to drier conditions. Obviously, less rainfall and higher evaporation rates will result in less soil moisture and lower flows in streams. The occurrence of wild fires is expected to increase.

Climate change predictions are presented as statistically modelled forecasts of the changes to global climate, based on the natural and man-made drivers and feedbacks. A variety of climate models for Australia are available on the OzClim website (www.csiro/ozclim). As an example, the scenario shown in Figure 3 were generated for the Wimmera using model CCHAM5/MPI-OM, SRES maker scenario A1B, with a 'moderate' global warming rate (i.e. "business as usual" - details at: www.ipcc.ch/ipccreports/sres/emission/index.php?idp=3).

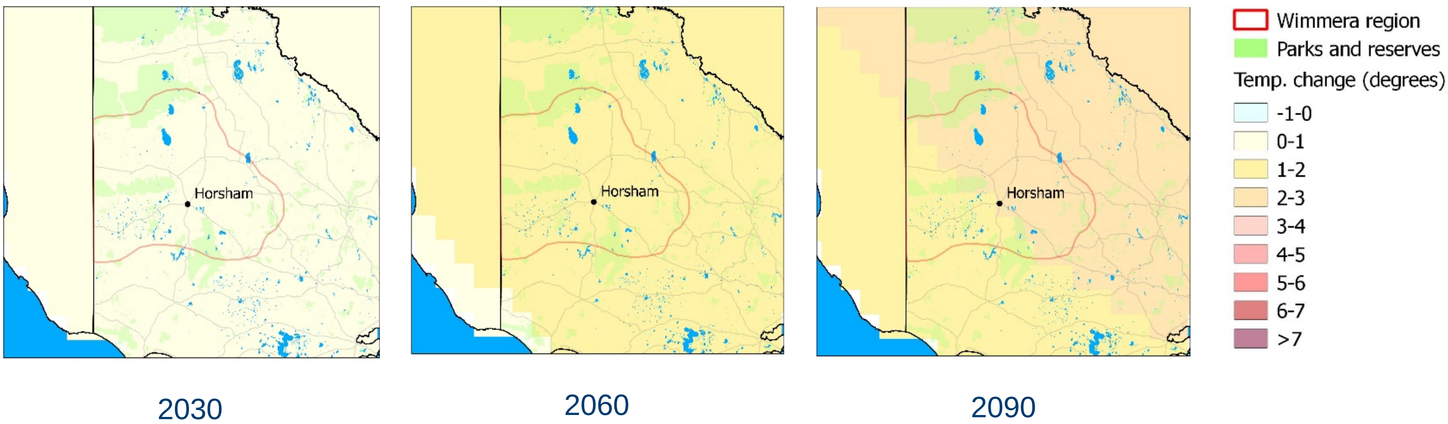

Figure 3a. Predicted change in mean annual surface temperature (°C)

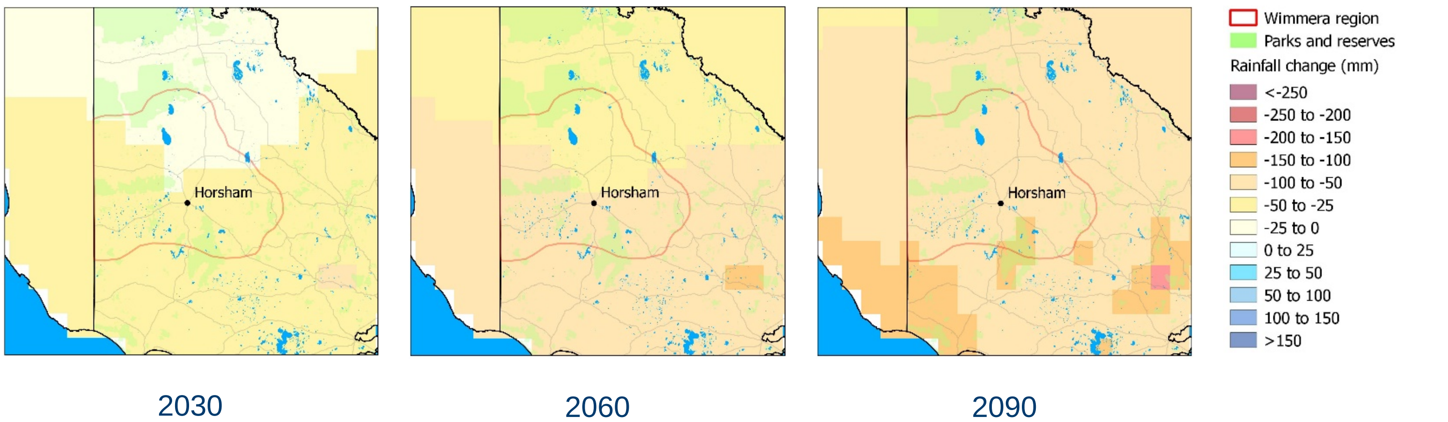

Figure 3b. Predicted change in total annual rainfall (mm)

Predicting the local impacts on land health, water availability, agricultural productivity, ecosystem health and social well-being is even more complex.

Climate change and agriculture

Global climate science predicts that Australia will be much more affected by climate changes than most other countries in the world (Garnaut 2008). Australian agriculture is predicted to be the industry most affected, with reduced farm productivity expected to result in a decline of 17% by 2050 (Commonwealth of Australia 2008). With the threat to the viability of rural communities and farming enterprises, it is surprising that rural communities remain sceptical and inactive about climate change, believing that the increasing amplitude and frequency of extreme climate events are a normal variation (Commonwealth of Australia 2008; Commonwealth of Australia 2010; Buys et al. 2012).

The predicted climate change impacts on agriculture within the Wimmera region include:

- wheat yields for 2050 range between an increase of 6% and a decrease of 10% (BRS 2008b)
- wheat yields decline by up to 18% by 2030, with greater yield variability (BCG 2008)
- decrease wheat yield (3.7t/ha) due to 47% increase in haying-off by 2050 (Nuttall et al. 2012)
- changed wheat yield due to increased heat shock (57% - 68%), frost risk (54% - 78%) and the timing of the autumn break (Fernando et al. 2013)
- elevated temperatures may increase cereal diseases (Nancarrow et al. 2014) and/or agricultural pests and decrease their natural predators (Thomson et al. 2010)
- lower wool production, more sheep heat stress, less reproduction, and lower growth rates (BRS 2008b)
- Agricultural water allocations will be less than current maximum in more than 50% of years by 2030 (BRS 2008a)

Perceptions and attitudes

While climate and earth scientists are equipped to identify the nature of climate change, the social sciences are arguably best equipped to investigate how climate change will be translated through to human activity and interaction at the community level (Duerden 2004).

CSIRO has been conducting annual surveys of more than 5,000 Australians, to assess their attitudes to climate change (Leviston and Walker 2010; 2011; Leviston et al. 2013; 2014). Their research supports the need for exploring alternative routes to behaviour change, especially since most people do not consider climate change to be a threat to them personally. Although more than 80% of those surveyed believed that climate change was real, there remains a high level of confusion, indecisiveness, and/or inconsistency about the root causes and how best to respond to the issue. Consistent with international research (e.g. Whitmarsh 2009), the CSIRO surveys showed that changes in everyday behaviour relevant to climate change is usually undertaken for a variety of reasons. The strongest predictors are personal relevance, feelings of moral and ethical responsibility, and experience with climate change.

The longitudinal CSIRO research shows that the 2,200 Australians involved in repeated surveys are growing slightly more trusting of a range of agencies to tell them the truth about climate change, with trust in university scientists and friends and family, remaining highest throughout the survey period (2010-2013). Those surveyed grew slightly more positive about the potential outcomes of responding to climate change, acknowledging that responding to climate change would foster greater community spirit and sense of purpose and were less concerned about the cost, and more positive that something meaningful could be done by Australia about climate change (Leviston et al. 2014).

A comprehensive and detailed study of Australian rural community perceptions and attitudes to climate change was recently published by Buys et al. (2012), with a focus on communities in north eastern Victoria and north eastern Tasmania (i.e. forest industries). Their research concluded that greater engagement of the rural communities in climate change issues will require significant changes in terminology and communication strategies. Their findings are supported numerous global studies examining the challenges in communicating the risks associated with climate change. The review by Buys et al. (2012) identified three main barriers: the first is a belief that because of the global scale and pace of changes, individual action and behaviour change is unlikely to be effective; the second is that the maths, science and systems thinking knowledge and language is too confusing for the non-expert public; and the third is that climate change science challenges socio-cultural values and belief systems, especially conservative political and religious values.

Surveys specifically targeted at Australian farmers include that by Donnelly et al. (2009), which included in-depth interviews with peak industry organisations, local producer groups and primary producers, and a national survey incorporating 1,000 urban dwellers and 1,000 primary producers. This research results reinforced the scepticism of farming communities with 27% of primary producers believing in anthropogenic climate change, compared to 58% of urban dwellers. However, despite disbelief in human induced climate change, many primary producers indicated that they have or would take up adaptation and mitigation initiatives for changes in climate and to improve the viability of their business. This does not extend to carbon trading, which their research indicated was viewed very negatively by primary producers who indicated a strong resistance towards its implementation.

The research by Donnelly et al. (2009) reported that primary producers have significant barriers to adapting to changes in climate such as financial stress from prolonged drought, an ageing workforce and succession issues. While communication is acknowledged as the foundation of behaviour change, communication strategies that will grab the attention of primary producers need to be relevant at the local level, credibly sourced, and refer directly to their area of activity, both geographically and thematically. The use of local media channels, specific rural publications, radio programs and internet services will support extension activities. All the forms of communication are required since farmers use them to test and interrogate the information they receive from their advisors, such as accountants, agronomists and government agents.

Research funded through the Bureau of Rural Sciences into climate risk and industry adaption (Milne et al. 2008) involved 149 participants in four Australian farming communities: two irrigated (Cobram & Mildura) and two dryland (Temora & Condobolin). The study found that people's motivations to respond to climate change were due to 1) an immediate sense of threat to livelihood, 2) rising to a challenge, and 3) a sense of moral responsibility. In analysing the links between personal beliefs in climate change and their willingness to adapt, four typologies were delineated:

1. those open to the idea of climate change, unsure if it was happening, but making strategic changes such as diversification to other industries (35% of those studied),
2. climate change sceptics who were making changes anyhow (15%),

3. those open to climate change, but still unsure, and feeling overwhelmed or saw climate change as low-priority (24%), and
4. sceptics more concerned with day-to-day survival or were struggling to cope (26%).

Similarly, a Rural Industries Research and Development Corporation (RIRDC) study (Hogan et al. 2011b; 2011a; 2011c) analysed a survey dataset provided by the Department of Agriculture, Fisheries and Forestry (DAFF) of 3,993 Australian farmers to ascertain factors that are associated with decisions making in adapting to risks posed by climate change. This study found that different types of farmers showed an interest in, and capacity to, adapt to climate change, based on their ability to cope with change, social connectedness, and their ability and readiness to use information. These studies by Hogan et al. segmented farmers in the basis of attributes such as health, values, beliefs, etc. in the context of their ability to adapt to climate change. Using cluster analysis their research found three clusters: the largest (55%) were identified as 'cash poor long-term adaptors', who are farmers that recognised that they were being affected by drought and drying and were actively engaged in adaptive practices, despite the fact that they had little income and poor farm resources. A third of this group reported their health was a barrier to sustained activity in farming. The second group, termed 'comfortable non-adaptors' (26%), are farmers who were not readily affected by drying, and enjoyed good incomes, good health and better farming conditions. This group expressed little desire to adapt. The third cluster were termed 'transitioners' (19%), being farmers who recognised that they were affected by drying and despite a desire to adapt, they had very little means to do so. Despite being younger, this group reported the poorest health and natural resources.

The same data set was used by Berry et al. (2011) in a detailed analysis of farmer health and adaptive capacity in the face of climate change. Berry et al. (2011) used hierarchical linear regression in a multivariate analysis of the data to examine 20 aspects of adaption to explore whether farmer's health was a barrier to undertaking farm work. Their results indicated that pre-existing health problems are a very important consideration in designing adaptation programs and policies. These problems may mediate or modify the relationship between adaptation and farmer health. The key message in the research by both Berry et al. (2011) and Hogan et al. (2011c) is that it is more important to recognise the intent to adapt, starting from where people are at in regards to their personal and financial health.

In 2009, research into Victorian 1,503 farmer's attitudes to climate change across a range of agricultural sectors (<5% in the Wimmera) found that 56% of those surveyed agree that climate change is a serious issue (WIDCORP 2009). The survey was timed near the end of a decade-long drought, which may have influenced the participants' adaptations to climate change, such as adoption of efficient water use practices (86.7%), adoption of new technologies (71.7%) and changes to their crop, pasture or grazing systems (69.7%). More than half of those surveyed had changed their business structure or management (51.6%), and changed their farming enterprise mix (45.5%). Four distinct farmer types were identified, to assist in targeting extension for practice change.

Following on from this research, a further survey of 1,306 Victorian farmers (14.5% in the Wimmera) was completed in 2011 (Schwarz et al. 2012). This survey was timed after the end of the millennial drought, which may explain why there was less farmer adaptation to climate change. Nevertheless, 68% of grain growers were changing cropping systems to no-till and 28% adopting variable rate technologies. Among the livestock producers 43% were adjusting the timing of key events and 40% changing to new pasture species.

Farmers' responsiveness to climate is reinforced by research undertaken for the North Central Catchment Management Authority (CMA) (McDonald et al. 2006; Thwaites et al. 2009) which found widespread scepticism of climate change but acceptance of 'climate variability'. The more recent of these projects was undertaken in 2008 in two communities: Muckleford and Kamarooka (36 participants). It found that broad acre farmers were more sceptical of climate change but more confident in their adaptive capacity to climate variability, partly attributed to improved information and technology (e.g. availability of weather and seasonal forecasts).

The confidence in adaptation to climate variability has been reinforced by Bureau of Rural Sciences research (Steffen et al. 2006) which concluded that the agricultural industries that were consulted were able to adapt to gradual changes in climatic averages, even a greater incidence of extreme events, through good management of within-season variability. It would not be true however, for major, abrupt changes in climate. They found that the type of climate information required to support farming decisions depends on whether tactical (within growing season) or strategic (multiyear or decadal) decisions are being considered. Most farmers recognise that within-season climate affects profitability, and therefore would like long-term forecasts of climate change to be stated in terms of how trends in local climate averages will be affected. Their research concluded that a risk-management approach provides the framework for identifying, analysing, evaluating and dealing with the challenges and opportunities associated with climate change.

Wimmera social profiling

Social research into landholder motivations for change in the Wimmera have been completed by the Institute for Land, Water and Society at Charles Sturt University for the Wimmera CMA (Curtis et al. 2008; Curtis and Mendham 2012) and the National Centre for Groundwater Research and Training (Mendham and Curtis 2014); by the Water in Drylands Collaborative Research Program (WIDCORP) for the Wimmera Mallee pipeline (WIDCORP 2006; Insightrix 2007; WIDCORP 2007); and community sustainability (Gaillard et al. 2011; Graymore and Schwarz 2013).

The most recent report for the Wimmera CMA (Curtis and Mendham 2012) documents research conducted in 2011 of 494 landholders with properties >10 hectares, and included respondents who had been surveyed 5 and 10 years earlier (Curtis et al. 2008). Farmers represented 56% of those surveyed in the Wimmera CMA region (cf: 80% in the 2002 survey). Among the respondents, 69% used their land as dryland pasture, 67% for broadacre cropping and 63% for sheep (63% for meat and 57% wool production). Not surprisingly, being surveyed after the millennium drought, water flows rated among the highest issues of concern, along with loss of rural services, declining soil health, managing weeds and pests and property viability.

Curtis and Mendham's (2012) report indicates that up to 50% of rural properties will change ownership in the next 10 years, creating a change from a relatively stable rural landholder population of the Wimmera, given that the median length of residence is 45 years and the median length of property ownership is 28 years. This may have implications for adaptation to climate change, with a new generation of property ownership.

Exploring the key factors linked to adoption of current recommended practices identified in the Wimmera Regional Catchment Strategy (WCMA 2013) was a key objective. The 18 survey items to explore current recommended practices were:

- Practices undertaken over the full period of your management
  - Area of trees and shrubs planted (including direct seeding) [ha]
  - Area of farm forestry established [ha]
  - Length of fencing erected to manage stock access to rivers/ streams/ wetlands [km]
  - Area of native bush/grasslands fenced to manage stock access [ha]
  - Area sown to perennial pasture and lucerne [ha]
  - Number of off-stream watering points established
  - Area of gully erosion addressed [ha]
  - Monitor bore height (please write NA if not applicable)
  - Monitor bore water quality (if not applicable write NA)
- Practices undertaken over the last five years
  - Maximum area of crop sown in any year using adaptive no-till techniques [ha]
  - Maximum area of crop sown in any year using minimum tillage techniques [ha]
  - Area sown to perennial pasture and lucerne [ha]
  - Used precision farming techniques for cropping
  - Area of trees and shrubs planted (including direct seeding) [ha]
  - Area of farm forestry established [ha]
  - Length of fencing erected to manage stock access to rivers/ streams/ wetlands [km]
  - Area of native bush/grasslands fenced to manage stock access [ha]
  - Have you put an artificial wetland on your property?

The most common adoptions were: planting trees and shrubs (56%) and adopting cropping practices (50%) such as adaptive no-till, minimum-tillage and precision farming.

The longitudinal studies by Institute for Land, Water and Society at Charles Sturt University for the Wimmera CMA reinforce the observations in the global literature that predicting the human response to climate change is not a simple task, as communities are not passive players that will respond in easily predictable ways. Human activity is highly localised, and responses will be influenced by local geographical and social factors, including sustainability of communities, economics, and ability to cope with 'change' in a broad sense. Within the literature more and more studies and surveys are yielding important information about community experiences, but research effort by social scientists falls short of what is required to reduce the level of uncertainty (Duerden 2004).

Agricultural adaptations

Agricultural adaptations to climate change fall into two categories:

1. Adaptations to reduce climate change impacts from farming enterprises. These include carbon farming initiatives, carbon sequestration, reduced emissions, use of renewable energy technologies, use of biofuel, reduced transport, etc. These are often referred to as planned adaptations, usually undertaken or directly influenced by governments (or non-government collectives) as public policy initiatives.
2. Adaptations of the farming enterprise to accommodate changing climates. These include improving water retention in soils, diversifying farm production, using new cultivars, increasing farm resilience, using sensor technology and 'smart farming' technologies, etc. These are more likely to be reactive adaptations in response to changing political, market, economic, social or environmental factors.

The two are not mutually exclusive and progressive farmers will adopt both adaptations. For example, carbon sequestration through the use of biochar will improve soil water retention, and carbon sequestration through agroforestry, will diversify farm production and increase resilience. However, in the literature, the two are often treated separately.

In relation to adaptations to reduce climate change impacts from farming enterprises, Gunasekera et al. (2007) point out that Australia's agricultural sector account for 60% of total methane emissions, 84% of total nitrous oxide emissions and 17% of overall greenhouse gas emissions in 2005. Their comprehensive and detailed research concludes that incorporating agriculture and land use sector emission into any proposed emissions trading scheme will be challenging. Their preliminary analysis shows that because the emission intensive farm inputs are a relatively low component of total farm costs, the indirect impacts of potential carbon pricing on on-farm costs are likely to be modest. They conclude that cost effective alternative adaptation and mitigation options need further research.

In a classic systems thinking approach to the role of agriculture in climate change Pielke et al. (2007) suggest a new paradigm which focuses on the vulnerability of agriculture to the spectrum of climate change and climate variability threats (Figure 4).

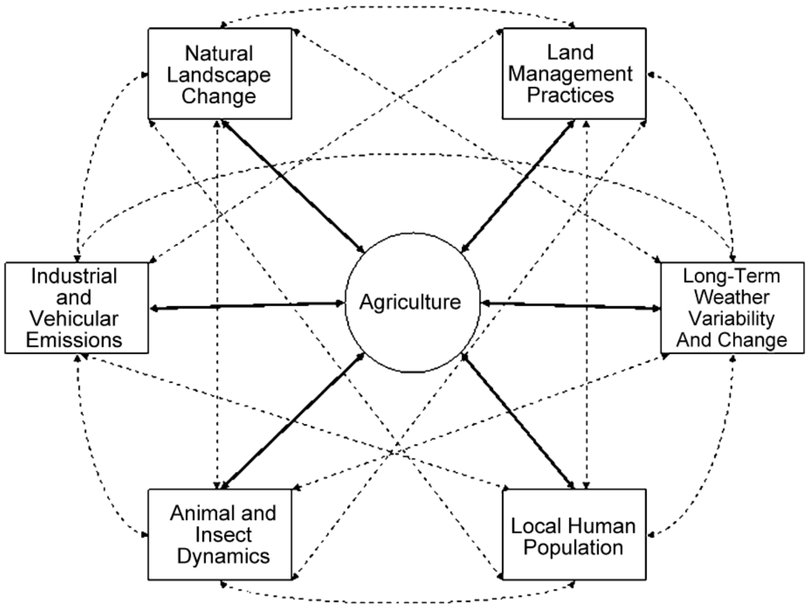

Figure 4. Schematic model of the relation of agricultural vulnerability to the spectrum of climate forcings and feedbacks. The arrows denote nonlinear interactions between and within natural and human forcings (Pielke et al. 2007).

Their model includes agriculture as both a contributor to climate change (through land management practices and emissions) as well as impacted on by climate change. Their intention is that this new paradigm will permit the non-climatic relative risks to be considered by policy makers, so that more informed decisions can be made regarding the resilience of agriculture.

Recent research by Steffen et al. (2011) explored the climate change risks to, and the adaptive capacity of, Australian agriculture in an attempt to determine what might constitute 'dangerous levels' of climate change. In combining the current nature of Australian agriculture with its sensitivity to future climate risks and the adaptive capacity of the farming enterprises, they conclude that for the vast majority of Australian agricultural enterprises water availability is more important climate parameter than temperature (*per se*). Because water availability is also affected by non-climate processes (e.g. desalination, water transfer, groundwater storage and retrieval, etc.) determining what constitutes 'dangerous climate change' is difficult. Broadacre dryland cropping may be more vulnerable because it does not rely on water availability from sources other than rainfall.

The news is not all bad, however. Sanderson and Ahmadi-Esfahani (2011) modelled the comparative advantage that Australia enjoys in global broadacre agriculture, using a hybridized Heckscher–Ohlin–Vanek (HOV) Ricardian framework to examine the implications of predicted climate change. Their analysis used shocks to the yields of grains and pasture activities to replicate potential climate change scenarios. Their results showed that Australia will continue to enjoy a comparative global advantage in the production of grain crops and livestock, which are the predominant agricultural ventures in the Wimmera. While there will be declines in the resilience of that comparative advantage, their proposition remains robust for the simulations up to the year 2110.

The Wimmera's current sensitivity to crop farm incomes had been compared to other regions in Australia using the Australian Bureau of Agricultural and Resource Economic's (ABARE) AgFIRM model in research funded by the Grains Research and Development Corporation (GRDC) (Nelson and Kokic 2004). Their analysis placed the Wimmera towards the higher end of sensitivity to climates when compared to Australian crop producing regions (Figure 5).

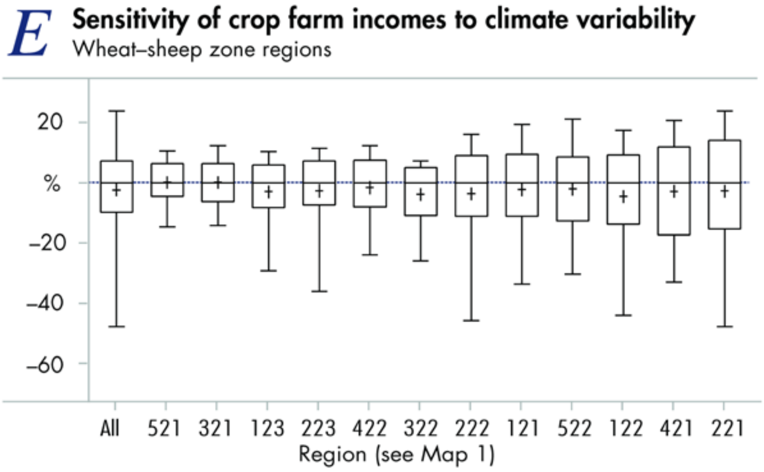

Figure 5. A comparison of sensitivity of crop farm incomes to climate variability for Australian cropping regions. The Wimmera is region 222.

(The box bounds the upper and lower quartile, the whiskers bound the 95th and 5th percentile. The cross is the mean) (Nelson and Kokic 2004).

On farm adaptations to improve broadacre dryland agricultural resilience in the face of climate change in the Wimmera region are well documented in the literature. These are summarised by the Bureau of Rural Sciences (BRS 2008b) as:

- zero-tillage to reduce soil moisture loss and to protect the soil in areas of increased rainfall intensity
- using seasonal forecasts to manage production risks
- extending fallows to effectively capture and store soil moisture
- planting later in the season when there is enough water in the soil profile
- widening row spacing, or skip-row planting
- lowering plant density
- staggering planting times
- developing efficient on-farm irrigation management
- monitoring and responding to emerging pests
- assessing fertiliser inputs

Strategies suggested by the Birchip Cropping Group (BCG 2008) include:

- introducing or increasing a fallow or pasture component in crop rotations to offset potential yield losses by retaining more available soil moisture. In one continuous cropping system, introducing a fallow improved median yields by up to 30%.
- retaining stubble or enhancing stubble retention is an effective way of offsetting potential yield losses in the region.
- options such as reducing planting densities, increasing row spacing, and changing to shorter-season varieties were shown to provide few benefits for the farms examined in this region

Apart from changing climates, the longer term global forecast for meat, energy costs and soil resource constraints will all encourage Australian cropping farmers to maintain mixed systems (Bell and Moore 2012). Although ley farming systems with phases of shorter annual legume pasture rotated with cereal crops dominate, dual-purpose use of cereals and canola for forage during the vegetative stage while still harvesting for grain is increasingly practiced throughout southern Australia's cropping zone. This practice, promoted in the Wimmera through the Grain and Graze program (Grain and Graze 2014), provides resilience while increasing both livestock and crop productivity from farms by 25–75% with little increase in inputs (Bell et al. 2014).

Agricultural industry diversification has also been examined in detail for the Wimmera through the Sustainable Agribusiness Opportunities from the Wimmera Mallee Pipeline project (SAOW). A series of feasibility studies were completed for the project, focused on the potential for lamb feedlots (Burger et al. 2008c), cattle feedlots (Watts et al. 2008), piggeries (Burger et al. 2008b), and broiler farms (Burger et al. 2008a), and included the development of an economic analysis tool (DPI 2009). A marketing prospectus was produced to encourage investment in intensive livestock farming and grain processing (DPI 2010) and published in both English and Chinese language versions. A series of factsheets have also been produced, most recently by the Wimmera Development Association (WDA 2012a; WDA 2012b). The project continues with a mapping program underway with the broad support of the participating councils (West Wimmera, Hindmarsh, Yarriambiack, Northern Grampians, Buloke and Horsham) as well as DEPI (Fletcher 2013).

In the Wimmera Southern Mallee Regional Plan (RMCG 2011; DPCD 2013), the first mentioned strategic direction is to *'strengthen the farming sector's capacity to prosper in a changing climate'*. The plan draws many of the same conclusions as this review, also noting that the region is capable of locally relevant research, especially with the Grains Innovation Park and BCG. The plan suggests that research and development of new plant varieties and farming systems, and improved information will be required for the agricultural sector to adapt. Actions identified for adaptation in the plan include: to analyse the impacts of climate change at the local level and use scenario analysis to assist comprehension of climate change; develop new plant varieties and sustainable farming systems; and explore the best use of the Wimmera Mallee Pipeline and improve local weather forecasting capabilities for reactive adaptation. These actions also concur with those listed in a Northern Grampians Shire Agricultural Sector Development Plan (SED 2010).

In the global literature, more forward-thinking adaptations include value-adding to the product by the development of cereal cultivars that are more suited to a diversified utilisation of the whole plant for food, feed, and non-food applications, such as fuel, plastic, paper and textiles (e.g. Figure 6 sourced from: Munck and Møller Jespersen 2010).

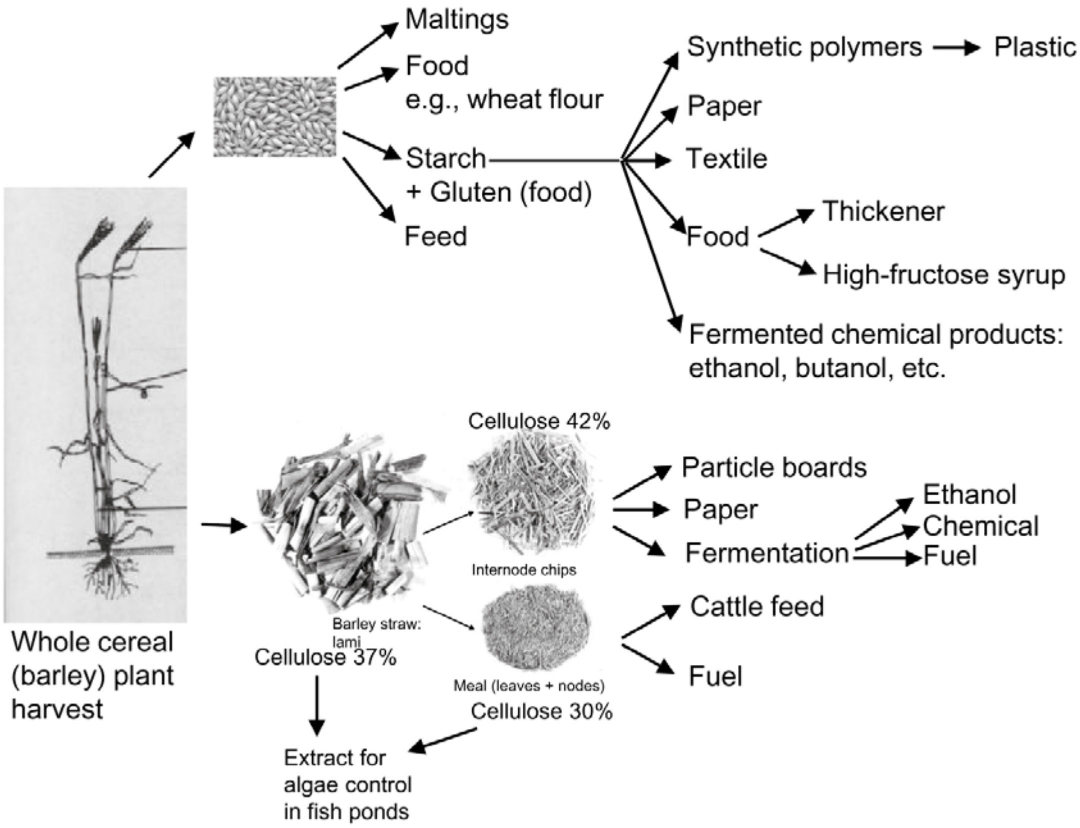

Figure 6. Whole cereal plant utilisation (Munck and Møller Jespersen 2010).

In the United Kingdom (UK) the Economics of Climate Resilience program recently released a report which investigated adaptation to climate change in the UK agriculture (Frontier Economics 2013). The analysis extended across all agricultural sectors and specifically examined:

- New breeds and varieties
- Storage infrastructure and buildings
- General farming practices for crops and livestock
- Responses to pests and diseases
- Water management
- Soil management
- Ecosystem services and agri-environment management
- Knowledge transfer, and
- Financial risk management

In regard to arable farming (cropping), the UK study reports that the key barriers to adaptation are behavioural and information-related. Farmers require immediate economic benefit to change behaviours and a lack of information compounds the problem. Similarly with livestock farmers, a lack of awareness is the key barrier to behaviour change. Soil management, knowledge transfer and financial risk management also are constrained by communication and information issues, with inconsistent messages, highly fragmented knowledge networks, poor science information and limited knowledge among farmers singled out as barriers to adoption.

The UK study concords with the global literature (including Australian studies), and has application to the Wimmera. The research acknowledges that climate change adaptation actions are currently being taken by many across the agricultural sector, or are likely to be taken in the near-term. However some key barriers to effective adaptation remain, namely:

- Intra-value chain dependencies resulting in a lack of incentive to develop climate change resilient breeds and varieties of crops; long lead times and a lack of translation of research into products;
- Cross-sector dependencies, where the adaptive actions by others can influence a farmer's adaptive capacity to reduce their reliance on nature (for water availability or the prevalence of pests and diseases, for example). The Wimmera Mallee pipeline is a local example;
- Information failures are perhaps the most commonly cited barrier. Accessible and practical information for farmers in relation to climate change risks and appropriate responses is often limited, with uncertainty over the impacts of climate change a particular issue;
- Poor co-ordination across the range of parties may limit a farmer's ability to jointly benefit from adaptive actions; and
- Behavioural failures in respect to short-term views and resistance to change can hinder the implementation of adaptive actions.

Summary

From this limited analysis of the literature on climate change and agriculture, a number of consistent messages are evident:

1. Rural populations, and broadacre farmers in particular, generally remain sceptical of climate change, but are accustomed to climate variability. The scepticism is founded in the discrepancy between actual observations and alarmist rhetoric; conservative political, religious and socio-cultural beliefs; the confusion of scientific and systems thinking knowledge and language; and the belief that individual action is futile in the global scale and pace of change.
2. Clarity in communication of climate change is paramount, with a focus on clearly objective scientific facts, without any reference to politics and belief systems. Effective communication requires the use of a variety of local media sources and internet resources. Information is best understood when it is up-to-date, credibly sourced, geographically relevant and thematically relevant. Above all, it must acknowledge the economic realities of farming and the practicalities of any suggested behaviour change.
3. There is a generally consistent typology of farmers when considering their adaptation to climate change. The largest group are those who recognise that climates vary (and may in fact be changing), and are actively engaged in adaptive practices, despite income limitations, poor farm resources and health issues. The intermediate group are farmers who are financially better off, in good health, better farming conditions and little desire to adapt. The smallest group are farmers who struggle to survive, are in poor health and overwhelmed by day-to-day farming without thinking of adaptation.

4. The message that agriculture is a contributor to climate change (through land management practices and emissions) is generally ignored, as reactive adaptations are more prevalent on farms than planned adaptations. Most farmers are confident at being able to adapt to gradual climate changes and irregular extreme events, through their experience. They rely on climate information for both tactical and strategic decisions. Adaptation to climate change requires credible long-term forecasts to be communicated in terms of how trends in local climate averages will be affected, which is difficult given the inexact nature of the systems science.
5. Despite the forecasts of lower crop yields, Australia will maintain its comparative global advantage in the production of grain crops. However, the farm incomes in the Wimmera are more sensitive to climate change than some other cropping regions in Australia and adaptations and diversification will be required to build more resilience to climate change for farms to maintain economic viability. Adaptations to improve broadacre cropping and crop-livestock systems are already being practised and encouraged through programs such as no-till farming and Grain and Graze. Ongoing research and development will continue to develop new crop varieties and cultivars to sustain the current practices.
6. Agricultural industry diversification projects are emerging, with substantial promise of building resilience. These may need to be linked to planned adaptation schemes, holistic use of products and pragmatic examples of economic benefit to encourage their uptake.

Reflection

Fundamentally, broadacre agriculture in the Wimmera exists because of its favourable planar topography, soils and climate. It is an important grain producing region that contributes to Australia's export market, and is likely to remain so for the foreseeable future. It is clear from this literature review that considerable efforts are being made to sustain the agricultural business as usual in the Wimmera.

In their seminal book - '*Resilience thinking*' - Walker and Salt (2006) argue that when considering regime shifts, such as climate change, aiming for sustainability is not enough. Based in part on a regional resilience assessment for the Goulburn-Broken Catchment (Walker et al. 2009), Walker and Salt convincingly argue that sustainability - *the likelihood an existing system of resource use will persist indefinitely without a decline in the resource base or in the social welfare it delivers* - is an inevitable path to system collapse. By comparison, increasing resilience - *the amount of change a system can undergo (its capacity to absorb disturbance) and remain within the same regime* - is required. In some systems (e.g. the Goulburn-Broken Catchment) they argue that given the current state of the system and the likely future trends, that transformational change - *the capacity to create a fundamentally new system when ecological, economic and/or social conditions make the existing one untenable* - will be required.

Learning and knowledge underpin the capability for adaptation that leads to greater resilience of agriculture in the Wimmera. Both require improved knowledge exchange between the experts and the practitioners. Reinforcing the findings of this literature review, the Australian Government Productivity Commission also identified information provision as a barrier to effective climate change adaption (Productivity Commission 2012).

Knowledge exchange

Having identified knowledge exchange as one of the main barriers in adaptation to climate change, this section explores some of the practical options to overcoming that barrier in the Wimmera. It should not be regarded a complete analysis (being limited by time and budget), but rather the start of a discussion that may lead to further actions.

Challenges

Providing information and knowledge to the broadacre agriculture industry has been a business since the commencement of farming in the Wimmera (e.g. HWT 2014) With the range of services now available, the supply of information and knowledge is highly varied, uncoordinated and almost infinitely widespread. Everyday sources include radio, television, newsprint, newsletters, websites, mobile applications, agribusiness fact sheets and sales brochures, and local grower groups to name a few. In fact, supplying information to the broadacre agricultural industry is a specialised business, with reputable private agencies such as the Kondinin Group (www.farmingahead.com.au) supplying an extraordinary breadth and depth of practical, relevant and useful information.

In general, the custodians of the data and sources of knowledge may be:

- The municipalities and regional development associations;
- Federal and State government organisations and agencies;
- regional agricultural groups, agronomists and practitioners;
- universities, research organisations and international agencies;
- multinational agricultural corporations;
- local agricultural industries and agri-businesses; and
- individual farmers, farming corporations and stakeholders

In the Wimmera, the 494 landholders surveyed by Curtis and Mendham (2012) relied on traditional information sources, with newspapers (59%) and books, magazines, journals (53%) rating the highest. Most gained their information through the post (70%), followed by desktop computer (36%), local groups (31%) and smart phones (4%).

However, some in the Wimmera community are aware of the potential of information and communication technology (ICT) to enhance agricultural production. A survey commissioned by the Wimmera Development Association in late 2012 found that around 50% of the 123 people surveyed (45% primary producers) rated the potential benefit of all ICT applications surveyed as above average, even if they did not use the technology (ORM 2013). The survey, which benchmarked the use of ICT in the agricultural sector found that ownership of smart phones by primary producers is above the national average and internet use was advanced in the agribusiness sector.

The delivery of information using ICT technologies is not without challenges. The reality is that Australian broadacre agricultural and agribusiness information and data is distributed via dozens of web-portals, web-based GIS tools, password protected portals, cloud storage, portable storage devices; hardcopy maps, theses, books, reports, newsletters, brochures, fact sheets, documents, newspapers, magazines, videos and podcasts. The same situation exists for climate change data. The search for relevant and current data, and its collection and collation is a substantial component of any agricultural adaptation research project, which often results in days, weeks, months or years spent trying to assemble decision-ready data for a project. As larger data sets, such as high-resolution remotely sensed data, on-ground sensor data, precision agricultural data, time-series monitoring data, interactive global climate models, climate forecasts and scenario models and digital archives are now readily available, the task has become exponentially more time-consuming.

Outside of the research community, this impressive resource of data, information and knowledge on climate change adaptation in agriculture is largely ignored simply because most people do not have the knowledge, capability or desire to deal with the data deluge. Many people feel increasingly time-poor and most would just like to get an authoritative, definitive, answer to their questions, preferably via Google, or an App on a mobile device. Even though most people may realise that there is a plethora of data available, there is little opportunity or desire to undertake the research required to answer the question.

Consequently, farm productivity, management decisions and climate change adaptation planning may be based on partial information, the selection of which may be subjectively biased by the argument for or against climate change, a proprietary product, or to influence a sales outcome. While objectivism is impossible in marketing, the ready availability of objective scientific information and data will result in farmers, agribusinesses and their advisors making better informed choices. This is particularly true if the information can be geographically targeted, to aid comprehension of the advantages or limitations of a specific place in the Australian landscape.

The literature on adaptation to climate change is quite clear on this challenge.

eResearch

Internet technologies and mobile devices have changed the paradigm for both researchers and practitioners in agriculture, with the ability to find and connect to people with similar interests and engage in global synchronous conversations, exchange data and engage in intellectual discourse (Anandarajan and Anandarajan 2010; Schmidt and Cohen 2013). *eResearch* is the term given to the use of digital information technology to support existing research or discover new forms of research. In popular usage it describes when and how to use the internet to enhance the research process (Anderson and Kanuka 2003). eResearch is collaborative, data intensive and often utilises interoperability or grid computing (Riedel and Terstyanszky 2009).

The use of spatial digital technologies for the deeper understanding of agricultural landscapes, farm productivity and resilience to climate change is a rapidly emerging area of eResearch. Recent examples in the international scientific literature include the linking of traditional farm management information systems (FMIS) to precision farming technologies (e.g. Nikkila et al. 2010); the web-delivery of interoperable agricultural data with Open Geospatial Consortium (OGC) standards (e.g. Rafoss et al. 2010; Phillips et al. 2014); the development of new OGC standards such as precision agriculture mark-up language (PAML) (e.g. Murakami et al. 2007) and farm mark-up language (FarmML) (McAllister et al. 2013); and web-based spatial visualisation (e.g. Kubicek et al. 2013). Experimental tools that use sensors for weed management in cereals (e.g Thorp and Tian 2004; Berge et al. 2012), or soil moisture (e.g. Phillips et al. 2014) or fertiliser application (e.g. Robertson et al. 2012); and tools for the integration of precision agriculture data (e.g. Blank et al. 2013) have also been developed. Similarly, experiments with novel deployment of sensors, such as using drones to improve real-time visualisations, have also been published (e.g. Zhang and Kovacs 2012; Torres-Sanchez et al. 2014). And a plethora of websites and mobile applications (Apps) are now available to assist the farmer and agronomist in on-farm decision making.

At FedUni, eResearch has focussed on the development of interoperable spatial knowledge systems with dynamic modelling and visualisation capabilities, which have been developed to assist agricultural research and production, natural resource management, socioeconomic research and municipal planning (e.g. Dahlhaus et al. 2011; 2012; MacLeod et al. 2013; Milne et al. 2014; Thompson et al. 2014). These systems typically have the following features:

- The data resides with the data managers (ensuring currency and validity)
- They are intuitive to use (similar to Google Earth)
- All forms of data are included - vector, raster, text and multimedia
- Data downloads are allowed (subject to data custodian's consent)
- Spatial data links to original source documents and images
- Spatial data links to real time data (data loggers, webcams)
- They are capable of analysing the interoperable data on the fly
- Interactive 3D visualisations can be created for user-selected scenes
- Users can add, edit or update data (subject to quality assurance and quality control)
- The spatial data and models are credible to the user

With the dawn of high capacity broadband and interoperable technologies, the federation of datasets into a single virtual online database has become a reality. This is evidenced by the research projects already completed or being completed by FedUni, such as Visualising Victoria's Groundwater (www.vvg.org.au).

A key component of these systems is that the current knowledge custodians are empowered with the capability to share their information and/or data in the same virtual space without losing custodianship or ownership of the information value. The e-research tools federate all or parts of databases with disparate schemas and stored on disparate systems, subject to the custodian's consent. The tools are capable of seamlessly linking together knowledge, displaying graphs or maps of data and information, and creating interactive 3D or 4D visualisations of data where relevant. Additional data, information and knowledge from the Bureau of Meteorology (BoM), GeoScience Australia (GA), Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) or Australian Bureau of Statistics (ABS) can be linked in where relevant to enhance and extend the value of the research information.

Other stakeholders such as grower groups, consulting agronomists, agricultural information services, agribusinesses and individual farmers would be encouraged to share their information. Web-based tools can be constructed to make it easier to find data, such as climate change scenarios for a particular place in the Wimmera landscape, and overlay that with current or historic climatic data, soil data, groundwater data or terrain data. Much of this can be provided in an intuitive-to-use web-portal using interoperatively federated data.

The primary purpose in setting up an eResearch knowledge exchange system for the Wimmera (Figure 7) would be to inspire and encourage the broadest possible stakeholder participation and provide a platform for proactive broadacre agricultural research information dissemination (i.e. the Wimmera climate and agricultural knowledge exchange), with a focus on climate change adaptation and to demonstrate what may be possible. The strength of this initial research is that it leverages value from the investment in research and practices already completed or being completed.

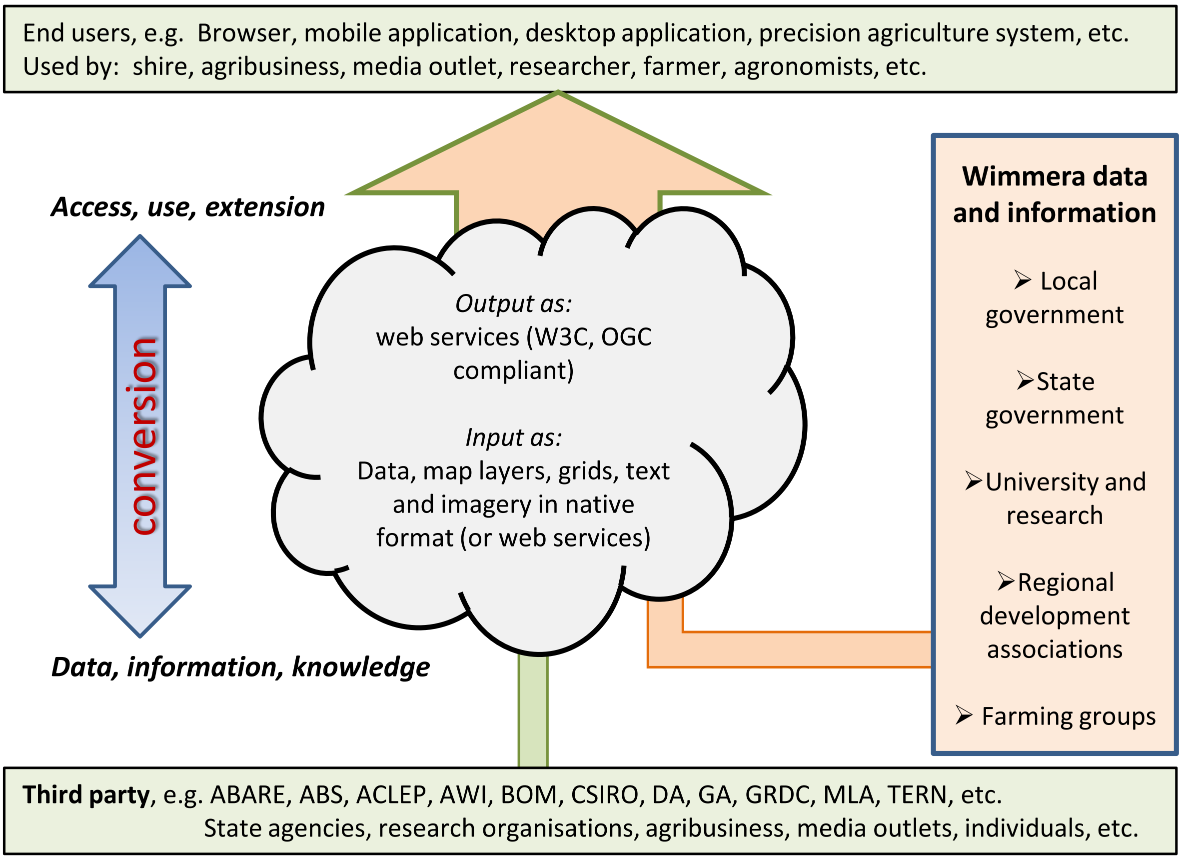

Figure 7. A conceptual system for e-research knowledge exchange in the Wimmera

As the interoperative knowledge base matures and becomes an integral component of Wimmera agricultural and agribusiness practice, the easy access to extensive data and information will inspire stakeholders with dozens of new and innovative eResearch opportunities. The intention is to: 1) improve the data availability and encourage adaptations that will build resilience in the current agricultural industries, and 2) encourage the generation of new research ideas and projects with other collaborators, locally to globally. In fact, the potential is limited only by the imagination.

Arguably the most challenging component of this proposed eResearch project will be in ensuring that the end users can utilise the technology to reap the rewards of the research investment. Potential limitations to success include issues such as the limited internet bandwidth and mobile coverage in regional Australia, and ensuring that the applications convey new information that is of practical use to the broadacre agriculturalist and agribusinesses in the Wimmera. These issues have also been flagged in the study on remote data use in agriculture (ORM 2013) and the Wimmera Southern Mallee Regional Plan (DPCD 2013). Both these limitations can be minimised by working closely with the Wimmera stakeholders and practitioners in the agricultural industry to ensure that the applications are efficient, intuitive to use and highly relevant to the end users.

The need for training was recognised in the Wimmera Development Association study on remote data use in agriculture (ORM 2013) and should be included as a component in the development of the Wimmera climate and agricultural knowledge exchange. A skill building program with workshops and mentoring is recommended, based on the highly successful Central Highlands Digital Enterprise program which has over the last 2.5 years supported thousands of individuals from SMEs and community organisations.

Smart farms

Some of the Australian Regional Universities Network (RUN) members have developed considerable expertise in digital technologies in agriculture. The University of New England (UNE), Southern Queensland University (USQ) and the University of Central Queensland (UCQ) all have expertise in precision agriculture and smart farming technologies. Both UNE and USQ have smart farms as part of their research and teaching resources. Refer to:

- UNE Smart Farm: www.une.edu.au/about-une/academic-schools/school-of-science-and-technology/research/smart-farm
- USQ Smart Farm: http://adfi.usq.edu.au/blog/?p=1564

Smart farms have the advantage of demonstrating in a practical way what is possible, especially with regards to best utilisation of precision agriculture and variable rate inputs (Lamb et al. 2008), in-paddock and in-farm sensor technologies (Phillips et al. 2014), real-time soil mapping (Christy 2008), robotics and drones (Slaughter et al. 2008), and the clever use of satellite remote sensing data and other global datasets such as agricultural commodity forecasts (Neumann et al. 2010; Han et al. 2012).

The creation of a smart farm in the Wimmera, perhaps utilising the Longerenong facilities, is encouraged as one means of providing practical adaptation demonstrations, as well as encouraging research that is relevant to the Wimmera agricultural landscapes. As a RUN member and with a campus in Horsham, FedUni is well placed to work with the Wimmera agricultural community and RUN partners in this proposed venture.

The role of local government

A study by the Australian Centre of Excellence for Local Government (ACLEG), University of Technology Sydney (UTS), resulted in a guide entitled *Climate Adaptation Manual For Local Government – Embedding resilience to climate change* (Inglis et al. 2014b; 2014a). The manual provides case studies and transferrable processes and tools that can be utilised to embed climate resilience in local government business and managing climate risk within the municipality. While the manual provides little relevance to the agribusiness sector, the principles of robust adaptation planning provided therein are clear about the need for greater communication and knowledge sharing, both internally and externally.

A municipal office or website is not the first place that a broadacre farmer would think of when seeking knowledge or information on adaptation to climate change. However, many of the on-farm decisions can be enhanced with data and information that is held within the Shires, such as high-resolution digital terrain models, soil maps, flood maps, roadside weed mapping, biodiversity maps, legacy documents on past agricultural research, water supply and drainage, or feasibility studies on agricultural enterprises, etc. In addition it is likely that shires will have access to studies or models that have been completed on climate change predictions, such as those recently completed for the Wimmera CMA (Spatial Vision 2014). Clearly, liberating this data and making it discoverable in a Wimmera climate and agricultural knowledge exchange portal would greatly assist in decision making in climate change adaptation and resilience building in the agricultural sector.

In examining barriers to climate change adaptation, the Australian Government Productivity Commission also recognised the role of local governments in providing information to property owners on current and future climate risks and state that it is the responsibility of state government to ensure that they are adequately resourced to do so (Productivity Commission 2012).

Conclusions and recommendations

It is clear from the literature that agricultural production in the Wimmera will be affected by climate change and almost all predictions are that crop yields will become more variable, with an overall drop in production over the next few decades. Considerable effort has been made to understand the attitudes and perceptions of Australian farmers, including those in the Wimmera, to climate change. The research shows that rural communities - and broadacre farmers in particular - are generally conservative and sceptical of climate change, but actively engaged in adaptation to climate variability, where health and finances allow.

Research is focused on adaptations to sustain and improve broadacre cropping and crop-livestock systems, through programs such as no-till farming, Grain and Graze, and ongoing research and development will continue to develop new crop varieties and cultivars. Agricultural diversification into intensive industries such as feedlots, piggeries and poultry are being encouraged, based around the Wimmera Mallee Pipeline. All efforts are being made to sustain the agricultural business as usual.

Resilience thinking suggests that sustaining the current broadacre agricultural systems will not be enough to maintain farm viability in the face of climate change and that adaptations are required to build resilience. These may include on-farm diversification, new agricultural ventures and developing new products from agricultural produce.

The single message that emerges from all of the research and studies is that the consistent barrier to adaptation to climate change in agriculture is the inadequacy of information and knowledge transfer. Knowledge exchange between the expert and the practitioner needs to be improved to increase the resilience to agriculture in the face of the predicted climate change in the Wimmera.

Recommendations

Three recommendations are made to improve the flow of climate change knowledge and information to farming and agribusiness, to encourage adaptation:

1. Establish a knowledge exchange portal to improve the information availability and encourage adaptations that will build resilience in the current agricultural industries, and encourage the generation of new research ideas and projects with other collaborators;
2. Adopt an open data policy among all the municipalities, state government agencies and research institutions in the Wimmera. Local government in particular has much to offer in unlocking access to the spatial information they hold and making it interoperably visible to other web portals;
3. Conduct training and skills-building programs that include workshops and mentoring to make best use of the knowledge exchange portal and the use of the data and information it provides access to;
4. Explore the feasibility of establishing a smart farm in the region, to demonstrate the practical advantages of new technologies;

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