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Creating a climate for food security: the business, people and landscapes in food production

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The businesses, people and landscapes in food production

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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ABSTRACT

Balancing human and environmental needs is urgent where food security and sustainability are under pressure from population increases and changing climates. Requirements of food security, social justice and environmental justice exacerbate the impact of agriculture on the supporting ecological environment. Viability of the Australian rural economy is intrinsically linked to food production and food security requiring systematic evaluation of climate change adaptation strategies for agricultural productivity.

This food-systems research drew on global climate change literature to identify risks and adaptation. The transdisciplinary team applied specialist experience through collaboration in social science, economics and land-management to provide comprehensive methods to engage researchers and decision-makers across the food-system. Research focus on the dairy and horticulture sectors in the SW-WA and SEQ provided a comparative context in food-systems and regional economies. Expert knowledge was engaged through a series of panel meetings to test and challenge existing practice applying conceptual and empirical approaches in Structural Equation, Value-Chain, Supply-Chain modelling and Analytical Hierarchy modelling. This iterative action-research process provided immediate generation and transfer of expert knowledge across the involved sectors. The scenarios and adaptive strategies provide evidence-based pathways to strengthen food-systems; account for climate change mitigation and adaptation; and weather-proof regional economies in the face of climate change.

The triple-bottom-line provided a comprehensive means of addressing social, economic and ecological requirements, and the modelling showed the interacting dynamics between these dimensions. In response to climate change, the agricultural sector must now optimise practices to address the interaction between economic, social and environmental investment. Differences in positions between the industry sector, the government and research sectors demonstrate the need for closer relationships between industry and government if climate change interventions are to be effectively targeted.

Modelling shows that capacity for adaptation has a significant bearing on the success of implementing intervention strategies. Without intervention strategies to build viability and support, farm businesses are more likely to fail as a consequence of climate change. A framework of capitals that includes social components - cultural, human and social capital-, economic components -economic and physical capital - and ecological components - ecological and environmental capital - should be applied to address capacities.

A priority assessment of climate change intervention strategies shows that strategies categorised as ‘Technology & Extension’ are most important in minimising risk from climate change impacts. To implement interventions to achieve ‘Food Business Resilience’, ‘Business Development’ strategies and alternative business models are most effective. ‘Research and Development’ interventions are essential to achieve enhanced ‘Adaptive Capacity’.

The individual components of TBL Adaptive Capacity can be achieved through ‘Policy and Governance’ interventions for building ‘Social Capital’ capacity, ‘Research and Development’ will develop ‘Economic Capital’, and ‘Business Development’ strategies will build ‘Ecological Capital’.

These strategic interventions will promote food security and maintain resilience in local food systems, agricultural production communities and markets, global industrial systems, and developing world food systems. Climate change mitigation and adaptation interventions reflect a rich conceptualisation drawing from the Australian context, but also acknowledging the moral context of global association.

EXECUTIVE SUMMARY

Predicted population growth over the next 50 years will raise global food demand (Trostle 2008). This is complicated by environmental changes such as climate, biodiversity, water availability, land use, pollutants and sea-level rise (Misselhorn *et al.* 2012). Development of appropriate strategies for minimising risks and enhancing adaptation and mitigation capacity across the food system is considered important for sustainable agriculture and food production in Australia.

This research combines social science, economics and ecological knowledge from two states (SW WA and SEQ). Two contrasting food production systems (Horticulture and Dairy) and a range of local, regional and global food interests were included. This integration of disciplines and practices has allowed a unique insight into the issues facing global food security, but more importantly the rich opportunities for positive change that might result from treating food as a triple-bottom-line system with global accountability and local innovation.

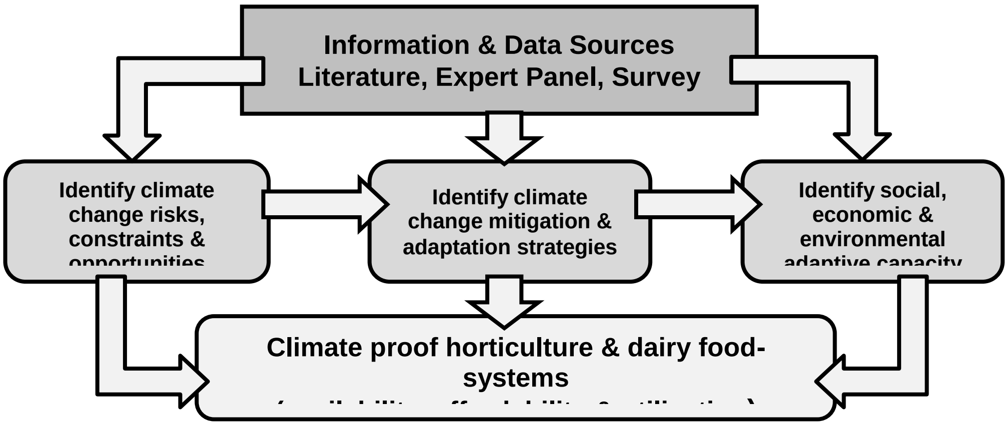
The outcome focus was on building resilience in food-systems through triple-bottom-line accounting in climate change mitigation and adaptation. The key message from this research indicates the importance of including triple-bottom-line values at the outset of planning for strategic intervention in climate change in agri-food systems.

RESEARCH FOCUS

- Who are the decision-makers, stakeholders and contributors that influence interventions to climate change in horticulture and dairy food systems?
- What risks to horticulture and dairy food-systems in Australia are generated through human-induced climate change?
- What are the best strategies for interventions to address climate change that will strengthen vertically linked food-systems?

RESEARCH STEPS

1. ***CONCEPTUAL DEVELOPMENT***
   a. A review of the international literature on food security to establish definitions and parameters.
   b. Identify risks to horticulture and dairy due to climate change.
   c. Establish a methodology and methods appropriate for application in triple-bottom-line approaches to food systems research.
2. ***SURVEY RESEARCH***
   a. Establish value positions in the horticulture and dairy sectors based on a profile of Expert Panel participants through survey methods.
   b. Identify climate change related risks in dairy and horticulture.
   c. Identify potential interventions to climate change in dairy and horticulture.
3. ***EXPERT PANEL CONSULTATION***
   a. Identify climate change risks, mitigation and adaptation strategies with potential application in horticultural and dairy food systems.
   b. Analysis to identify key positions in risk, mitigation and adaptation and strategic intervention.
4. ***EVALUATION OF CAPACITY, OPTIONS & IMPACT OF CLIMATE CHANGE INTERVENTION STRATEGIES***
   a. Identify scenarios suitable to test and identify points of intervention for policy development and practice.
   b. Conduct integrated modelling to identify trajectories, requirements for and implications of strategic interventions.
   c. Identify effective climate change intervention strategies (mitigation and adaptation) to climate proof horticultural and dairy contributions to resilience in food systems.



RESEARCH FRAMEWORK

RESULTS

- The experts contributing to this research indicated that:
  - The oil crisis has significant implications for food systems
  - Technology is important in the future of food
  - Australia does not hold a significant responsibility for providing for global food needs
  - Agriculture has some impact on ecological systems
  - Human-induced climate change will have a consequence for rising temperatures
  - The most urgent environmental issues facing production landscapes are introduced plants and animals
  - Climate change will have significant consequences for production landscapes.
- The results of both the survey analysis and the EP workshop analysis indicated differences in the way climate change risk is likely to impact in SEQ and SW WA.
  - In WA risks due to climate change related to changes in food production requirements (water, rainfall, average temperatures) reducing production in marginal horticultural and dairy areas. The Panels indicated a flow-on effect for social cohesion in rural communities.
  - In SEQ climate change risks related to extreme weather events. Participants indicated that these events caused major shocks to the whole food system from producers through to consumers. Pest incursion was noted as resulting in uncertainty and a potential shift to alternative production sites. The costs of capital investment were mentioned as a risk to adopting practices of mitigation and adaptation.

MITIGATION AND ADAPTATION INTERVENTIONS

- ***HORTICULTURE***
  - Irrigation and water saving techniques/water re-use;
  - Selection of plant varieties
  - Managing soil carbon
  - Mixed crop management
  - temperature management through shading;
  - Alternative energy use
  - Improving transport infrastructure
  - Better Decision Support Systems
  - Flexible Production Systems

- ***DAIRY***
  - Construction of shading
  - Selection of higher temperature resistant animals
  - Land scape resilience through revegetation
  - Altered farm management
  - Water efficiency
  - Transport and market infrastructure

RECOMMENDATIONS BY EXPERT PANELS

- Improved cooperation across sectors to manage the impacts of climate change in their industries
- Investment in research and development in crop and livestock production to suit changing climatic conditions
- Protection of "all agricultural land in SEQ" and policy to support food production generally
- Develop industry levy structures that support local and regional needs
- Investment in R&D to develop new technologies and approaches that encourage adaptation through incentives for adoption of innovation.

Top ranked strategic interventions by scale of implementation (recommended by expert panels)

	INCREMENTAL	TRANSITIONAL	TRANSFORMATIONAL
LOCAL	• short-term land management approaches • efficient water use • soil security • local sources of input	• best farm management strategies • investment in extension and technology • creation of fertiliser for higher productivity • local sources of input	• best farm management strategies • reliable power generation • new irrigation opportunities
REGIONAL	• transport infrastructure • reliable power generation • soil security	• varietal development • creation of fertiliser for higher productivity • government support for efficient water use and technology	• varietal development • reliable water supply
NATIONAL		• industry collaboration • creation of fertiliser for higher productivity • reliable predictions for planning future	• industry collaboration • national levies • best water reticulation systems • reliable predictions for planning future
GLOBAL	• crop variety development	• genetic engineering	

SUMMARY OF OUTCOMES

- Differences in positions between the industry sector and the government and research sectors relate to sources of information on mitigation and adaptation. These differences demonstrate the need for closer relationships between industry and government if climate change interventions are to be appropriately targeted.
- The relationship between policy and industry implementation of intervention strategies must be based on a stronger collaboration based on co-operation that reflects industry perspectives and interests if it is to be effective.
    - Modelling shows that capacity for adaptation has a significant bearing on the success of implementing intervention strategies. It is important to use a framework of capitals that include social components (cultural, human and social capital), economic (economic and physical capital) and ecological components (ecological and environmental capital) to assess capacities. The study found evidence that without intervention strategies to build viability and support farm businesses are more likely to fail as a consequence of climate change.
    - A priority assessment of climate change intervention strategies through analytical hierarchy modelling shows that strategies categorised as 'Technology & Extension' are most important in minimising risk from climate change impacts. In implementing interventions to achieve 'Food Business Resilience' (formulated as a response to the risk of failure of business systems) 'Business Development' strategies are most effective. 'Research and Development' interventions are identified as most effective in achieving enhanced 'Adaptive Capacity' which is also a key to enhanced food security.
    - For individual components of Adaptive Capacity, it was found that 'Policy and Governance' interventions are most effective for building 'Social Capital' capacity; 'Research and Development' are the key to develop 'Economic Capital' while 'Business Development' strategies are most effective interventions to build 'Ecological Capital'.

Agriculture in responding to climate change must now optimise practices to address not only productivity, but also rural development, environmental and social justice (Pretty *et al.* 2010). Increasingly the interaction between economic, social and environmental costs drive decision-making in food production (Misselhorn *et al.* 2012). The research identified strategic interventions to promote food security and maintain resilience in local food systems, agricultural production communities and markets, global industrial systems, and developing world food systems. Climate change mitigation and adaptation interventions were defined to reflect a rich conceptualisation drawing from the Australian context, but also acknowledging the moral context of global association.

INTRODUCTION

Balancing human and environmental needs is urgent where food security and sustainability are under pressure from population increases and changing climates. Requirements of food security, social justice and environmental justice exacerbate the impact of agriculture on the supporting ecological environment. A UK Government report on the future of the global food-system (The Government Office for Science 2011) identified maintenance of biodiversity and ecosystem services in agricultural systems as a key challenge. A report to the Australian Prime Minister (PMSEIC 2010) indicated predicted changes in climate and population will necessitate the import of basic foods to meet Australian domestic requirements.

Predicted population growth over the next 50 years will raise food demand globally higher (Trostle 2008), which is complicated by environmental changes such as climate, biodiversity, water availability, land use atmospheric and other pollutants and sea-level rise (Misselhorn *et al* 2012). The Universal Declaration of Human Rights adopted over sixty years ago has not yet guaranteed access to sufficient, safe and nutritious food. More food is now produced per capita but access to food is still inadequate despite increasing production (Franklin 2012).

Adaptation to the impact of climate change on food production, processing and consumption is hampered by fragmented knowledge derived through disparate case studies and contesting interests (Hofmann *et al.* 2011). While an extensive body of knowledge is evident in a general review of research across a wide range of disciplines and interests, results reflect competing knowledge frameworks that cannot be compared.

This food-systems and food security research draws on climate change literature to provide systematic identification of risks and approaches to adaptation in food production, processing and consumption. The focus was within a framework that relates to building resilience in food-systems and accounting for climate change mitigation and adaptation drawing on a broad range of literature with reference to regional economies. Sources of literature included grey literature accessed directly through the research partners and research literature.

Three key objectives defined this food security and climate change research in two vertically linked agricultural sectors, dairy and horticulture. Each of these objectives contributed to research strategies that were developed and implemented to establish and build on knowledge about the interactions of social, economic and ecological dimensions in decision making. The first objective was to identify the producers, processors, resource suppliers, science providers, consumers and three tiers of government engaged with policy and regulation of food systems.

The second objective was to identify risks to horticulture and dairy food-systems in food security generated through human-induced climate change. These risks were identified through linked processes of literature review and contributions of expert panel workshops to address potential mitigation and adaptation intervention strategies. Once synthesised the risks, mitigation and adaptation interventions provided an evidence-based approach for modelling scenarios and climate change intervention impacts.

The third objective was to develop and test mitigation and adaptation approaches suitable for building resilience in vertically linked food-systems, accounting for climate change mitigation and adaptation, and weather-proofing regional economies. This was achieved through the development of a series of interlinked modelling approaches to evaluate and identify the implications of different interventions by scale, type of intervention (incremental, transitional, transformational) and within a range of scenarios (identified through the EP Workshops).

This report is presented in six sections: Section 1 provides an overview of the literature on food security giving definitions and parameters of consideration. Section 2 provides an outline of methodology and methods used in this transdisciplinary research program. This section provides an insight into the disciplinary tools applied to data derived through cross-disciplinary processes. Section 3 provides information on the different value positions likely to be taken in the horticulture and dairy sectors. This is based on a profile of expert panel (EP) participants who contributed to the research. Section 4 provides an outline of the way in which risk incurred through how climate change induced risks to for food security were identified and defined. Section 5 provides the climate change mitigation and adaptation strategies with potential application in horticultural and dairy food systems identified through the research. The final section, 6, provides the results of modelling climate change mitigation and adaptation intervention strategies in relation to capacity for a range of scenarios identified as key risks.

This report engaged with a range of stakeholders and interests in the dairy and horticulture sectors both as a means of discovering their opinions and insights into the implications of climate change for food security, but also as a means to provide information exchange across and between sectors. As such the research had immediate impact, but it is expected that the impact will extend to a broad range of dairy and horticulture interests through the distribution of a summary report derived from the formal content in this report.

The research is based on an extensive reading of international literature on food security as a means of establishing the differences in paradigms that engage with food security as an issue. Australia is a food provider of international importance, but the keen interest in local food production systems and associated social issues such as justice and health mean there is a wider interest in food security beyond commodity agriculture. In addition, a food systems approach demands triple-bottom-line framing that acknowledges the interactions between social, ecological and economic values in food systems as they are impacted by climate change. This report is aimed at those who develop policy and decision-support frameworks that span food systems and engage with the issues of food security and climate change as researchers in the peak industry sector and overarching formal governance.

SECTION ONE: FOOD SECURITY AND CLIMATE CHANGE – DEFINING CONCEPTS AND PARAMETERS

Predicted changes to climate have been identified by key government reports to be of concern for food security and the environmental and social systems upon which this security depends (The Government Office for Science 2011, PMSEIC 2010). Though more food is now produced per capita, supply is still inadequate to meet global needs (Misselhorn *et al.* 2012). Population growth and changes in social expectations globally will put additional pressure on production systems and natural capital such as water and biodiversity. Current food security evaluation continues to be hampered by fragmented knowledge derived through competing and incommensurate interests (Hofmann *et al.* 2011).

This research combines social science, economics and ecological knowledge from two states, two contrasting food production systems and a range of interests that span from local food producers to global food business interests, along with the policy and practice people associated with each step in these food systems. Through reference to an international literature on food security this integration of disciplines and practices has provided a contemporary insight into the issues facing food security in rapidly growing regions in Australia. The lessons and implications can be extrapolated to guide interventions in similar systems globally. The report identifies opportunities for, and strategies to, drive positive change ranging from local innovation to global triple-bottom-line (TBL) accountability systems. This section of the report provides an overview of the literature on food security giving definitions and parameters of consideration.

DEFINING A FOOD SYSTEM

A food-system includes different socio-geographical scales such as local, community, regional, national and global (Nazrul Islam *et al.* 2011). Regardless of scale the success of a food-system may be evaluated using distinct overarching sets of criteria. In the past the practice was primarily to evaluate food-systems from an economic or agricultural production perspective (Stimson *et al.* 2006) but increasingly the triple-bottom-line criteria of sustainability dictates evaluation of the success of a food system (Nazrul Islam *et al.* 2011).

The elements contributing to identifying a food-system are diverse and include all the activities required in feeding a population ranging from primary agricultural production to food consumption (Kloppenburg *et al.* 2000, Koc and Dahlberg 2004). Food-systems are based on direct links between producers of food and the consumers of food and include production, processing, distribution, marketing, retailing, consumption and waste disposal (Donovan and McWhinnie 2011).

Ericksen et al (2009) noted that the food system concept was not new with several frameworks for analysing food systems in use but with the few existing models focused on one disciplinary perspective or one component of the system. These models included food chains, food cycles, food webs and food contexts, in addition to nutrition. Other approaches outlined by Ingram (2011) used a cultural economy model for identifying power in commodity systems, and other approaches were based on a political economy perspective (Lawrence *et al.* 2012). Some approaches to identifying food-systems were defined by a socio-ecological framework (Fraser *et al.* 2003) to identify vulnerability within a physical landscape.

Models of food systems, if they are to provide an insight into the impact of climate change, need to identify the processes that may offer points of policy and practice intervention, mitigation, or adaptation strategies in inherently cross-level and cross-scale settings (Franklin 2012).

Misselhorn *et al.* (2012) note that equitable food systems ensure adequate amounts of nutritious food that is “affordable and accessible to all at all times”. In addition, effective food systems are noted to provide equity in market access and adequate R&D support for

agricultural producers globally catering to both the poor and rich farmers operating both at large and small scales (Franklin 2012, Vermeulen *et al.* 2012). Misselhorn *et al.* (2012) indicate that effective food systems provide the basis for equity in human development.

Differentiating between food-systems provides the means firstly of identifying relevance of scale, and secondly application of intervention approaches (either mitigation or adaptation). Food-systems in a production and consumption sense have been defined by Islam, Nath *et al.* (2011) as: conventional food systems, global food systems, community food systems, organic food systems, cooperative food systems, and slow food systems.

The social, geographical location and economic needs contribute to differences between food systems. Islam, Nath *et al.* (2011) indicate a range of factors that motivate producers which in turn impact on social expectations, environmental conditions and the economy.

Each of these food-systems have different links and processes in operation and are evaluated for purposes of adaptation and mitigation differently. Misselhorn *et al.* (2012) indicated that the value of using a food-systems approach to address issues of food security includes:

- identifying the range of actors and interests that should be involved in dialogue for improving food security
- providing a framework capable of addressing multiple socio-economic vulnerabilities
- identifying points of intervention to limit potential food insecurity.

Strong indications from global food analyses suggest that innovation and adaptation in the capacity to produce and distribute food is essential to address forecast changes to climate, population demography and patterns in economic development in both developed and developing economies. The debates about priorities in agro-food production systems reflect a range of sentiments and meanings that are addressed more directly through a broader focus on food security (Abrams 2010).

SUSTAINABILE FOOD SYSTEMS

Islam *et al.* (2011) have developed a conceptual model to identify and explain the gaps and opportunities for an agriculture and food system that meets triple-bottom-line criteria. This model (Nath and Islam 2010) can be used to address food security issues at local, regional and global scales in changing climatic conditions. They defined a world-class food system as ‘a complex and diverse process that include the production, processing, distribution, and consumption of high quality safe and secure food” (p21). In addition a world class food system is managed to minimize waste and contributes to “a growing, competitive and market oriented agriculture and to the well-being of the rural community, farm security, environmental sustainability, and economic diversification” (p 21). Sustainable food systems are expected to respond to “domestic and international changing food needs with a secured high quality and nutritious food supply” (p 21). The authors have defined the related social, ecological and economic variables for a food system and developed a basic framework for developing a regional food system model with potential to ensure food security that addresses economic, ecological and social needs in a changing climate.

DEFINING FOOD SECURITY

Food sustains health and wellbeing for individuals and communities, defining cultures and framing global interactions. Thus food defined here as operating within a food-system binds individuals and extends as a vital link across socio-geographic scale. This very broad framing ensures that food security is also considered in a wide range of contexts with equally broad implications.

A standard definition from the 1996 World Food Conference (Timmer 2010) defined food security as being met “when all people at all times have physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life” (p2). This definition rests on food security meeting three requirements (1) sufficient quantity and quality of food that might be supplied through either domestic production or through import; (2) individual and household access to foods providing a nutritious diet; and (3) sufficient water, sanitation and health care to ensure available food may be utilised to meet these requirements. In other definitions, food security is defined by the UK Government within a wider geopolitical frame as “ensuring the availability of, and access to, affordable, safe and nutritious food, sufficient for an active lifestyle, for all, at all times” (Defra 2009a: in Fish 2012).

Food security has come to include notions of availability, access, utilisation and stability of supply with nutritional security as integral to the definition. Food security is affected by water quality, storage, disease as well as socio-cultural norms of food preparation and consumption. These food related activities play a significant role in changing environments and the world’s climate through water, carbon, nitrogen, biodiversity, soils and landcover in turn undermining the food systems and natural capital upon which food security is based (Misselhorn *et al.* 2012). Food security is thus not only dependent on the production of enough calories to meet global population requirements but also impacts on the capacity to produce.

A range of positions include definitions in the narrowest framing in which food security is enough food available at global, national, community and household levels to meet dietary energy requirements and acting as a proxy for national self-sufficiency. In a broader framing food security recognises the socio-cultural elements of preference that are socially and culturally acceptable to religious and ethnical requirements. In addition, food security may be differentiated between transitory supply that is periodically insecure and permanent food insecurity where there is a long-term lack of access to sufficient food (Pinstrup-Andersen 2009b).

Debates defining the discussion on food security relate the contested relationship between scale of production and capacity to meet TBL sustainability criteria. This discussion extends beyond the pragmatic and technological potentials for production expansion to embrace notions of social and environmental justice, both within the context of production and extended to a global view of equity (Fish, Lobley & Winter 2012). Fish, Lobley & Winter (2012) provided strong evidence for the engagement of UK food producers through an analysis of farmer understandings of food security which show that while perceptions are conditioned by the context of a farming situation, notions of safety and traceability are considered as important as guaranteed supply to national and global markets. In general results indicate a strong need to reconcile concerns for sustainability with production to address the “failings of a highly industrialised and globalised agro-food system” (p. 10). Fish, Lobley & Winter (2012) indicate that domestic resilience in food supply, and thus food security, was thus built not only on “patterns of economically and socially viable local farming”, but also on the potential to realise “greater productive potential in an environmentally sustainable, way”.

In extending the debate around food security from food production in an agricultural context, to the broader global context of food needs, the emphasis shifts from increasing food production to increasing access to food thus integrating processes of food availability and food utilisation (W. N. Adger *et al.* 2005). This shift in focus from production to access and equity highlights the holistic conceptualisation of food security which considers multiple aspects of food security and food systems to include a wider range of research challenges that engage not only with the biophysical sciences, but by necessity also with the humanities, social and economic sciences (Ericksen *et al.* 2009).

The analysis of food security includes a wide range of socioeconomic 'drivers' that interact in a combination of local and non-local origins. Ingram (2011) indicates that resilience of local food systems is prone to external as well as internal stresses. Global-level influences such as climate change, trade agreements, and world food and energy pricing affect local and regional food systems in addition to local factors such as property rights, local market policy and the state of natural resources. Contemporary food systems are inherently cross-level and cross-scale (Ericksen *et al.* 2009).

Ingram (2011) identifies key research requirements in agronomic research as: "(i) to understand better how climate change will affect cropping systems…; (ii) to assess technical and policy options for reducing the deleterious impacts of climate change on cropping systems while minimizing further environmental degradation; and (iii) to understand how best to address the information needs of policy-makers and report and communicate agronomic research results in a manner that will assist the development of food systems adapted to climate change" (Ingram *et al.* 2008, p 418 in Ingram 2011). In addition, other activities related to food processing, packaging, distribution, retailing and consumption are identified as of key importance in considering food security.

This broader focus, according to Ingram (2010), "helps to identify the actors involved, the roles they play, and the many and complex interactions amongst them". This focus brings challenges in addressing environmental change requiring research into the translation of seasonally based plot-level approaches to larger spatial and temporal levels that better identify solutions to food security issues (Ingram *et al.* 2010).

Researchers (Burke and Lobell 2010, FAO 2008, Ingram 2009) have identified three key considerations necessary to meet food security needs:

a) **Food Availability and Climate Change -** The concept encompasses issues of global and regional food supply which might be affected by climate change. Changing climatic patterns have the potential to negatively impact on potential cropped area, crop selection and agricultural yields as well as influencing distribution and exchange of food.

b) **Food Access and Climate Change -** Access to food includes affordability, allocation and preference which might be negatively affected under various climate change scenarios in relation to four basic criteria - household income, food prices, integration of local food markets with global markets, and broader longer-run prospects of community for livelihood improvement.

c) **Food Utilization and Climate Change -** Food utilisation which addresses nutrition, social value and food safety can be negatively affected by climate change and can limit the ability to grow food with enough protein, nutrient and quality necessary for a healthy and productive life.

FOOD SECURITY, CLIMATE CHANGE AND HEALTH

In the short term demographic forces will result in aging societies thus changing the composition of households. There will be further limits to what the environment will sustain and the way in which climate change will challenge agricultural productivity. Cultural flows will change Eastern and Western views of food and health and new forms of science, information technology, and nanotechnology will be required to meet agricultural and food challenges (Grains 2011). A re-focusing on the driving forces shaping food and agriculture will be needed to apply ingenuity and technology to create positive outcomes for people, organizations and the regions they operate in.

The concept of food security is employed in stark divergence in health with the implications of too much resulting in obesity in developed countries as diseases of affluence and, too little food resulting in malnutrition and starvation in developing countries. These contrasts drive competing agendas in food security and human health (Brown and Funk 2008, Abrams

2010, Frison *et al.* 2011). The debates around food quality and food quantity link to the environmental and natural capital on which food systems are dependent.

Food quality is dependent on environmental state provided through environmental and natural capital to provide favourable health conditions (Beniston 2010). Thus, the impact of climate will potentially determine the future course of human societies defining rivalries over natural resources and environmentally driven conflicts and migrations (Beniston 2010). As a consequence food production problems will result from climate change, market asymmetries and food access declines caused by poverty. In addition food responsibility failures resulting from privatized knowledge production have significant implications for security in human populations and associated environmental support systems (Gertel 2010).

Food insecurity has a potential to result in political and socio-economic crises that emerge at a range of geo-political scales (Team and Manderson 2011) with implications for health related practice. Poland *et al.* (Poland *et al.* 2011) identified the need to address to key related points: the alignments between environmental destruction and environmental justice; and the strengthening of engagement with local communities and local interests to re-align with notions of building resilience rather than managing risk. This has implications for the exchange of knowledge between science and policy communities to re-focus research to account both for mitigation as well as environmentally sustainable objectives. This will improve potential for informed choices (Gill and Johnston 2010).

In Australia predicted climate change scenarios for food producing regions pose substantial (largely indirect) risks to human health. Climate change will add additional stressors for example, as a result of more frequent and prolonged droughts, and potential increased dryland salinity that have been shown to increase rates of hospital admissions for depression (Speldewinde *et al.* 2009). Widespread drought-related income erosion attributed to increased costs, decreased agricultural production, capital depreciation, loss of stock, and increased personal and business debt (Helen L. Berry *et al.* 2011), coupled with less frequent but more severe storm/ flooding events has the potential to impact mental health within rural agricultural communities. Farmers, who are often asset rich and cash-flow poor particularly during times of drought, report especially severe drought-related economic hardship (Helen L. Berry *et al.* 2011).

Many rural and remote Australian communities are also service poor and resource poor, and these deprivations are strongly linked to health disparities. Hardship is expected to flow from climate change in which climate extremes result in disasters which may exacerbate adversity by further limiting access to services. As communities decline, so also do services shrink (such as retail and trade outlets, schools, and health services). Drought and other weather-related challenges can thus exacerbate a lack of resources, while the lack of resources simultaneously hinders recovery from drought and other extreme weather events (cyclones etc). People unable to access support or leave these communities may become increasingly disadvantaged (Alston and Kent 2004)

FOOD SECURITY AND AGRICULTURE

Agriculture is the core of food security defining current practices of land use to produce food and define structures of international markets and patterns of consumption. The complex interactions of environmental, economic and social factors define the form and means of sustainability (Nelson *et al.* 2010, Head *et al.* 2011). Agriculture in response to climate change must now optimise practices to address not only productivity, but also rural development, environmental and social justice as well as changed social values (Pretty *et al.* 2010). Increasingly the interaction between economic, social and environmental costs drive decision-making in food production directly linking energy with food systems (Misselhorn *et al.* 2012).

A brief review of the literature indicates that food production and food security is understood differently in developed world contexts of commodity and industrial agriculture in contrast to

developing world contexts where subsistence and local food production faced with extreme events is more dependent on international networks of food supply. Sustainability increasingly defines production values in developed world contexts (Fish 2012), while the key issues of justice drive food security discussions in developing world contexts. Food insecurity can exist in developed world contexts where production is focused on export and commodity production with limited local production for local consumption (Kelly and Schulschenk 2011).

A range of writers on food security indicate that climate change expressed through frequency of extreme events and changes in historical patterns of variability (Howden 2007, Quiggin 2007) will have implications for food demand from the developing world and burgeoning middle class, as well as the mitigation policies that drive biofuel production (Head *et al.* 2011). The dependence on a relatively small number of food species and the declines in biodiversity have implications for the seed bank that genetic diversification in response to changing climatic variables requires (Padulosi *et al.* 2012). The interacting processes of mitigation and adaptation that impact on agriculture have different implications for the global north and global south with context dependence both in place and in business form (Head *et al.* 2011).

Food security in relation to agriculture has been considered in four different contexts:

1) local food systems
2) agricultural production communities and markets
3) global industrial systems
4) developing world food systems.

Local food systems

In local food systems, local community and regional control of the diverse features of food production is considered a key form of food sovereignty and food security. Land preservation, ecological stewardship, food supply, rural development and traditional cultures conserve food production resources and the human and environmental resources necessary to maintain productivity (McMichael 2011).

Intensification and agricultural development applied in local contexts and scales in several countries of Africa during the 1990s and 2000s are provided as examples of local benefit of sustainable agricultural systems. Development of crops, forestry, soil conservation and other agricultural practices through novel policies and partnerships in developing countries (Misselhorn *et al.* 2012) has also emerged with similar urgency in developed world contexts such as peri-urban landscapes where diverse communities occupy changing landscapes (Wardell-Johnson 2008b, Wardell-Johnson and Strike 2009). Demand for locally produced food has the potential to build food security locally (McMichael 2011). This differentiation between bio-regionally specific production systems from commodity based agricultural produce provides a useful means of understanding food security locally and local economic security resulting from food production Responding to the need for climate change adaptation in local food production contexts has led to applications of social and cultural research addressing traditional agricultural issues providing improved understanding of connections between social, ecological and economic landscapes at local scales (Head *et al.* 2011).

Agricultural production communities

This sector of food production according to researchers comprise family farms operating in a broad acre and commercial production context. The focus of climate change adaptation research in these contexts has been on agronomy and the technical approaches to farming practice and crop yield (Howden *et al.* 2009) often at the expense of social implications and

solutions with national visibility (Head *et al.* 2011, Alston 2011). In general, farmers in the commercial production scale are considered to work within a risk management frame addressing climate variability as a core interest (Sthapit and Padulosi 2012).

This sector of food production is expected to produce more food while reducing the environmental footprint through optimising yield in cropping and other production efficiencies (Foley *et al.* 2011). Key approaches to mitigation are framed in carbon and greenhouse emissions and farming practices are based on perennial production, livestock with minimal impact and the protection of natural assets through protecting vegetation and water conservation (Scherr and Sthapit 2009).

Global industrial systems

In contrast with local food production systems the literature on food security outlines this type of food system as engaging with global commodity markets with little attention to production for either personal or local use within the production landscape (Head *et al.* 2011). As the population facing food insecurity increases, there is a renewed focus on industrial scale agriculture as a supply for food (McMichael 2011).

There are indications in the literature that this scale of production is considered more resilient (Head *et al.* 2011). However, studies elsewhere indicate that communities associated with this scale of production may be food insecure (Kelly and Schulschenk 2011). As with agricultural community scale production, at the global industrial scale of producers the household scale of policy development has poor attention despite capacity to measure and monitor social and ecological variables (Head *et al.* 2011).

The focus on nutritious, safe and affordable food for a growing world population, and increasing middle class within narrowing limits to production is likely to result in increasingly conventional productivist commodity production systems (Fish *et al.* 2012). Kelly and Schulschenk (2011) claim that the vulnerabilities of food systems through the dominance of large-scale commercial agriculture of long value chains and the dominance of national retailers is likely to increase food insecurity and poor nutrition. Standardised agricultural practices of mono-cropping and limited commodity crops dominating food systems will result both in genetic and cultural erosion (Padulosi *et al.* 2012).

The global South

In developing economies climate change is likely to have the most significant adverse effect on agriculture. Research indicates that farm households in these countries comprise most of the poor people of the world and the production of food is likely to fall due to productivity declines resulting from higher temperatures and humidity in the tropics. Unskilled labourers who comprise the bulk of the labour force in food production will suffer most from temperature and humidity changes reducing competitiveness in the international economy (Valenzuela and Anderson 2011).

In general, food security and agriculture in the global south has been driven by the need to understand hazard, risk and vulnerability (Head *et al.* 2011). The household scale of social justice that recognises local social dimensions of issues receives more attention in the developing than in the developed world. Subsistence production is seen to provide a buffer against the impacts of climate change (Head *et al.* 2011). This contrasts with the intensive developments of small scale agriculture seen to be successful in generating independence and food security in many developing African countries (Maxwell 2010). The gains from economic growth in the agricultural sector for households practicing small scale food production is substantially higher but is hampered by yield gaps resulting from inconsistent seed supply, poor technology availability and lack of capital and infrastructure (Misselhorn *et al.* 2012). Adaptation activity primarily addresses technology, agronomy and policy inputs, and better management of extreme events and increased climate variability on agriculture (Vermeulen *et al.* 2012). Small scale farm productivity improvements through new inputs

and incorporation into global markets is possible through adapting industrial scale agricultural value chain processes to provide a potential solution to food security through short value chains (McMichael 2011).

Sustainability increasingly defines production values to include issues of justice in developing and developed world contexts to meet production for local consumption and economic viability for local communities through food production. Thus the interaction between economic, social and environmental costs drives decision-making linking a range of justice issues (such as access and opportunity) with food systems. Interventions for climate change mitigation and adaptation have different implications for the global north and global south and four different contexts of food production provide different contexts for focus: local food systems, agricultural production communities and markets, global industrial systems and, developing world food systems.

FOOD SECURITY POLICY

Macro and micro policies shape decision making processes not only for government but private food enterprises across the food system. As Lang (Lang 2010) points out the post-World War Two policy was based on increased output efficiencies to feed a hungry world but now the situation is more complex. Layered over the existing food system concerns are emerging foundational environmental issues, including climate change, water scarcity, biodiversity threats, depletion of cheap non-renewable fuels, soil degradation and competing land use priorities (Lang 2010). To add to policy challenges, Lang *et al.* (Lang *et al.* 2009) argue that sustainable food systems include health, social and cultural aspects as well as these emerging environmental issues. The measure of food policy effectiveness can no longer be based solely on 'value-for-money' but must include practices that integrate broader issues (Lang *et al.* 2009).

Food policies can have direct or indirect impact (DAFFA 2011) with the roots of food system problems often being in wider policy areas (UK Cabinet Office Office 2008). The authors of *The Future of Food and Farming* report (The Government Office of Science 2011) stress the importance of interconnecting policy development as a futuristic buffer against food supply threats and resulting catastrophic implications. In the complex governance structures in place today policy development is required both horizontally within food production sectors and vertically within food systems and value chains (Barling *et al.* 2002). Currently, policies are developed across a broad number of government departments and regulatory authorities in a silo approach which severely restricts their effectiveness. Due to this fragmented approach inconsistencies, overlap and gaps are highly probable (DAFF 2012) with significant implications for identifying and implementing policy and practice interventions.

Food pricing policies in response to rising food prices have generally resulted in short term measures (Demeke *et al.* 2009). These policy responses include: trade-oriented responses using policy instruments (tariff reduction, export restriction); consumer-oriented policy that supports consumers and vulnerable groups (food subsidies, social safety nets, tax reductions and price controls); and producer-oriented policy to support increased farm production (input subsidies and producer price support). Slade and Wardell-Johnson (2013) identify three approaches that impact the food system both directly and indirectly: research, governance and policy.

THE RISKS OF CLIMATE CHANGE ON FOOD SECURITY

Potential changes in key climate variables, such as increased average temperatures, changed rainfall patterns and increased climate variability, are projected to directly affect food security and agricultural productivity in Australia. There may also be indirect impacts on agricultural productivity through changes in the incidence of pests and diseases and increased rates of soil erosion and degradation (Bills and Gross 2005).

The impacts of climate change in Australia based on assumed global developments (slowdown in global economic activity and a decline in agricultural productivity) and domestic developments (a decline in agricultural productivity in key growing regions) have been assessed by different studies (Bills and Gross 2005, Binning 2000). These authors indicated that with projected changes in climate, Australian production of key agricultural products is estimated to decline — wheat by 9.2 per cent at 2030 and 13 per cent at 2050; beef by 9.6 and 19 per cent; sheep meat by 8.5 and 14 per cent; dairy by 9.5 and 18 per cent; and sugar by 10 and 14 per cent respectively. Australia is projected to be one of the most adversely affected regions from declines in agricultural production driven by climate changes.

Australia will experience more frequent and severe extreme weather events such as in the heat waves in 2008 which resulted in record temperatures rising by 87% of Victoria's summer average. These temperatures generated the nation's worst recorded fire event. In 2010, southwest Queensland recorded its worst flooding in more than a century. In contrast, downstream, 44% of New South Wales and more than 95% of Victoria and South Australia experienced severe drought. Over time, weather-related disasters can erode the social and economic base on which farming communities depend (Berry *et al.* 2011).

FOOD SECURITY AND MITIGATION OF AND ADAPTATION TO CLIMATE CHANGE

Addressing issues of scale from developing and developed country local scales, through the regional and national scales of commercial agriculture, and the global scale of industrial commodity agriculture, provide a range of contexts for mitigation and adaptation strategies. Resource management issues, institutional structures and the meso scale of organisational capital such as farmers organisations and rural development groups all offer avenues and pathways to address climate change and food security. Islam *et al.* (2011) suggest that improper governance of agriculture and food systems across socio-political scales contributes to continuing problems with food provision. Improving the flow of information between scientists, policy makers and practitioners would improve the potential for adaptation based on evidence-based policy (Pretty *et al.* 2010). Including broad-based values of sustainable development and the power of investments to develop productivity within an open world trade system would improve action for both mitigation and adaptation (Nelson *et al.* 2010). Key to all proposals is enhancing democratic processes of participation (Ludi 2009).

Mitigation strategies aim to reduce the impact of changes to climate and the associated risks from anthropogenic (human) processes. Adaptation strategies and actions are those designed to adjust to and limit the potential impacts relating to hazard and risks arising from extreme weather events, climatic variability, climate change, sea level rise and other processes. Adaptation is generally considered an evolving, long-term dynamic process in which the building of the adaptive capacity of stakeholders is crucial.

It is not easy to define mitigation and adaptation either separately or explicitly because it is difficult to predict their efficacy in limiting the impacts of climate change. They are generally separated due to their different potentials as policy and practice mechanisms (Beddington *et al.* 2011). The general use of both indicates recognition that approaches to solving problems of climate change include both mitigation and adaptation (Sheppard 2011). As Sheppard writes: "Regardless of misinterpretations on the distinction between mitigation and adaptation, these concepts accurately represent pervasive social attitudes and values" (p 71).

Adaptive capacity is defined as ''the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences'' (IPCC 2001, p. 982). Some studies have used the term 'vulnerability' interchangeably with adaptive capacity, although, the relationship between adaptive capacity and vulnerability depends crucially on timescales and

hazards. The vulnerability, or potential vulnerability, of a system to climate change that is associated with anticipated hazards in the medium- to long-term will depend on that system's ability to adapt appropriately in anticipation of those hazards (AEA 2007).

A number of different types of mitigation and adaptation interventions ranging between incremental, transitional and transformational can be distinguished. Incremental Strategies are those where it is logical to take a step-wise approach. In this approach it is considered that the issue can be addressed by starting a process and building on first steps as knowledge, commitment and solutions develop over time. Transitional Strategies in a climate change context are those which are undertaken in the realisation that they will only be effective for a limited period of time or within a specific set of climate change variables. Transitional strategies are those which aim to promote action immediately as a bridge to new (e.g. transformational) strategies in the future. Transformation Strategies break from the 'status quo' to create a significantly different operating environment. Transformational strategies are generally required where the change to the system is so large that existing process (e.g food production systems) cannot adjust to new conditions (Bailey 2010, Baker 2009, Bala 2009).

Adaptation strategies include anticipatory and reactive adaptation, private and public adaptation, and autonomous adaptation and policy-driven adaptation. Autonomous adaptation describes actions that are taken as natural by individuals, households, businesses acting as agents in response to actual or expected climate change, without the active intervention of policy (Barrett 2010). It may be that the agricultural sector is one in which autonomous adaptation is a particularly important category because farmers have traditionally adapted their methods in response to felt changes. In contrast, policy driven adaptation is "the result of a deliberate policy decision" (Barrett 2010). Policy-driven adaptation is therefore associated with public agencies, either in that they set policies to encourage and inform adaptation or they take direct action themselves, such as public investment (Black 2005).

The UK Government (Black *et al.* 2003) has used a common categorisation of planned adaptations into two main groups:

1. 'Building adaptive capacity' which involves and ensures that the scientific, technical and socio-economic evidence, the skills, the governmental and non-governmental partnerships, the policies and the resources are in place to enable adaptation to be undertaken.
2. 'Taking adaptive action' that involves increasing the resilience of systems, structures and people to climate risks by reducing their vulnerability and optimising their ability to accommodate and adapt to change.

Studies also reported concern about the effectiveness, efficiency and legitimacy of adaptation (N Adger *et al.* 2005). Effectiveness relates to the capacity of an adaptation action to achieve its expressed objectives. Effectiveness can either be gauged through reducing impacts and exposure to them or in terms of reducing risk and avoiding danger and promoting security.

While efficiency in adaptation involves assessment of the economic efficiency of adaptation actions require consideration of: 1) the distribution of the costs and benefits of the actions; 2) the costs and benefits of changes in those goods that cannot be expressed in market values; 3) timing on adaptation actions; and 4) the success of an adaptation action can be argued to depend not only on its effectiveness in meeting defined goals, but also on issues of equity and perceived legitimacy of action. It is important to note here that present-day adaptations to the risks from climate change are imposed on present-day society as a result of previous actions in perturbing the climate system. The whole issue of adaptation therefore begins from a suboptimal and 'unfair' starting position because of the intergenerational nature of the problem.

Although in recent years there has been an increase in literature on how climate change will impact on agriculture and adaptation (see for example: (Stokes 2010, Black and Reeve 1993, Allouche 2011, Garnaut 2010, FAO 2008, Blair 2004, Blake 2001) literature on explaining how food producers adapt to different production options and management strategies in response to biophysical and socio-economic changes are scarce. Such knowledge is important in formulating adaptation planning for producers to adjust their production and management strategies in the face of increased intensity and frequency of storms, drought and flooding. Other literature reporting on adaptation indicates that altered hydrological cycles and precipitation will have implications for future agricultural production and food availability. Farm level analyses have shown that potential reductions in adverse impacts of climate change are possible when adaptation is fully implemented (Blake no date).

INTERVENING IN THE FUTURE: MODELS FOR MITIGATION AND ADAPTATION

Both mitigation and adaptation approaches are important for strengthening vertically linked food-systems, to account for carbon and weather-proof regional economies. A comparative context provides contrasting knowledge and practice contexts about adaptation approaches in food-systems and regional economies. Integrated transdisciplinary expertise is required to identify variables to apply in the modelling of scenarios and adaptive strategies to strengthen food-systems; account for climate change mitigation and adaptation; and weather-proof regional economies in the face of climate change.

Identifying points of vulnerability and their impact on food security is more obvious when analysis focuses on factors/ variables and interactions within a whole food systems construct rather than only the supply end of agriculture (Eakin 2010 in Ingram 2011). In the past adaptation measures tend to focus on technical agricultural interventions to reduce food security vulnerability. A food system approach can identify broader strategic interventions which enhance the resilience of food distribution and supply e.g. improving supporting infrastructure (roads, telecommunications, etc); stimulating technological innovation (food storage, processing and packaging); and social policy development to enhance adaptive capacity. Thus adaptation measures may be better focused through points of intervention identified within a discrete TBL value set, and thus more immediate policy application (Ingram 2011).

If we are to maintain and build resilience through sustainable practices in food systems then we need to account for TBL values. But, more importantly, we need to account for a range of processes both in support of status quo and often resistance to change. The variables that define the change in social systems evolve at different temporal scales as either fast of slow variables and contribute in different ways to maintaining resilience or systemic integrity (Wardell-Johnson 2007, Janssen 2002, Marion 1999, Midgley 2000). Slow variables act to moderate the impact of change thus providing constancy in a system. These variables structure complex systems through the bifurcation points past which faster variables are unlikely to transgress (Davidson-Hunt and Berkes 2003). Fast variables are able to react more flexibly to evolve and develop innovative and experimental responses but within the constraints set by the slow variables that maintain systemic resilience. Flexibility within social systems in response to perturbation is set by fast variables without sacrificing all memory and learning maintained by slow variables (Wardell-Johnson 2007). In social terms, culture is a slow variable that maintains a constant state in which:

> *despite, and because of, its interactive nature; it protects its own integrity and it lends that stability to the society that emerges from it. Social structures do respond to social activity, and consequently culture can be dynamic and alive; yet it responds sluggishly, thus it possesses constancy (Marion 1999 p. 133).*

The impact of these slow variables was identified by Harich (2010) as “the great blind spot” that is evident as change resistance. In recommendations outlined through a scenario modelling approach he advocates a specific engagement with the slow variables that entrench status quo and resistance to socio-political change (Harich 2010).

Climate change was identified as a primary challenge to the Australian food economy in the *National Food Plan Green Paper* (Department of Agriculture Food and Forestry 2012). The plan identified that fifteen per cent of all Australian jobs are in the food industry with the majority occurring in rural and regional areas (90 per cent of food production jobs and 50 per cent of food processing and manufacturing). The vulnerability of food production derives from supply side effects (Garnaut 2010). The viability of the Australian rural economy is therefore intrinsically linked to food production; pricing within international commodity markets and the current retail market. Food security in Australia thus requires a systematic evaluation of climate change adaptation strategies for agricultural productivity and food value chains including:

- institutional frameworks that support food-systems;
- training and access to technology in vertically linked food-systems;
- biosecurity and nutritional access; and
- socio-cultural values in changed food-systems.

A range of critical issues relates to discussions about the impact of climate change on food systems and related food security:

- human health
- biosecurity for production and for environmental protection
- industrial, commodity and local scale agricultural production and enterprise
- adaptation policy and related practice
- mitigation of climate change impacts in relation to food systems
- social capital and adaptation (micro, meso and macro scales addressing individual, community, society and governance)
- social expectations and food systems
- sustainability principles and practice across food systems
- climate change impacts on horticultural and dairy production systems
- policy interventions and incentives (such as carbon accounting systems)
- social structures and social catchments in development of mitigation and adaptation approaches
- integrative tools for trans-disciplinary practice
- models to integrate and test potential approaches for intervention and decision-support.

This food-systems research used climate change literature to identify risks, mitigation and adaptation strategies. This research has two contrasting agricultural production areas as context (SW WA and SEQ). The production systems in dairy and horticulture in these areas represent two of Australia’s most rapidly changing landscapes in terms of socio-cultural values, population growth, and changing food production capacity. Contrasting governance offers insights for a range of mitigation and adaptation policies and practices. Limits to adaptation are understood through projections in climate change and global economic context of each food-system with potential application in regional mitigation and adaptation strategies for other places. Research focus is the south west Western Australia (SW WA)

(contributes ≈$6billion to WA's economy) and south east of Queensland (SEQ) (total farm-dependent economy including inputs, transport and processing in SEQ is valued at $8 billion (McFarlane *et al.* 2008).

Research into food systems and the mitigation and impacts of climate change requires trans-disciplinary approaches combining social science, economics and land-management. Specialist input representing contexts from production to international points of export that include governance and research are necessary to understand points of potential mitigation and adaptation interventions to manage the impacts of climate change.

SECTION TWO: RESEARCH APPROACH: OVERVIEW, METHODOLOGY, PROCESS AND ANALYSIS TOOLS

The research methodology integrated methods and tools from a range of disciplines. The approach allowed the development of tested and applied models for evaluating interventions for climate change in policy, practice and research contexts. This section provides an outline of methodology and methods used in this transdisciplinary research program.

Research into food systems and the mitigation intervention to minimise the adverse impact of climate change requires trans-disciplinary approaches combining social science, economics and land-management. Specialist input representing contexts of the whole of food supply chain i.e. from production to marketing and export are necessary to understand points of potential adaptation and mitigation interventions to manage the impacts of climate change.

THE CONTEXT

This research used two contrasting agricultural production areas as context (SW WA and SEQ). These areas represent two of Australia's most rapidly changing landscapes of socio-cultural values, population growth, and changing food production capacity. Contrasting governance offered insights for a range of mitigation and adaptation options and approaches.

The multifunctional landscape of SW-WA is climatically favourable and culturally diverse. This region forms only a fraction of the WA landmass, but is home to about 90% of the State's 2.4 million people. These high rainfall landscapes contribute nearly $6 billion annually to the State's production and processing of a wide variety of fresh foods. This amounts to about 50% of the total value of the State's agrifood sector contributing nearly $6 billion to the Western Australian economy (Nath and Islam 2010). These landscapes are also Australia's only internationally recognised terrestrial biodiversity 'hotspot' (Myers *et al.* 2000).

The peri-urban landscapes of SEQ contribute a significant part of Queensland's total production of food and fibre. This landscape is supported by an environment of high biodiversity in sub-tropical, riverine, coastal and marine environments.

CLIMATE CHANGE SCENARIOS

Australian food producers are constrained by the most variable climate in the world (CSIRO and Bureau of Meteorology 2007) with predicted changes to climate through human activities potentially limiting food security, both in Australia and for those nations depending on Australian agriculture (PMSEIC 2010). Australia's temperatures are projected to rise and rainfalls decline and climate changes will be expressed through extreme events such as flooding and heatwaves. Within the most conservative of estimates food production and associated sectors will be impacted. Kingwell describes the impact of climate change "as the shift of climatic zones and their associated agricultural activity toward the poles and to higher elevations" (Kingwell 2006). The vulnerability of food production derives from supply side effects (Garnaut, 2010). Much of Australian agriculture operates close to the upper margins of the temperature ranges at which agriculture is undertaken successfully, and close to the low margins rainfall requirements.

SW WA CLIMATE SCENARIOS

The South West region of Western Australia is considered to have experienced various levels and impacts of Climate change since the mid-1970s (Morgan *et al.* 2008). In this region changes in rainfall patterns since the 1970s have resulted in a "shift from perennial to ephemeral streams and a decline in the runoff coefficient (runoff/rainfall) in the last decade"

(Petrone et al 2010). Petrone et al (2010) further suggest that a new hydrologic regime has developed with important implications for future surface water supply in the south west of WA. The projected rainfall decreases in the south-west in winter and spring are up to 30% (Morgan *et al.* 2008). Observed changes to the climate of South West Western Australia include:

- 0.8ºC increase in temperature since 1910
- 10 to 15 percent drop in annual rainfall from the 1970s to present.

The Department of Agriculture and Food WA internal reporting suggests that the best estimate of annual warming over Australia by 2030 relative to the climate of 1990 is approximately 1.0ºC, with warmings of around 0.7-0.9ºC in coastal areas and 1-1.2ºC inland (Morgan *et al.* 2008). Further predictions indicate a mean warming in winter to a little less than in the other seasons, as low as 0.5ºC in the far south. The range of uncertainty is predicted to about 0.6ºC to 1.5ºC in each season for most of Australia. These warmings were based on the A1B emission scenario, but allowing for emission scenario uncertainty expands the range only slightly - warming is still at least 0.4ºC in all regions and can be as large as 1.8ºC in some inland regions. Morgan et al (2008) indicate that natural variability in decadal temperatures will be small relative to these projected warming. Projected warming for 2050 and 2070 later in the century is more dependent upon the assumed emission scenario. By 2050, annual warming over Australia ranges from around 0.8 to 1.8ºC (best estimate 1.2ºC) for the B1 (low emissions) scenario and 1.5 to 2.8ºC (best estimate 2.2ºC) for the A1FI (high emissions) scenario. By 2070, the annual warming ranges from around 1.0 to 2.5ºC (best estimate 1.8ºC) for the B1 scenario to 2.2 to 5.0ºC (best estimate 3.4ºC) for the A1FI scenario (Morgan *et al.* 2008). Regional variation in the SW of WA follows the pattern for 2030, with less warming predicted in the south (Morgan *et al.* 2008).

The SW WA region contributes about 13 % to the State's GVAP, 33 % of horticulture produce and more than 95 % of the milk and dairy products. The horticulture industry is the largest agricultural sector in the region – contributing about 40 % to the value of agricultural products produced in the region. In terms of production and exports the gross value of vegetables produced in SW-WA was $289 million in 2007-08 (Islam *et al.* 2011).

Among the vegetable crops, potatoes are the major produce in WA and 18.0 % of total vegetable production was potatoes, mainly concentrated in the higher rainfall areas of the state's South-West (DAFWA 2009). With reduced vegetable production in eastern Australia due to water shortages, WA is increasingly being seen as a supplier of vegetables to eastern states markets. Carrots are the other major vegetable crop produced in SW-WA, accounting for 90 % of Australia's carrot exports with major markets in Singapore and Malaysia plus increased exports to Middle East markets (DAFWA 2009).

Over the last 5-year period milk production in WA varies between 377 million litres in 2005/06 to 319 million litres in 2007/08 (DAFWA 2009). Over the same period the number of registered dairy farms has reduced by 31 % to 170 thousand in 2010/11. However, milk production per cow has increased from 5,369 litres to 6,584 litres. Climate change is affecting the feed availability and thereby likely to have adverse effects on WA dairy sector.

SEQ CLIMATE SCENARIOS

The Office of Climate Change has identified that the last decade (2000–2009) was the hottest on record in Queensland with temperatures 0.58 °C higher than the 1961–1990 average (Whitfield *et al.* 2010). This report went on to suggest that Queensland regions can expect increased temperatures of between 1.0 °C and 2.2 °C by 2050; a 3 – 5% decrease in rainfall in the south-east Queensland region; more frequent hot days and warm nights; less frequent cold days and cold nights; and increased flooding, erosion and damage in coastal areas due to increased numbers of severe weather events. It is expected that cyclones will occur further south potentially impacting on south east Queensland more often.

Whitfield, Oude-Egberink *et al.* (Whitfield *et al.* 2010) expect that climate change will increase the difficulty in supplying water to meet agricultural demand due to decreasing rainfall and runoff, and increasing temperature and evaporation. Laves (2008) concurs and suggests that industries that depend on irrigation to remain viable will be vulnerable to decreased water availability in the northern part of the region. He further concludes that support will be needed to assist producers to reduce vulnerability and to adopt sustainable agriculture practices based on applied climate change knowledge. The climate change adaptation process he suggests will be vital to the success of the agricultural industry (Laves 2008).

Coupled with these impacts increases in mean annual temperature will lead to shorter growing seasons for some crops as well as increasing the decomposition of soil organic matter, the depletion in soil fertility (native N stocks), decline in soil structure and reduced soil cover. Grace (2008) argues that on-farm management of soil carbon and nitrogen use efficiency will play an overriding role in adapting to climate change (Grace 2008).

Horticultural production in SEQ is dominated by commercial scale vegetable systems with Lockyer Valley primarily growing temperate crops during the mild SEQ winter. A range of sub-tropical fruits and nuts (macadamias, pineapples, strawberries avocadoes and mangoes) are produced on smaller scale farms. Deuter (2008) considers that temperature changes are likely to be the key aspect of climate change forcing adaptation. Together with variable rainfall patterns this is likely to lead to increased pest and disease pressures and changes to fruit development (ripening and post-harvest) which has the potential to influence market access opportunities (Deuter 2008). While initially deleterious to traditional food systems in SEQ the ability to produce more ‘tropical’ produce (e.g mangoes) may assist with any changes to current production systems.

Livestock respond to increasing temperature by drinking more and eating less. Heat stressed cattle will as a result decrease body weight and increase body temperature. Hotter summer temperatures are already impacting on dairy cows with the number of days where the Temperature Humidity Index (THI) is greater than 72 each year increasing from 2000-2004 relative to the 1961-1990 mean (185 days) in SEQ/NNSW. With predicted increased extremes of heat it is likely that without adaptive practice THI levels exceeding 72 will have a more significant impact on milk production (lower milk volume and reduced components), reproduction (lower conception rate) and cow health (increase in ticks, buffalo fly, eye cancers) (Miller 2008).

METHODOLOGY

The research methodology was based on an integration of methods and tools from a range of disciplines including both qualitative and quantitative collection of information (or data). There was a strong attempt to reduce assumptions so as not to define the issues and results according to pre-determined assumptions. The team working together represented a range of disciplines, practice and theory contexts and interests. The approach combined and synthesised approaches and results to form tested and applied models for evaluating interventions for climate change in policy, practice and research contexts. To be effective the approach required a research process based on a transdisciplinary methodology drawing on tools and methods from each of the three triple-bottom-line disciplines (ecology, economics and social science) in addition to that of planning and governance in the applied context.

The basis of this transdisciplinary methodology uses a definition of science as a systematic knowledge base drawing on prescribed and recognised practices with a capability of prediction. The skills and techniques in acquiring knowledge are based on tested methods drawing from and contributing to an identifiable body of knowledge (Bullock and Trombley 2000). While the concept of interdisciplinarity emerged as a term nearly a century ago, based on the assumption that organising principles and criteria inherent to the practice of science and research were independent of social activity (Tress *et al.* 2005) the extensive

examination of the practice of science by Khun (Kuhn 1988) revealed the subjective nature of paradigms.

This research not only develops an applied approach to managing the implications of climate change for food security but also provides a practice methodology for sustainability science. Differentiation of approaches in collaboration in science reveals five processes of generating knowledge. Disciplinarity (1) operates within a single discipline to develop new knowledge and theory that is discrete. Multidisciplinarity (2) is based on a loose cooperation of disciplines for the exchange of knowledge to develop disciplinary theory through collegiate goal setting within themes. Interdisciplinarity (3) develops integrated knowledge and theory through common goal setting and integration that crosses disciplinary boundaries. Transdisciplinarity (4) develops an integrated knowledge and theory that spans both science and society. This is thus the integration of both academic or scholarly and scientific disciplines with non-academic and community participants (Tress *et al.* 2005). The fifth approach is postdisciplinary (5) which seeks to transcend the ideology of the philosophical divide between biophysical and social sciences, qualitative and quantitative methods and other limits to solving intractable and wicked problems (Jessop and Sum 2001). This research applies a transdisciplinarity approach within processes and philosophy of a postdisciplinarity in order to integrate risks and interventions across food-systems scales and values of the triple-bottom-line. This integration and methodology requires learning about approaches used in related triple-bottom-line disciplines that are based of respect, diversity and alternative paradigms or discourses.

To fulfil the research methodology and objectives, the study followed a mixed method research design to cover a three stage research process; first, a review of the past studies to define and conceptualise the relevant works and develop the survey instruments (information sources); second to administer the survey to collect expert opinion from the food system social catchment on climate change related risks and approaches to adaptation and mitigation, analyse the data; and finally to develop scenarios and third to evaluate intervention strategies through complementary modelling approaches. The process these three steps involved is shown in Figure 1.

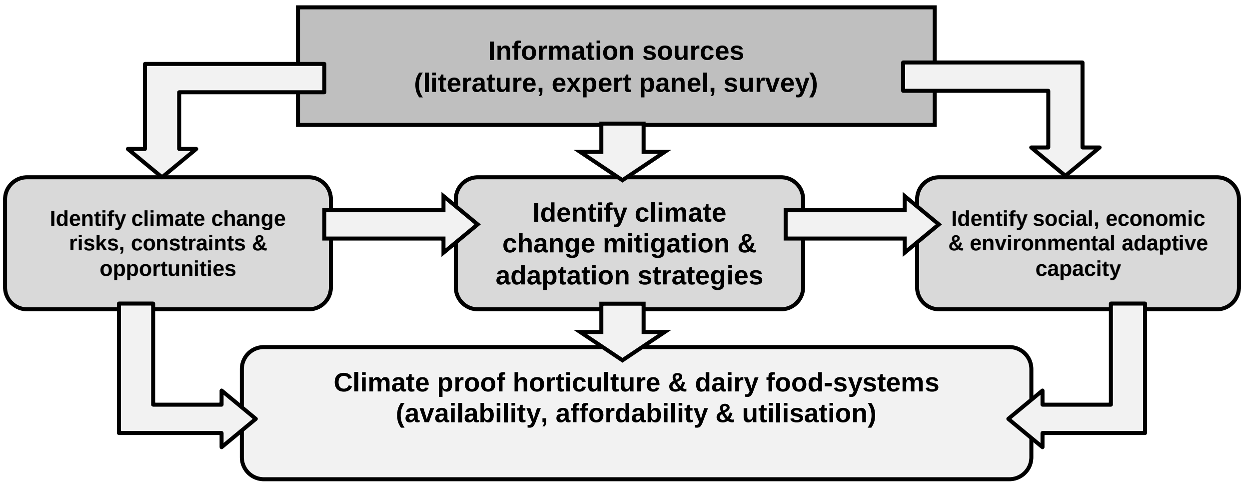


Figure 1 Research framework

Recommendations for working in sustainability science from Hirsch et al (Hirsch Hadorn *et al.* 2006) includes attention to systems, targets and transformations. The systems level involved identifying processes and change to identify effects on purposive and normative dimensions. An ecological sampling and identification of perceived risks, key paradigms/ discourse frameworks provided these insights. The target level involved identifying better

practices or targets such as mitigation and intervention strategies. The transformational objectives identified pragmatic and normative practices in systems criteria and practice through the evaluation of likelihood of implementation and potential impact. This provided insights into most effective focus for strategic interventions, as well as identifying the gaps in current approaches. By differentiating between process and content, this research identified criteria that has a values basis for food security and for understanding the impacts of climate change on the dairy and horticultural food systems.

THE RESEARCH OBJECTIVES

Three key objectives defined the research agenda. Each of these objectives comprised research strategies that established and built upon knowledge generated horizontally and vertically. The first objective was to identify decision-makers, stakeholders and contributors based on social catchment criteria. This objective aimed to ensure participation and selection of expert opinion reflecting horizontal and vertical components of a dairy and horticulture food system. This objective was important in identifying and understanding the interactions of social, economic and ecological dimensions in decision-making. The first research objective identified expert contributors based on social catchment criteria to meet food-system stakeholder engagement requirements. A key social catchment criteria consists of social scale comprising: micro scale (producers, small business and local communities); meso scale (regional agents in business, government and community); and macro scale (governance, institutions, global economics and international obligations). Two vertically linked agricultural sectors within context were represented by the dairy and horticulture sectors. Other criteria included representation from a range of sectors within a food-system including producers, processors, resource suppliers, science providers, consumers and three tiers of government engaged with policy and regulation of food-systems.

The second objective was to identify risks to horticulture and dairy food-systems and food security generated through human-induced climate change. These risks were identified through linked processes of literature review and contributions of expert panel workshops. These risks were used as the basis for identifying potential mitigation and adaptation intervention strategies for managing risks to food-systems and food security. Once synthesised the risks, mitigation and adaptation interventions provided the basis for modelling scenarios and climate change intervention impacts.

The third objective was to develop and test mitigation and adaptation approaches suitable for strengthening vertically linked food-systems, accounting for climate change mitigation and adaptation through carbon accounting processes, and weather-proofing regional economies. This was achieved through the development of two modelling approaches using Structural Equation, Value Chain, Supply Chain and Expert Choice modelling. This objective provided a concrete means of evaluating and understanding the implications of different interventions by scale, type of intervention (incremental, transitional, transformational) and within a range of scenarios (identified through the EP Workshops).

The outcomes of the research have provided a means to develop and test mitigation and adaptation approaches suitable for strengthening vertically linked food-systems, accounting for climate change mitigation and adaptation through carbon accounting processes, and weather-proofing regional economies.

Research tools: Experts and Social Catchments

Experts are increasingly used in acknowledgement that “science and policymaking are social activities” (Tomlinson and Davis 2010). The Expert Panel approach contributes to policy and practice through the peer process to increase transparency and give “credibility to the process and the results” (Patterson *et al.* 2007). Literature indicates that as time-lines for decision-making are often shorter than those of scientific consensus, the “landscape of expert opinion can greatly inform such decision-making” (Anderegg *et al.* 2010, Wardell-

Johnson *et al.* 2011). The key research questions operationalised through a short survey and the short background paper on food security were distributed to participants prior to convening the Expert Panel Workshops. The responses to the survey questions provided an evaluation of Expert positions both on the impacts of climate change on horticulture and dairy, but also on their socio-demographic profiles, paradigms (discourse frameworks) and the social values underpinning their decision-making.

Two regional landscapes that include vertically and horizontally linked decision-making in food-systems and climate change adaptation met social catchment criteria. Social catchments represent interests that contribute to decision-making across socio-political scale in geographical context. Experts from each of the social scales (micro, meso and macro) and interest sectors spanning the food system were identified. Participation in Expert Panel Workshops was sought from the micro scale of farmers and communities; the meso scale representing extended regional economic, social and ecological communities that local communities are a part of; and the macro scale including formal and informal institutional entities that structure decision-making at the national and global scale (Wardell-Johnson 2011).

Research tools: discourse frameworks

Capturing opinion and perspective from the diverse set of paradigms (or rural discourse frameworks) was sought to effectively represent the range of decision-making frameworks underpinning the food-systems contexts in this research. Representation of these discourse frameworks indicated a well distributed cross section of the typology of possible positions. This was typology developed by Wardell-Johnson (Wardell-Johnson 2008a) (Figure 2) to identify the range of positions evolving in association with British and United States influences as ‘cultural cousins’ since white settlement in Australia. The contrasting discourses of Agrarianism (US) and the Rural Idyll (British) provided the means to identify discrete Australian positions and distinct eras of policy, as well as distinct discourse positions (or paradigms) that have evolved during that time. This typology was used as a means to test for the full range of contributing paradigms in decision-making in the context of this research.

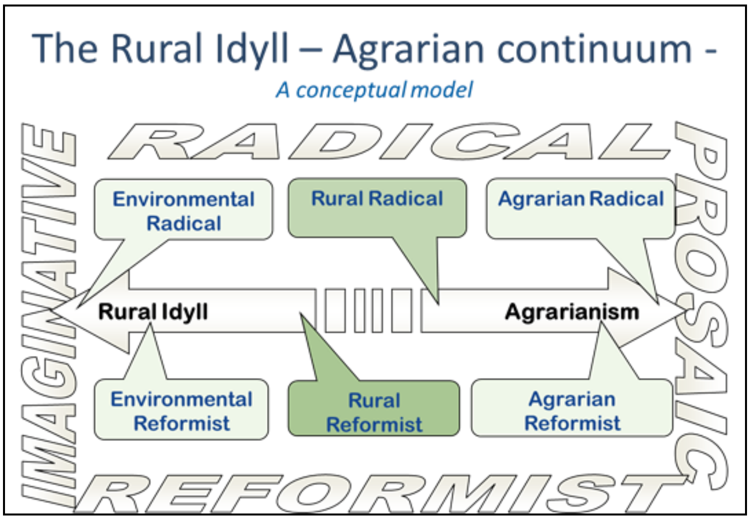


Figure 2 Rural discourse conceptual model

The rural discourse framework represents a continuum of six social value positions in relation to the rural agricultural environment from Agrarian Radical to Environmental Radical. These positions were identified through a set of normative statements representing explicit ideals, ideology and practice within rural agricultural contexts (See APPENDIX 3 for survey). **Agrarian Radicals** are driven by production ethics and believe they act as individuals in a global market. They have strong individual property rights ethics and feel they are only

responsible for their own properties. This position is similar but different to **Agrarian Reformism**. These people feel the market is an important part of developing appropriate business systems in agricultural landscapes and believe that science provides the best information for implementing best practice. They feel that their activities should be part of a larger landscape approach to maximising investment in agriculture with a focus on enterprise.

Rural Radicals feel that rural landscapes provide a base for a diverse range of activities and industries and believe that best practice is based on a wide range of triple bottom line considerations using regulation and services to enhance opportunities for non-traditional activities in rural Australia. They feel that rural landscapes offer huge potential value in a range of new uses and investments such as amenity, recreation values and regional clusters. **Rural Reformists** feel that rural landscapes provide a key value location for national cultural identity as a reflection of rural community values that coalesce around farming communities.

The final two positions are key environmental positions. **Environmental Reformists** are driven by a need to modify the capitalist system of production to account for ecological values. They feel that people and ecological systems are connected through a notion of ecosystems health and social health and behave as though ecosystems form a core of human and community wellbeing. **Environmental Radicals** are driven by an ideology of ecosystems values and believe that practice in rural landscapes should focus on the ecological systems needs. They feel that ecological values should take precedence over other rural values….the bush is not about people, but about biodiversity.

This typology of rural discourses provides an insight into responses to climate change and food security, in addition to showing which decision frameworks are most likely to define policy and practice trajectories.

Research tools: survey development

Adaptation to the impact of climate change is hampered by fragmented knowledge derived through disparate case studies and contesting positions (Hofmann *et al.* 2011). While an extensive body of knowledge is evident in a general review of research across a wide range of disciplines and interests, results have emerged from discrete and sometimes incommensurate knowledge frameworks. This food-systems and food security research drew on climate change literature to provide systematic identification of risks, and approaches to mitigation and adaptation in food production, processing and consumption. The focus provided by the broad literature related to building resilience in food-systems, accounting and auditing for climate change mitigation and adaptation, and building adaptive capacity for regional economies in the face of climate change. This literature provided the basis for survey development and Expert Panel discussion focus. A short background paper outlining food security issues developed from this literature provided the background information for eight Expert Panel Workshops.

The survey (see APPENDIX 3) comprised 29 questions directly relating to decision-making and values relating to climate change and horticulture and dairy food systems. In addition, there were 9 questions providing socio-demographic profile, and insight into sources of knowledge and influence on climate change perceptions.

The survey was developed using a combination of tested index questions (rural discourses, capacity through a capitals framework, knowledge/ information sources on climate change) and through a broad review of literature on climate change and food security submitted as a milestone through the NCCARF grants process.

The survey format was developed specifically to provide data suitable for the modelling process. Each section provided a specific component to address the requirements of several different theoretical and statistical models.

Research tools: data and the expert panel process

Expert Panel participants were selected through a conceptual model of social catchments to reflect a range of interests in a food system with specific focus on horticulture and dairy. Participants were contacted directly, mostly by phone, or in some cases by email. A peer was used for introductory purposes and an outline of the program of research was provided. Once the invitation to participate in the research had been accepted, the direct contact was followed up with an email with an outline of the research, information on the venue and time, in addition to a short background document (see Appendix 1) and a survey (see Appendix 3).

Over 50 participants were contacted in each state. Eight Expert Panel workshops were held within a two month time frame. The first round included three in each state held at USC and at Technology Park Convention Centre, in Perth. The second round comprised one Panel workshop in each state with a mix of previously attending participants, and a selection of new participants. This second round was held to ground-truth results and source further information. One workshop was held in each state (at DAFF HO in Brisbane, and at DAFWA in Bunbury). A number of factors contributed to a low response rate including school holidays, flu virus and mid-year business commitments. In all cases those participated were enthusiastic about the research, and in many cases alternative participants were suggested or nominated. While the sample was representative of the possible breadth of positions on the subject matter, and reflected a sound mix of government, industry and research sector, the issues, risks and potential solutions indicate reasonable correlation with those identified through a broad literature. The potential limitations due to limited sample size were minimised by the breadth of representation in the expert participants.

The Expert Panel workshops proved both interesting to participants, and also provided unique and valued opportunity to exchange information between food systems sectors. The process allowed for an evaluation at the end of each workshop and these evaluations provided a means to alter and re-frame the process to ensure we maximised opportunities. Comments indicated that the process and the research was strategically useful across the food-systems sectors and was considered very valuable to the horticultural and dairy industry sectors.

While each participant was selected for particular expertise and experience pertinent to the research, a range of strategies were used to ensure independent input. An equivalent process was used at all Expert Panel (EP) workshops. All EP workshops were attended by the majority of the research team comprising academic researchers from University of the Sunshine Coast (USC) under leadership from Dr Angela Wardell-Johnson, and agency staff from Dept of Agriculture and Food WA, Department of State Development Infrastructure and Planning Qld and Department of Agriculture, Food and Fisheries Qld. This ensured cross institutional and interstate contributions to focus discussion, as well as opportunities to learn from alternative contexts.

The running sheet outlining process for the workshop (see Appendix 2) shows that the discussion was focused to move from identifying broad impacts of climate change on food security, and then move to identifying mitigation and adaptation strategies. Potential for implementing these strategies through an evaluation of likelihood and impact exercises provided significant input to discussion through small group work-shopping.

In addition to a significant set of processes aimed at broad group discussion, both at the large scale of the workshop and then within the interests of small working groups, an opportunity was provided a various points in the process for individual Experts to contribute their own perspectives privately in writing. This process ensured that all voices contributed

during the workshops allaying the potential for specific interests to capture the outputs and skew results. This process has been extensively used by this research team in previous research (Wardell-Johnson *et al.* 2012) and has been refined with specialist facilitation skills generated through the team's experience. Results for the analysis of discrete components of the workshops are presented in this report, while other components formed the variables used in the modelling.

METHODS FOR THE ANALYSIS OF TEXT (WORKSHOP DATA)

A comparative analysis was conducted of the workshop data (text data generated during the EP workshops) to identify differences between SEQ and WA responses. The analysis was conducted of three discrete components: the issues and impacts of climate change on food security; constraints and opportunities to address climate change issues; and mitigation and adaptation strategies for intervention in climate change impacts.

The EP workshop process was recorded both by the facilitators as well as by contributions in group work processes. Other text was generated through qualitative responses to the survey. A text analysis of the workshop generated data was conducted through a semantic mapping using the analysis package Leximancer (Smith 2003, Smith 2005). This automated content analysis uses emergent clustering algorithms to discover and extract concepts from the text to generate a thematic map. These concepts are derived from an analysis of frequency, as well as a comparison of phrases and words with similar usage. A strength of this approach is the identification of co-location of phrases and words through clustering like-concepts. This text analysis identifies and clusters concepts that define each theme thus characterising both overt and underlying structure. Themes are depicted in the graphs as large circles and the concepts are depicted as labelled dots within the themes. This method of text analysis is not based on a prior allocation of values to sort, but rather depends on an algorithm to identify themes emerging from concepts in the text data. This analytical approach reduces the likelihood of introducing researcher assumptions and influences in the process and produces a "global context and significance of concepts" beyond "anecdotal evidence which may be atypical or erroneous" (Smith and Humphreys 2006 p262).

METHODS FOR THE ANALYSIS OF SURVEY DATA (NUMERIC DATA)

The survey data was analysed using a multivariate approach using standard descriptive statistics (Excel) as well as numerical classification comprising cluster analysis, multi-dimensional scaling ordination and network analysis to analyse the data. Manly (Manly 1994) describes multivariate analysis as a means of considering with equal importance, several related and random variables simultaneously. Standard approaches that usually combine such methods as Principal Components Analysis, Factor analysis, Discriminant function analysis and Cluster analysis have been further developed through numerical classification and multi-dimensional scaling ordination to take full advantage of computer based approaches that provide a more statistically reliable outcome. This allows simultaneous numerical classification that avoids hierarchical approaches and compounded errors thus exposing structure in systems more effectively (Wardell-Johnson 2005).

The survey data was subjected to an analysis to assess simultaneously relationships between cases and variables that portray relationships of people with values through clustering, ordination, networks and statistical evaluation. This provided a robust and process based validation that emphasized characterization of sets of cases as individuals clustered into social assemblages.

The multivariate analysis package, PATN, provides a conclusive statistical basis for what is usually achieved through subjective, qualitative, inductive and intuitive approaches to gauging and assessing 'trends' or structure in systems (Belbin *et al.* 2002). The analysis is based on the values derived from socio-demographic, capability, risk and mitigation/adaptation variables. This approach did not require a normal distribution of data,

and was not dependent on *a priori* decisions about the importance of specific variables (dependent and independent variables) in defining the clusters, ordination or networks. The state of the system is portrayed by the co-ordinates of cases (participants) with variables (research questions) in a matrix within this abstract dimensional space (Wardell-Johnson 2005).

Dissimilarity between cases based on variables associated with each of the three social dimensions was quantified using the Bray Curtis metric (Bray and Curtis 1957). This method has performed consistently well in a variety of tests and simulations on different types of data (Faith *et al.* 1987). Cases were clustered (forming social assemblages) using UPGMA (unweighted pair group arithmetic averaging) with Beta set at -0.1. Under such conditions the clustering strategy is space-dilating and resists the formation of a single large group (Booth 1978). Groups of variables (attribute clusters) were derived using the Two-step metric (Belbin *et al.* 1984) also with Beta set at -0.1. The association between case (social assemblages) and variable groups (attribute clusters) and extrinsic variables (the socio-demographic variables) were compared using Kruskall-Wallace tests. This statistic is a non-parametric equivalent of the f-ratio and based on average rank of each attribute (Belbin 1993).

The dissimilarity matrix was visually presented through semi-strong hybrid multidimensional scaling ordination (SSH MDS). SSH MDS seeks to provide in few dimensions, an accurate representation of the resemblance between cases on the basis of their descriptive attribute profiles (values and socio-demographic variables). The relationship of cases, values and socio-demographic variables, with the ordination axis was evaluated using principal axis correlation (PCC procedure in PATN) (L. Belbin 1995). The significance of correlation of each group of cases (social assemblages), and each value and socio-demographic variable were assessed using Randomisation tests (with 100 permutations) and the MCAO procedure (Monte Carlo's permutations) of PATN (L Belbin 1995, Belbin *et al.* 2003). These vectors of variables that are statistically correlated to the ordination axis and clustering expose the contrasts in values in the combined survey data.

The results of the numerical taxonomy portray the system in a range of visual forms. Multi-dimensional scaling ordination exposes diversity in populations (through the data) rather than a reductionist portrayal that excludes 'outliers'. A minimum spanning tree shows the network of relationships between individuals (each dot) and social assemblages (defined by colour). A two-way table shows actual relationships between individual cases and variables. Row and column dendrograms portray visually the statistical clustering of cases (individuals) and variables. Overlaid statistically critical biplot vectors indicate statistically critical tensions within the social catchments. Each biplot vector shows direction of correlation with ordination axes (positive association with individuals and social assemblages). Positive association is in the direction of the biplot label and emanates from the centre of the ordination space. Negative association of the variable with the individuals and social assemblages is in the opposite direction from the biplot vector label across ordination space. The neutral zone is in the centre of the ordination space.

MODELLING INTERVENTION STRATEGIES

RESEARCH TOOLS - CAPACITY AND CAPITALS

Capacity has a significant bearing on the success of implementing intervention strategies. To assess capacity, a framework of seven capitals was used to locate values representing the triple bottom line (TBL) (Wardell-Johnson 2011) (Table 1).The data to evaluate the relative perceived importance of these capitals was derived from a series of questions in the survey data. Three social components reflect the social dimension of the TBL: cultural, human and social capital. Two economic components reflect the economic dimension of the TBL: economic and physical capital. Two ecological components reflect the ecological dimension of the TBL: natural and environmental capital.

The social dimension: Cultural capital develops within the family sphere and provides a non-economic means of acquiring qualifications, employment and status. Human capital is the sum of individual human skills, ability, experience training and knowledge that reflects and consolidates social and cultural capital of the family of origin. Social capital can have a multiplication effect with positive or negative influence on other forms of capital. It comprises networks of relations of trust and norms of reciprocity and exchange. These social obligations are a collective resource derived through group membership and connections that are convertible to economic capital.

The economic dimension: Physical capital such as infrastructure, tools and equipment is convertible to money and institutionalised as property rights. Economic capital comprises financial capital and is a potential outcome of social capital. Two components of the ecological dimension of the TBL are environmental capital which encompasses water, soil, forests, biodiversity and scenery, and holds material value. While natural capital represents values from the 'natural' world that holds symbolic value with partial public good. Natural capital rarely has market value.

Table 1 Capitals framework (Wardell-Johnson 2011, Flora and Flora 1996)

TBL VALUE	CAPITAL	DESCRIPTION
SOCIAL VALUES	Cultural capital	Non-economic means of acquiring qualifications, employment and status
		Develops within the family sphere
	Human capital	Individual human skills, ability, experience training and knowledge
		Reflects and consolidates social and cultural capital of the family of origin
	Social capital	Social obligations and connections convertible to economic capital
		A collective resource derived through group membership
ECONOMIC VALUES	Economic capital	Convertible to money
		Institutionalised as property rights
	Physical capital	Includes physical infrastructure, financial capital, tools and equipment
		Potential outcome of social capital
ECOLOGICAL VALUES	Environmental capital	Encompasses water, soil, forests, biodiversity and scenery
		Holds material value
	Natural capital	Representing values from the 'natural' world
		Holds symbolic value
		Partial public good and rarely has market value

By understanding the relative allocation of value of capitals comprising the TBL sustainability framework, it becomes possible to indicate the need for certain forms of capacity to intervene for climate change mitigation and adaptation.

Research tools: theoretical and statistical models

To develop and test mitigation and adaptation approaches suitable for strengthening vertically linked food-systems that account for capacity, and climate change mitigation and adaptation Structural Equation, Value Chain and Supply Chain modelling approaches suitable for strengthening vertically linked food-systems, were used. These statistical models drew on data generated through the integration of three theoretical models: Theory of Reasoned Action, Theory of Planned Behaviour and Diffusion Innovation Theory.

This integrated modelling allows insights into trajectories, both of climate, but more importantly of requirements for and implications of strategic interventions. By integrating Structural Equation Modelling and a hybrid of the Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1975), Theory of Planned Behaviour (TPB) (Ajzen 1991) and Diffusion Innovation Theory (Rogers 1995) applying the conceptual framework of the "world-class food system model" (developed by Nath and Islam 2010) it is easier to explain stakeholders adaptive behaviour. This integrated approach to modelling identified scenarios to test and identify points of intervention for policy development and practice. Scenarios provide simple and synthesised descriptions based on consistent sets of assumptions and verified real data to outline stories about potential alternative futures. This approach helps decision-makers and a range of stakeholders recognise interactions and implications of climate change (Ingram 2011).

A theoretical framework enables predictions to be made of any business activities and, therefore, it is helpful to have a theoretical foundation within which the testable assumption can be drawn. It is for these reasons the principles of the theory of reasoned action (TRA), theory of planned behaviour (TPB) and protection motivation theory (PMT) have been used for this study to develop testable assumptions about the factors related to climate change adaptation and mitigation. Modelling to test points of interventions for strategic achievements in mitigation of climate change impact and adaptation in the dairy and horticulture industries will be achieved by utilising the data/information obtained through both the survey results and the expert panel data by designing, developing and applying a Structural Equation Modelling. The Structural Equation Modelling approach will follow the approach used by Quaddus et al (Quaddus *et al.* 2006); and Jackson *et al.* (Jackson *et al.* 2007) where a hybrid of the Theory of Reasoned Action (TRA) of Fishbein and Ajzen (Fishbein and Ajzen 1975) and Theory of Planned Action (TPA) of Ajzen (Ajzen 1991) and Diffusion Innovation Theory of Rogers (Rogers 1995b) is developed and used to construct appropriate variables and their links in explaining stakeholders adaptive behaviour. This integration of conceptual and empirical approaches through Structural Equation, Value-Chain and Supply-Chain modelling allowed testing of strategic points of intervention and the consequences.

Theory of reasoned action (TRA) and theory of planned action (TPB)

Ajzen and Fishbein's (1980) TRA is "an especially well-researched intention model that has proven successful in predicting and explaining behaviour across a wide variety of domains" (Davis 1989) TRA is "designed to explain virtually any human behaviour" (Ajzen and Fishbein 1980) and provided useful strategies for identifying consequences of the behavioural factors related to the climate change adaptation (Jackson *et al.* 2006) involved in the horticultural and dairy industry sectors.

TPB uses perceived behavioural control to predict behaviour in two ways: through motivational factors and the intention to perform the behaviour (via the 'Intention' construct) and also through actual control via direct link between the 'Perceived behavioural control' and 'Behaviour' constructs which is not mediated by intention (Madden *et al.* 1992).

Protection Motivation Theory (PMT)

PMT (Rogers 1983, Rogers and Prentice-Dunn 1997) is one of the four major theories within the domain of psychological research on health behaviour. Although, a few of the studies (Blok 2007) successfully applied PMT to earthquake preparedness, application of PMT to environmental and agricultural adaptation is limited. Grothmann and Patt (2003) developed a process model of adaptation and adaptive capacity mainly based on PMT (Grothmann and Patt 2003). Results shows the socio-cognitive model of private proactive adaptation to climate change with "risk perception" and "perceived adaptive capacity" (Grothmann and Patt 2003).

In the first process – 'threat appraisal' (also known as risk perception) – a person assesses a threat's probability and damage potential to things he or she values, under the condition of no change in his or her own behaviour. In the second – 'coping appraisal' (perceived adaptive capacity) – a person evaluates his or her ability to cope with and avert being harmed by the threat, along with the costs of taking such action.

The risk perception comprises both a person's expectancy of being exposed to threat (to use a natural-hazard example that a flood reaches the house in which a person lives) and perceived severity of harmful consequences of the threat to values and that that is valued (e.g., a flood in the area would harm valued things, such as home or property). Rogers and Prentice-Dunn (1997) use the term 'vulnerability' instead of 'probability'.

Coping appraisal, or perceived adaptive capacity, by contrast, comes after the risk perception process and only starts if a specific threshold of threat appraisal is passed. "A minimum level of threat or concern must exist before people start contemplating the benefits of possible actions and ruminate their competence to actually perform them" (Schwarzer 1992 p. 235). The coping appraisal has three subcomponents. First, it includes a person's perceived adaptation efficacy, that is, the belief in protective actions or responses to be effective in protecting oneself or others from being harmed by the threat (e.g., a judgment that relocating electric devices in upper floors would prevent damage from a flood). The second component, perceived self-efficacy, refers to the person's perceived ability actually to perform or carry out these adaptive responses (e.g., a person with few technical skills might perceive it as rather difficult to relocate electric devices). The third component is perceived adaptation costs, the assumed costs of taking the preventive response. These can be any costs (e.g., monetary, personal, time, effort) associated with taking the risk-reducing adaptive response.

Based on the outcomes of the threat- and coping-appraisal processes, a person responds to the threat. Two general types of responses can be differentiated: adaptation and "maladaptation". Adaptive responses are those that prevent damage or increase benefits (e.g., precautionary action like avoidance of expensive interiors on flood-prone floors), and are taken if the risk perception and the perceived adaptive capacity are high. "Maladaptive" responses – including denial of the threat, wishful thinking and fatalism – do not prevent monetary or physical damage in the case of a climate change impact but only the negative emotional consequences of the perceived risk of those impacts (e.g., fear). A person would take "maladaptive" responses if his or her risk perception is high but the perceived adaptive capacity is low.

Diffusions of Innovation

In addition to these established theories, (Fliegel 1993) with support from Feder and Umali (Feder and Umali 1993), proposed a more widely accepted, non-linear approach to the adoption of agricultural innovations. He argued for viewing the farmer as an active individual who responds to random forces related to social participation and communication. In terms of Diffusions of Innovations in agriculture and rural sociology, a survey of the literature was conducted by Rogers (1995) of some 3,890 publications, rural sociology contributed the greatest percentage of research to the broader field of diffusion. This literature indicated that diffusion of agricultural technologies provided useful leads to agricultural scientists to have their research applied by farmers.

Structural Equation Modelling

Structural Equation Modelling (SEM) is a statistical technique for testing and estimating hypothesised causal relationships among the factors of a casual model using a combination of statistical data and qualitative causal assumptions. SEM allows modelling multiple relationships among multiple predictors in the form of multiple regression and path analysis (Hair *et al.* 1998). These theoretical models were applied and integrated through SEM

allowing an understanding of relationships between risk, intervention strategies (both mitigation and adaptation) as well as the contribution of capability (through the capitals framework).

OVERVIEW OF THEORETICAL AND METHODOLOGICAL CONCEPTUALISATION OF RESEARCH

Climate change mitigation and adaptation interventions were defined to reflect a rich conceptualisation drawing from the Australian context, but also acknowledging the moral context of global association. This association in security terms reflects both the need to import (within the national setting and from the international provider) food or food-related technology (such as genetic variety) and the need to export food as a commodity to supply food for global populations and provide livelihood for rural Australian populations.

Three key objectives defined the research agenda. The first objective of this research was to identify decision-makers, stakeholders and contributors based on social catchment criteria. This objective aimed to ensure participation and selection of expert opinion reflected in a food system, and knowledge about climate change impacts on dairy and horticulture. Each research objective comprised research strategies that established and built upon knowledge generated horizontally and vertically. Climate change mitigation and adaptation interventions were identified from three key sources of data: literature; survey data; and Expert Panel discussions. Results of the analysis of these sources of information are reported in four sections: 1. identifying positions taken; 2. risks; 3. mitigation and adaptation strategies; and 4. interventions. These sections reflect the interlinked processes of conceptualising and gathering data: the literature, survey, the Expert Panel workshops and the modelling. Each of these processes reflected the transdisciplinary approach used in sustainability research (Hirsch Hadorn *et al.* 2006) that establishes purpose and norms in food-systems, identifies and defines targets in these systems and outlines transformation potential in these systems.

SECTION THREE: DESCRIBING THE EXPERT POSITIONS

Expert Panels are increasingly used to contribute to policy and practice. Their input provides insights when time-lines for decision-making are short and the conservatism of scientific consensus is constrained by poor links between the testing of theory, and learning gained through application and experience. Getting a range of practice, theory, research and governance people around one table makes for a rich insight into problem solving potential that is very useful for policy development and practice strategies. It was important to garner these unique insights, but also to understand the socio-cultural values that define the insights. The discrete Australian positions contrasting with historical discourses of Agrarianism (US) and the Rural Idyll (British) define distinct discourse positions (or paradigms) to provide a typology of policy and practice in rural Australian contexts (Wezel 2009). These discourse frameworks are at play in global policy and negotiation where food is a commodity, a form of aid or a tool for development.

Social catchments represent interests that contribute to decision-making across socio-political scale in geographical context. Experts from each of the social scales (micro, meso and macro) and interest sectors spanning horticultural and dairy food systems contributed their expertise to this research. Participants represented the micro scale of farmers/ producers and communities; the meso scale that included extended regional economic, social and ecological communities; and the macro scale including formal and informal institutional entities such as a range of governance and research institutions that structure decision-making at the national and global scale. The outcomes of the Expert Panel process captured opinion and perspective from the diverse set of paradigms (or rural discourse frameworks) that effectively represent the range of decision-making frameworks underpinning food-systems in these industries.

This section provides an insight into the EP socio-demographic profiles, paradigms (discourse frameworks) and the social values underpinning their decision-making. It provides information on the different value positions likely to be held in the horticulture and dairy sectors.

DESCRIBING THE EXPERT PANEL PARTICIPANTS

EXPERT PANEL POSITIONS

The survey data were analysed using Excel and SPSS for descriptive statistics to observe the frequency, and percentage of the responses. Most questions were based on a ranking scale thus percentages of responses to each rank are used to indicate level of agreement with a statement. Expert Panels included representation from a range of government, industry and interest sectors contributing to decision-making in rural agricultural landscapes and horticulture and dairy food systems. In total there were 24 surveys completed, representing 12 participants in each state. There was equal distribution between genders (6 women in SW WA and 6 women in SEQ).

The first five survey questions sought to establish importance of climate change in moral and value framing (Figure 3). These statements were ranked from 0 = disagree strongly to 4 = agree strongly. The statements ranked were:

1) Australia is responsible for meeting global food needs under circumstances of decreased food supply and increased poverty.
2) Agricultural practice impacts negatively on ecological integrity and environmental quality.
3) The global oil crisis has implications for food production and transport.
4) Human-induced changes in climate will result in temperature increase & rainfall decrease requiring political and practice adaptation strategies for food systems.

5) The development and adoption of new technologies will overcome climate and peak oil constraints on food production, processing and supply.

Results of the analysis of these questions indicated that the experts contributing to this research considered in general that technology has a role to play, that the oil crisis has significant implications for food systems and that human-induced climate change will have a consequence for rising temperatures. They did not feel that Australia holds a significant responsibility for providing for global food needs, but felt that agriculture has some impact on ecological systems.

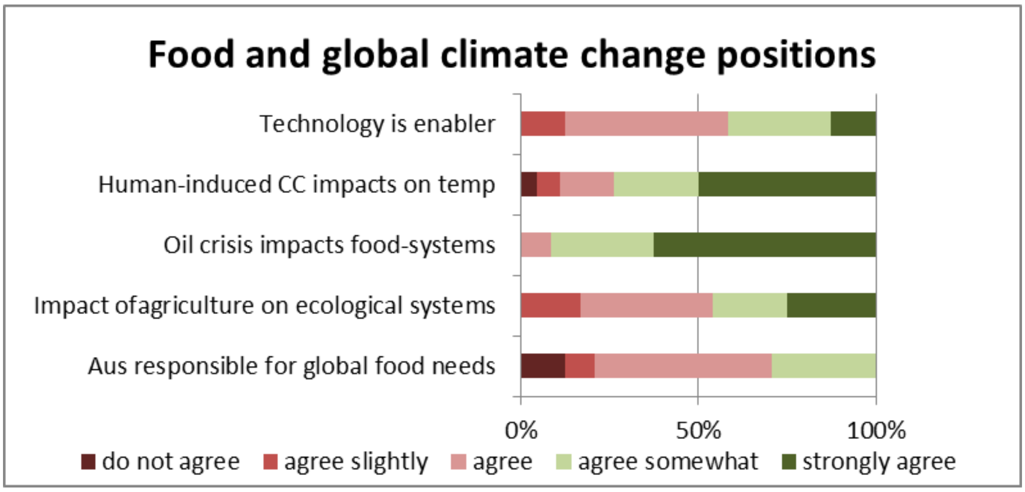


Figure 3 Ranked responses for food and global climate change positions (n = 24)

Most people identified climate change through extreme weather (58%), sea level rise (42%), rainfall decline (42%). Melting ice-caps and temperature increase had lower scores of 38% each. Nearly 80% of responses indicated a confidence in the dairy and horticultural sectors adapting to climate change. EP participants indicated a reasonable level of agreement (around score of 3) in each of the TBL values that Australian horticulture and dairy food systems achieved ranking as a world-class food-system (Figure 4).

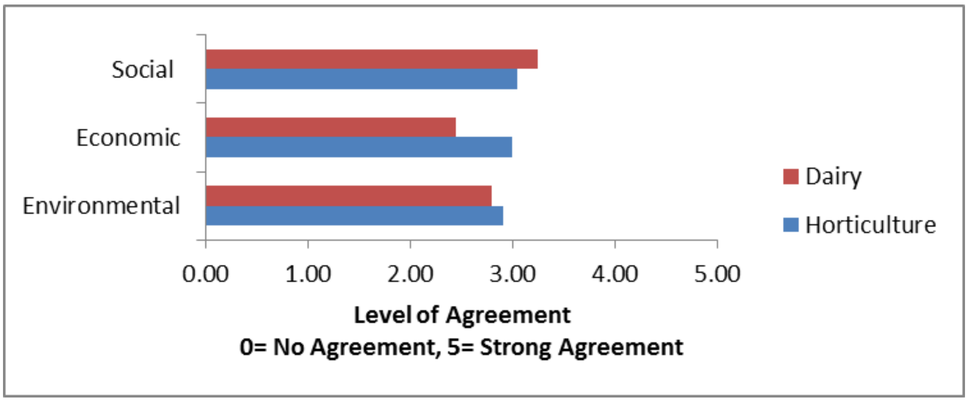


Figure 4 Ranking of horticulture and dairy as world-class food-system (n=24)

In understanding which parts of the environment are most in need of attention, Question 19 in the survey asked: What are the most urgent environmental issues faced in production landscapes? Responses indicated that introduced plants and animals and climate change were very important issues (Figure 5). Of less importance was declining air quality, protection of species, soil erosion and salinity.

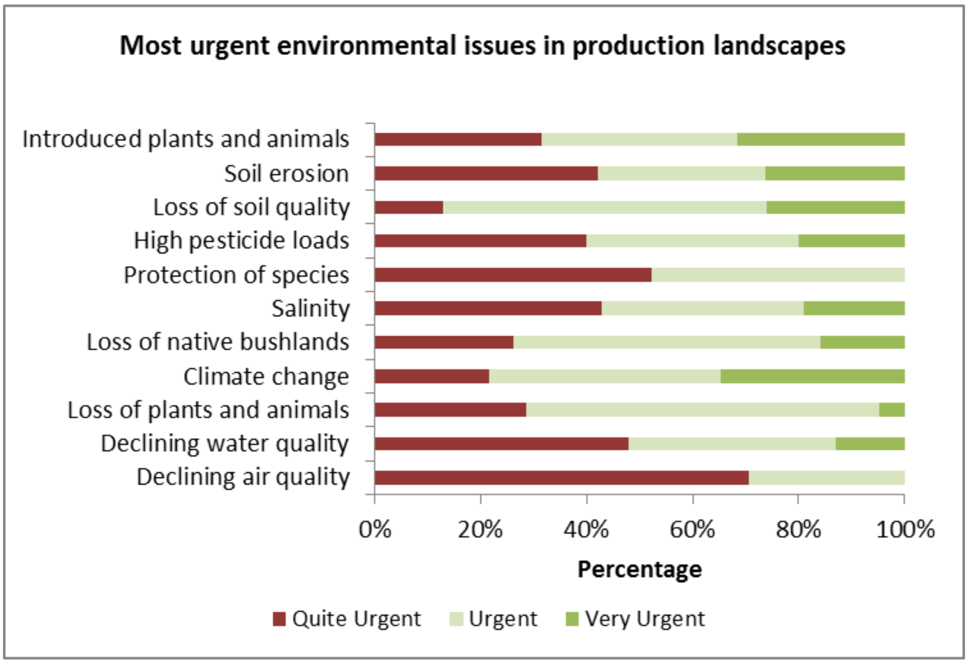


Figure 5 Ranking of environmental issues in production landscapes (n=24)

Once including climate change as an issue alongside other environmental issues it becomes evident that people engaged in horticulture and dairy have a wide range of environmental concerns. It was thus important to understand in addition the range of value positions that EP participants held in relation to rural production landscapes in general. This was established through the index of rural discourses derived through the conceptual model (Figure 2).

Expert Panel participants reflect a distinct set of characteristics. In other research into sources of information on climate change in rural Australia there is a wider range of sources than in evidence from this set of participants (Figure 6). In general, this sample of participants uses the internet and university resources (which include formal scientific resources). Friends, family and neighbours are also used to a lesser extent, as are NGOs and the local commercial sector.

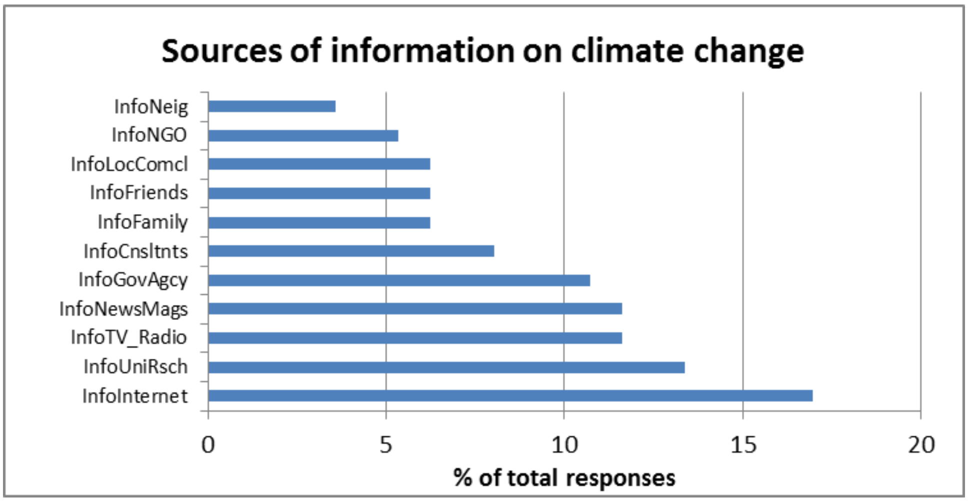


Figure 6 Sources of information on climate change (n=24)

While neighbours, friends and family are less likely to be used as sources of information, it is evident from this result that government agencies are less likely to be sources of information on climate change than TV, radio and magazines. This result shows that the experts

selected for this study are most likely to be informed by scientifically derived information, and are likely to use the internet to source that information but that all sources of information are likely to be used.

Rural discourse framework

The rural discourse framework represents a continuum of six social value positions in relation to the rural agricultural environment from Agrarian Radical to Environmental Radical. These positions were identified through a set of normative statements representing explicit ideals, ideology and practice within rural agricultural contexts (See APPENDIX 3 for survey). The questions used to develop an understanding of the paradigms/ discourse frameworks represented at the EP workshops were represented through six discrete statements that reflected each of the six rural discourses. These statements can be further explored in the survey. The questions were:

- Survey Question 20. Rate your agreement with these ideal characteristics associated with country landscapes:
- Survey Question 21. Rate your agreement with these statements indicating the way in which people manage and use country landscapes:
- Survey Question 22. Rate your agreement for how people think of themselves in country landscapes:

Agrarian Radicals (15% of total EP representatives: Figure 7) are driven by production ethics and believe they act as individuals in a global market. The emphasis on individual property rights indicates that they are less likely to engage in the wider agricultural landscape system. This position is similar but different to **Agrarian Reformism** (18%). These people feel the market is an important part of developing appropriate business systems in agricultural landscapes and use science for implementing best practice. They feel that their activities should be part of a larger landscape approach to maximising investment in agriculture with a focus on enterprise.

Rural Radicals (16%) feel that rural landscapes provide a base for a diverse range of activities and industries to enhance opportunities for non-traditional activities in rural Australia. They consider agricultural production to be a marginalised activity, but a useful means of commodifying landscapes to allow more entrepreneurial behaviour developing innovation and diversity outside the traditional agricultural landscape frameworks. **Rural Reformists** (18%) feel that rural landscapes provide a key value location for national cultural identity and rural community values that coalesce around farming communities. These people behave as reflection of rural community farming and family values in the traditional sense taking into account changing societal values.

The final two positions are key environmental positions. **Environmental Reformists** (17%) are driven by a need to modify the capitalist system of production to account for ecological values.. They feel that people and ecological systems are connected and form a core of human and community wellbeing. **Environmental Radicals** (16%) are driven by an ideology of ecosystems values and focus on the ecological system needs. They feel that ecological values should take precedence over other rural values and focus on biodiversity. The representation of discourses is shown to be reasonably equivalent indicating that the diverse range of positions was captured in the experts represented in the research (Figure 7).

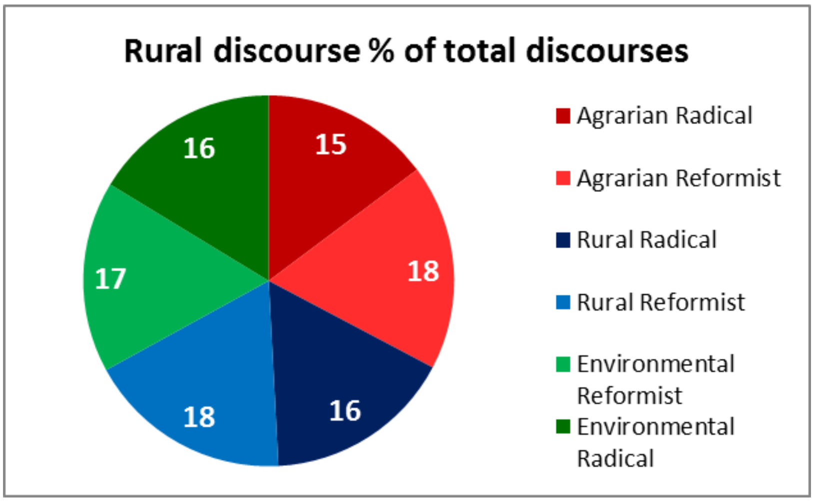


Figure 7 Rural discourse representation by Expert Panel participants (n=24)

A comprehensive representation of paradigms underpinning decision-making in rural landscapes contexts was provided through the Expert Panel participants. As contributions to decision-making and the results from this project are likely to have relevance to a wide group of stakeholders and end users including producers through to agribusiness consultants, agricultural researchers, research funders and policy-makers a range of triple-bottom-line values through disciplinary interests were included. A comprehensive representation including a range of social contexts, socio-cultural value frames and social scales involving industry sectors across the food system was necessary. In addition, each of these discourse frameworks represents an emphasis either on economic, social or ecological values effectively covering TBL sustainability focus.

Sectoral representation

A range of government, industry and interest sectors involved in horticulture and dairy food systems were represented. These figures were drawn from socio-demographic questions in the survey in which participants self-nominated the industry sector they represented. In total there were 24 surveys completed, representing 12 participants in each state. There was equal distribution between genders (6 women in SW WA and 6 women in SEQ).

In SW WA the three largest sectors represented (each of 21% of total industry interests) (Figure 8) were from state government (SGovIndus), local government (LGovIndus) and the water industry sector (WaterIndus). In addition, the tertiary education sector was represented (EdInuds 14%) and the arts sector (ArtsIndus), horticulture (HortIndus) and the agricultural sector (which included those self-nominated from the dairy industry) (AgIndus 7%). The industry representation reflected the key issues of water in WA horticulture and dairy sectors. Federal government interests were represented by experts nominating themselves as the research sector included in the agricultural industry sector.

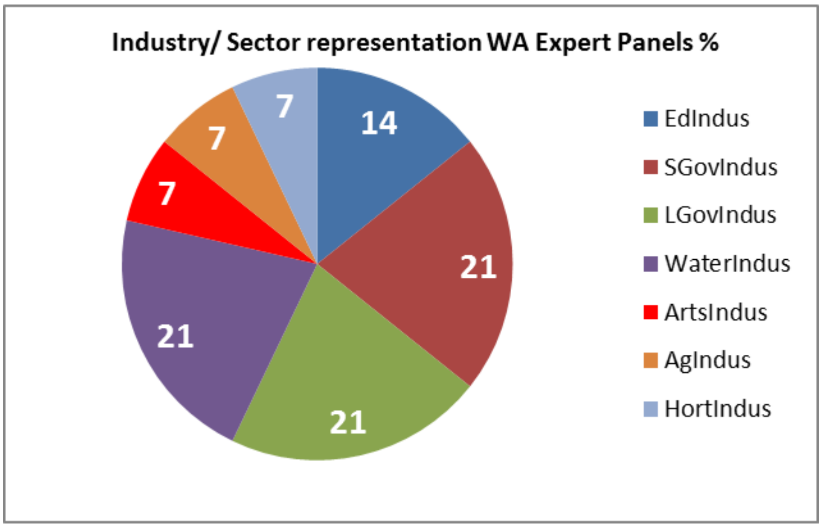


Figure 8 Industry/ sector representation in SW WA Expert Panels (n=12)

In SEQ state government representation was about one third of the total contribution (33%: Figure 9). Similar representation to that of SW WA included a diverse cross section of interests in a food system.

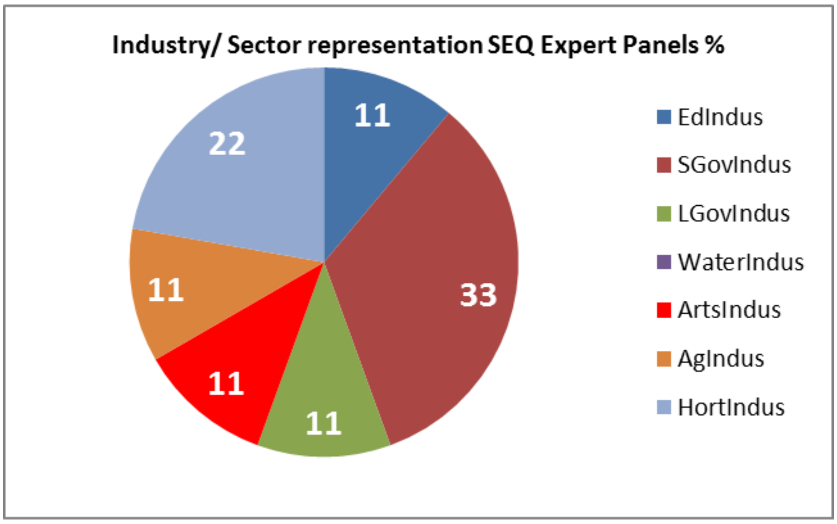


Figure 9 Industry/ sector representation for SEQ in Expert Panels (n=12)

The range of industry sectors represented was also reflected in the range of occupations nominated by EP participants. These included: academics, agronomists, CEOs, public servants, economic development officers, extension officers, facilitators, farmers, horticulture development officers, policy officers, town planners.

There was a reasonable cross section of age groups representing interests and positions in food security and climate change through the Expert Panel Workshops. There were 14 people aged between 40 and 64 years of age (Figure 10) and 3 of the 25 to 39 year age group. Two participants declined to record their age in the survey.

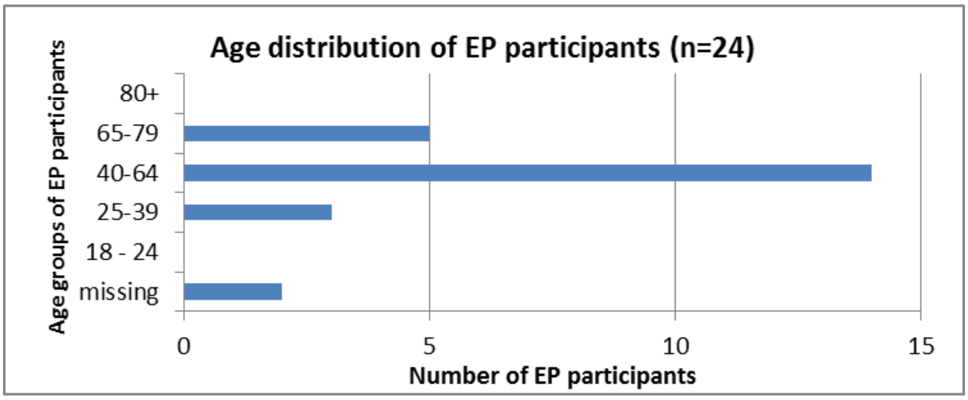


Figure 10 Age distribution of EP participants in both states

This age representation reflects career and expertise development to be accorded expert status.

MULTIVARIATE RESULTS FROM SURVEY DATA

The survey data was analysed using a multivariate approach using standard descriptive statistics (Excel) as well as numerical classification comprising cluster analysis, multi-dimensional scaling ordination and network analysis to analyse the data. The results show sets of cases as individuals clustered into social assemblages forming three discrete groups of positions (Figure 12).

The results of the numerical taxonomy portray the system in a range of visual forms. Multi-dimensional scaling ordination exposes diversity in populations. A minimum spanning tree shows the network of relationships between individuals (each dot) and social assemblages (defined by color) (Figure 12). A two-way table showing actual relationships between individual cases and variables is provided. Row and column dendrograms portray visually the statistical clustering of cases (individuals) and variables (Appendix 3).

This analysis sought to identify any relationships between individuals (24 EP participants) and variables (76 showing values, ranked importance of adaptive capacities, socio-demographic descriptors such as age, industry sector, sources of information and other variables from the survey). The analysis identified three different social assemblages (Figure 11). There was equal representation between SW WA and SEQ in the largest social assemblage (red) which had 67% of the total representation. The blue assemblage had 25% representation, with more from Qld, and the yellow assemblage of only 8% only included SW WA EP participants.

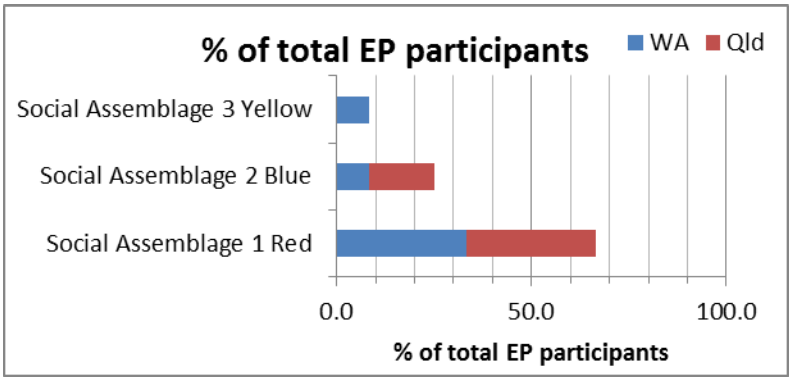


Figure 11 % of total EP participants in social assemblages by state (n=24)

The ordination shown in Figure 12 indicates the relative relationships between individuals within and between social assemblages.

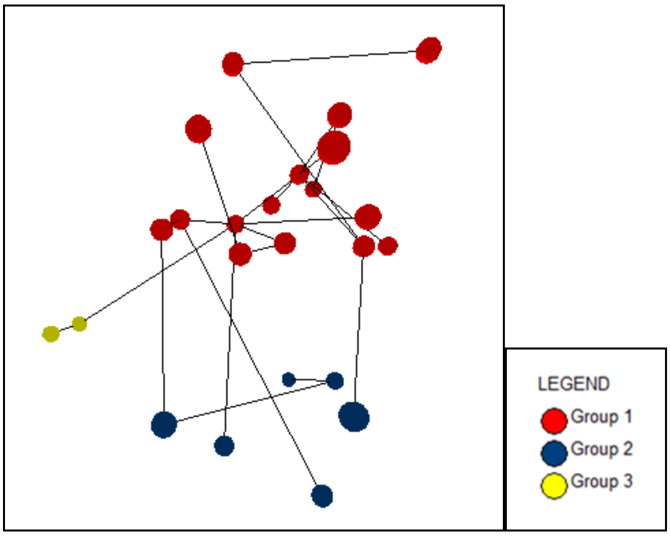


Figure 12 Ordination showing social assemblages (n=24)

As the ordination is shown in three dimensions, the larger dots (individual EP participants) are not more important, only closer to the viewer. The ordination shows that the yellow assemblage is quite different to the other assemblages. The blue assemblage, though cohesive statistically share characteristics not necessarily identifiable through the variables. The larges assemblage (red) is cohesive. The row dendrogram shows which individual EP participants are to be found within each assemblage (see the column dendrogram shows which attributes are clustered to indicate shared values and other descriptive variables (see Appendix 3).

A two way table shown indicates that the yellow social assemblage (smallest) of two SW WA people shared a common value frame indicating no agreement with Australia's responsibility for global food needs (0AusSpplyFood), little faith in technology providing solutions to climate change (1NewTechCCSoltn) and found that global oil is of minor concern for food-systems (2GlOil). These two also felt that society (SocietySolveCC) and the Federal Government were responsible for solving CC issues (FedGovSolvCC) with a strong political intervention necessary for adaptation to occur (4CCneedsPolitAdpt). Both work for state government and are aged between 40 and 64 years. There is some indication through this result that there are differences in the way in which western Australians engage with managing climate change in food systems.

In contrast the largest **social assemblage (red)** had strong agreement that a range of organisations and political scales responsible for solving CC but less likely to depend on local government (InfoLocCncl) and their neighbours (InfoNeig) for information on climate change. The **blue assemblage** felt that agriculture has a considerable impact on ecological systems (4AgNegEnv), that Australia has a minor responsibility for providing global food needs (1AusSpplyFood) and is most likely to use the internet as a source of climate change information (InfoInternet). This assemblage largely represents the industry sectors (HortIndus, AgIndus, WaterIndus).

The ordination showing the biplots provided an indication of binary positions evident in the Expert Panel workshops. There were distinct differences between positions taken by the industry sector and the government and research sectors. These differences extended to the sources of information most likely to be accessed to mitigate and adapt to climate change issues, and potentially demonstrated the need for closer relationships between industry and government if climate change interventions are to be appropriately targeted. The relationship between policy and industry implementation of intervention strategies must be based on a stronger collaboration based on co-operation that reflects industry perspectives and interests if it is to be effective.

This result was discussed at length in the second round of expert panel workshops and shown to be an accurate portrayal of current values associations and the need for stronger institutionally based collaboration. From the discussion it appeared that the industry sector had a sound understanding of their stakeholders. In addition, it was clear that extension officers were somewhat limited by the policy interventions they had access to for the horticultural and dairy sectors.

The strength of locating the social in association the ecological and economic frames has allowed an understanding of the socio-cultural drivers (the slow variables in a complex system) to emerge. The importance of these variables is reiterated in the modelling results, and must be accommodated in early stages of planning for interventions in climate change.

SECTION FOUR: RISKS

Potential changes in key climate variables, such as increased average temperatures, changed rainfall patterns and increased climate variability, are projected to directly affect food security and agricultural productivity in Australia (Allouche 2011). Indirect impacts on agricultural productivity include changes in the incidence of pests and diseases, increased rates of soil degradation and erosion, slowdown in global economic activity and a decline in agricultural productivity in key growing regions (Gunasekera *et al.* 2007, Kokic *et al.* 2007). Australia is projected to be one of the most adversely affected regions from declines in agricultural production driven by climate change. The risks in food production inherent to climate change are different for each food production sector. This research focuses on dairy and horticultural food systems.

Section 4 provides an outline of the way in which risk incurred through climate change for food security was identified and defined. This links with Section 5 which provides the climate change mitigation and adaptation strategies with potential application in horticultural and dairy food systems identified through the research.

The survey responses provided by the EP participants indicated some differences in perceptions of risk (Figure 13). Bush fires were perceived by the EP to be of greater concern to the horticultural sector but lower market prices and rainfall were greater issues for the dairy sector.

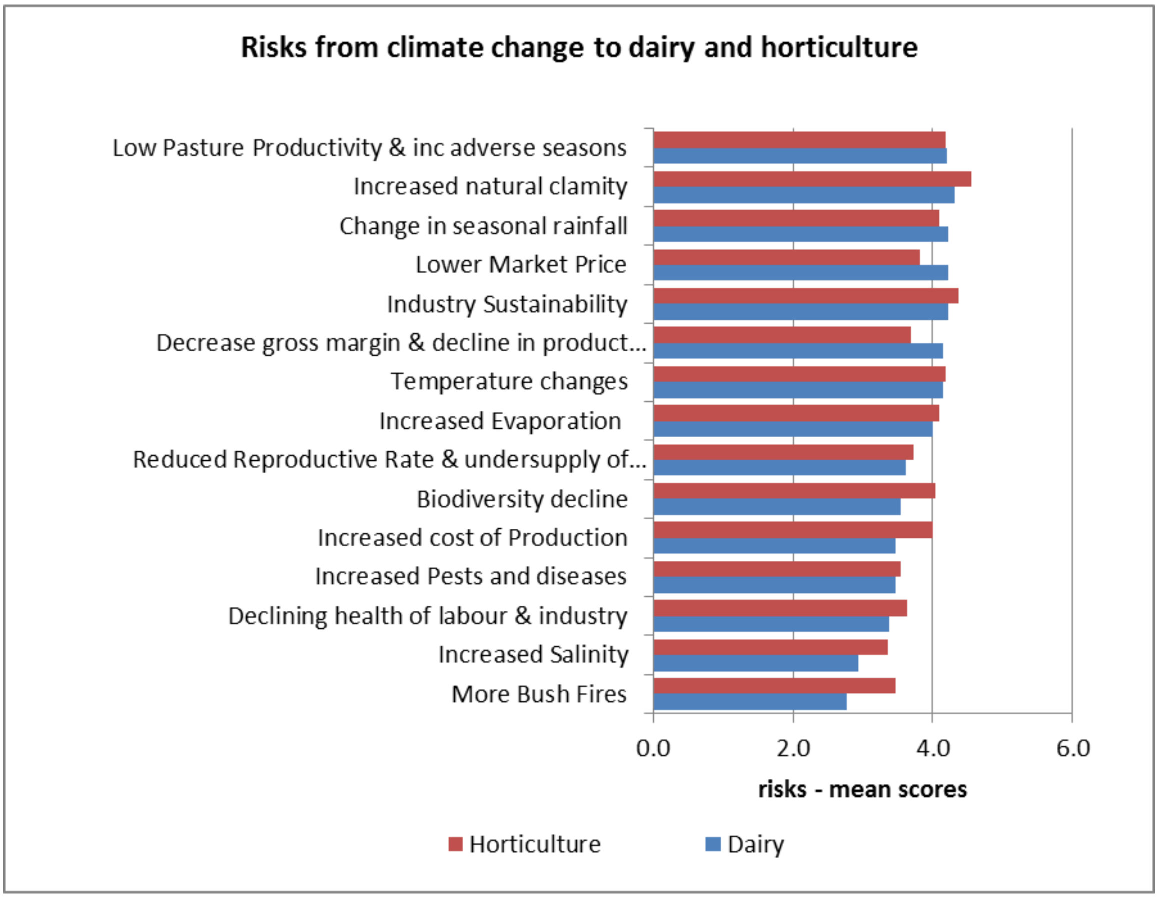


Figure 13 Risks from climate change to dairy and horticulture

In general risks related to climate change were seen to be of more concern to horticulture.

RISK TO FOOD SECURITY THROUGH CLIMATE CHANGE

Survey results indicated that both the horticulture and dairy sectors acknowledged a range of climate change related risks to their industries. These results were followed up through a correlation and extension exercise in the Expert Panel workshops. A round table question identifying risks from climate change within the horticultural and dairy sectors was used to focus the research framing, identify sector interests and to identify mitigation and adaptation discussion themes for each workshop. The question – 'How do you think climate change will impact on food security?' – showed both contrasting and similar positions for each food-systems landscape.

Risk in SW WA: Issues and impacts of climate change on food security

Twelve experts representing a range of interests in horticulture and dairy provided the text data through participation in Expert Panel workshops for these results. Nine themes emerged from the analysis (Leximancer) including ***food***; ***water***; ***costs***; ***systems***; ***power***; ***capacity***; ***producers***; ***increased***; ***Availability***. The discussion focus on food was evident with food ranked at 100% (Figure 14). The most relevant concept was also *food* with *production*, *water* and *use* all scoring a relevance ranking of over 50% (Figure 14).

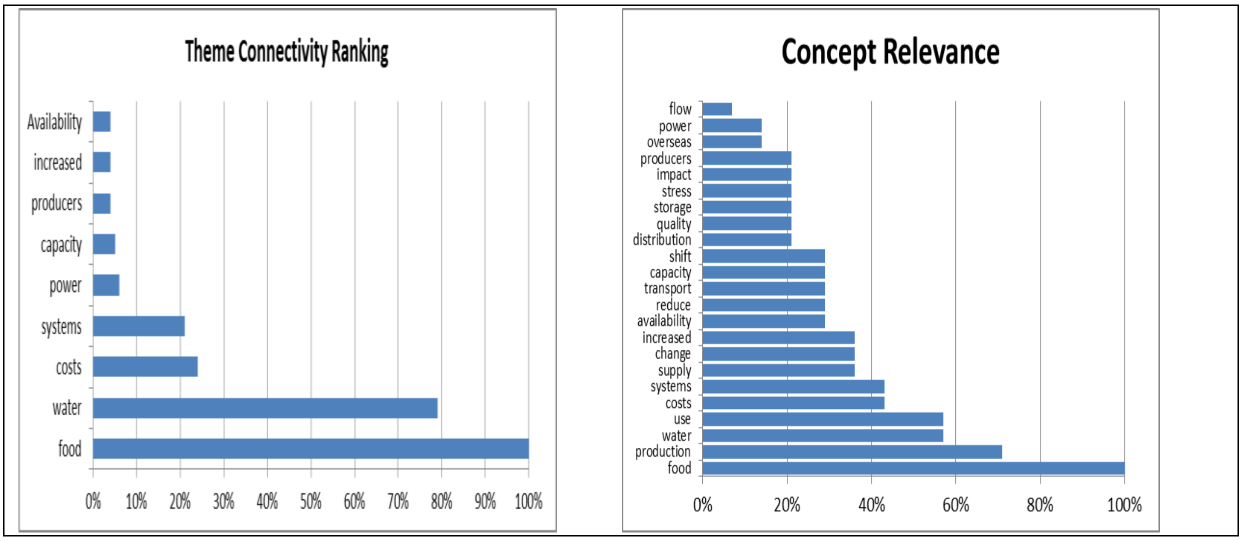


Figure 14 SW WA impacts and issues of climate change theme rankings and concept relevance

The relative proximity of the themes and concepts is shown in Figure15. This shows relative relationships in framing of perceived risks from the SW WA Expert Panel discussions. The key theme of ***food*** comprises a thematic cluster which includes ***costs***, ***systems*** and ***Availability***. ***Water*** is a secondary thematic cluster linked to ***capacity*** and ***producer***. The secondary theme ***power*** is shown as a distinct and separate thematic issue.

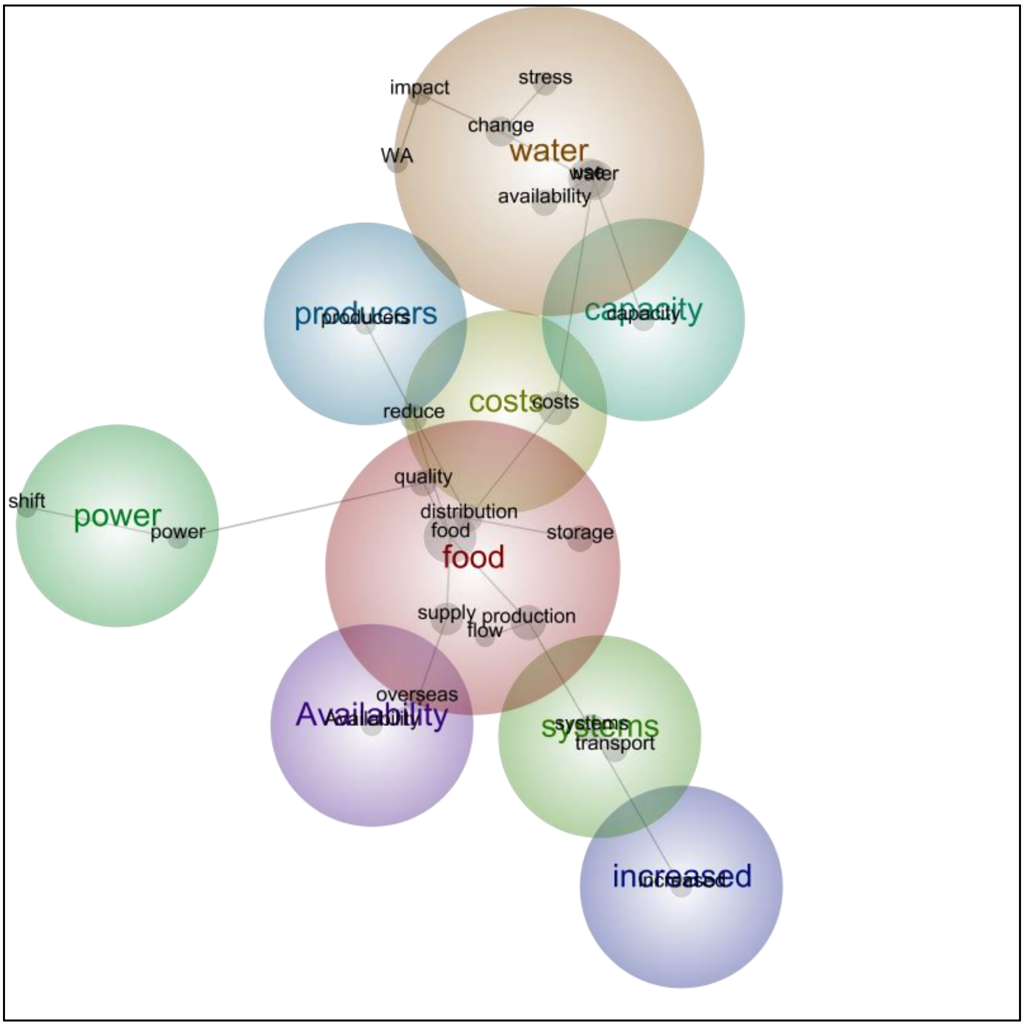


Figure15 Issues and impact of climate change (SW WA Expert Panel) thematic map

SW WA thematic descriptions of issues and impacts of climate change on food security

The results of this analysis provide the exact phrases from participants that define each of these themes. The key theme of discussion about impacts of climate change on food security related directly to ***food*** (100% connectivity). This theme was defined by the concepts of: ***food***; ***production***, ***supply***, ***distribution, quality*** and ***storage***. Discussion identified both potential "shortfall due to unpredictable supply of imported foods", as well as indicating an unlikely failure of food supply (and thus security) within the Australian context. Production costs were indicated as a key impact of climate change on food security. The impact of "increased costs on production" (transport, technology) and distribution (quality and transport) of food was indicated as a potential impact on both producers and consumers. Extreme weather events were indicated to be an impact on both distribution and storage, disrupting both power supply and supply chain distribution. Wastage of food was seen as an important implication for food security, both in supply and distribution components of food systems.

Changes in food production requirements were identified as key impacts of climate change reducing production in marginal horticultural production areas, as well as reducing volume of food production (seasonal changes, water availability, and land capability/ availability). Food quality impacts on shelf life, quality and availability were seen as constraints on food security. The flow-on effects of farm community decline on social cohesion ("numbers/

vibrancy", "knowledge") was identified as an issue for livelihoods, food production and food security.

While the SW WA Expert Panels did not anticipate any reduction in the availability of food supply or decline in food security, they identified a degree of uncertainty and increased costs of production as a potential impact on social cohesion, profitability and income margins.

The second key theme (connectivity of 79%) was **water** with concepts of water, use, change and availability. The key impacts identified were on water availability due to drying seasons, land use changes and availability (rural to urban and water level changes) reducing access to water for agriculture. Technology application and improved water conservation was seen as a potential adaptation impact of declining availability of water and rainfall.

Two other sub-themes - **costs** (connectivity of 10%) and **systems** (8% connectivity) identified costs of production, water and transport as key impacts of climate change on food security. Reduction of energy consumption, irrigation and water use were seen as key impacts.

A further five minor themes – **power, capacity, producers, increased** and **availability** each with a connectivity ranking of 2% - identified impacts relating to policy, extreme events, social resilience, consumer preferences/ behaviour and biosecurity. Alternative energy sources, import policy and storage systems were identified as potential adaptation focuses.

Risk in SEQ Issues and impacts of climate change on food security

Twelve experts from SEQ representing a range of interests in horticulture and dairy provided the text data through participation in Expert Panel workshops for these results. Six themes to emerge from the analysis (Leximancer) were: ***events*** (100% connectivity), ***Climate*** (100%), ***weather*** (44%), ***security*** (44%), ***pest*** (44%) and ***cost*** (22%). The key concern with extreme events due to the recent floods in SEQ was evident through the themes of ***events*** and ***climate*** each ranking 100% connectivity (Figure 16). The most relevant concepts were also ***events*** *(100% ranking),* ***climate*** scoring a relevance ranking of 83% and ***weather*** scoring 50% (Figure 16).

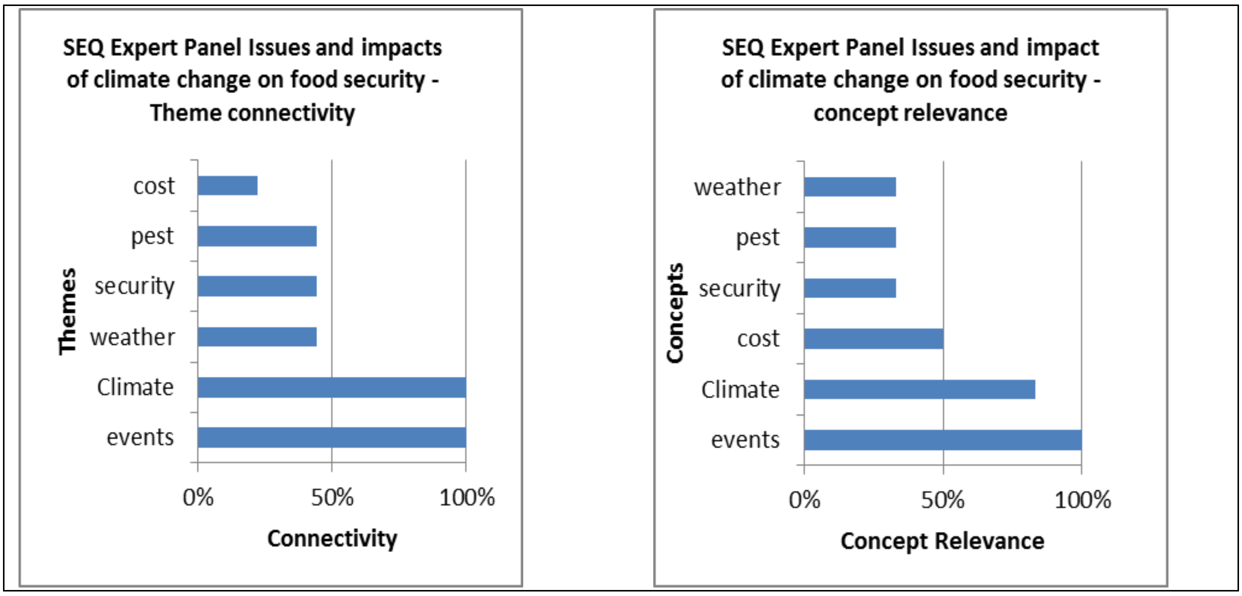


Figure 16 SEQ EP issues and impacts of climate change on food security

The relative location of themes and concepts is shown in Figure17. This shows relative conceptual relationships of themes of risk from the SEQ Expert Panel discussions. The key

theme of ***events*** comprises a theme which includes the concept of ***events***. ***Climate*** is a secondary theme and ***weather*** is shown as an additional theme.

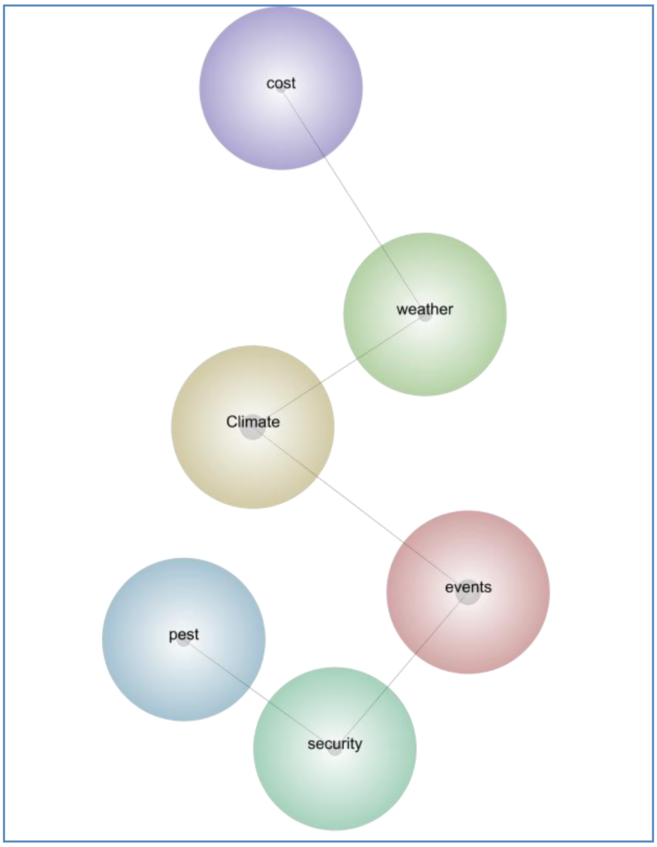


Figure17 Thematic map of SEQ EP issues and impacts of climate change on food security

SEQ thematic descriptions of issues and impacts of climate change on food security

The results of this analysis are described using the exact phrases from participants that define each of these themes. The key theme of discussion about impacts of climate change on food security related directly to ***events*** (100% connectivity). This theme was defined by a single concept of: ***events.*** Risks outlined were those of the "likelihood of extreme rainfall events" that are "[u]npredictable" and producers are "unable to plan for these events". EP participants indicated that "[c]limate events cause major shocks to whole supply chain" and that "[s]mall producers….[had]…difficulty in managing extreme weather events". The Gympie flooding was used as an example of how there was "vulnerability of relying on food transported from outside and within the area". Participants mentioned that "intensity of storm events – results in pest incursions (Farmers in Lockyer valley had downgraded lettuce quality because they were lulled into a false sense of security)". "Changes in pest and diseases" and "soil borne disease e.g. – SE ginger" were associated with these types of climatic events. An "uncertainty in planting/ quality/harvesting" could indicate a need to "move to less suitable locations to produce" and the need for "different agronomic practices".

The theme of ***climate*** reiterated the impact of extreme events but went on to indicate risks through the "cost of capital investment – about practice and adapting practices". Participants indicated that in "Queensland a dominant 30 year water cycle (La Niña) and warming will be occurring underneath this weather pattern". The theme of ***cost*** indicated that production would "cost less in more favourable climate – longer production - kg/ha strawberries" and would entail the "cost of capital investment – about practice and adapting practices". Key to

this risk related to the “Uptake of technologies” and “technology costs…[acting as]… constraints to innovation”.

CONCLUDING ON RISKS

Australia can expect climate change to have a considerable impact on temperatures, rainfall and climate variability. Not only will these projected changes directly affect food security and agricultural productivity but will also result in changed business systems and food production regions. Over time, the impacts of extreme events (floods, droughts etc) can erode the social and economic base on which farming communities depend (Berry *et al.* 2011). Food security is thus, not just about who has access to food but also about who depends on food production for livelihood. The notion of security in a food system reaches across the range of sectors involved.

The survey questions were generated through identifying categories of climate change associated risk to dairy and horticultural food systems. These categories were further explored and expanded through the Expert Panel workshops to provide additional text data. The results of both the survey analysis and the EP workshop analysis indicated distinctions in evaluation of risk between SEQ and SW WA. The differences in climate and recent extreme weather events acknowledged as changed weather systems were a key component of these distinctions.

In the SW WA EP risks due to climate change for food security were identified through changes in food production requirements reducing production in marginal horticultural and dairy areas. The EP indicated an expectation that the volume of food would be reduced and that food quality and availability would be impacted. This Panel indicated a flow-on effect for social cohesion in rural communities. Water availability, power/ energy requirements to continue production, and the application of technology were also identified as key issues with the potential to impact negatively on dairy and horticultural food-systems.

In the SEQ EP risks due to climate change had a strong focus on the extreme events expected to occur more frequently as the climate changes. The recent floods in SEQ 2011 were used as both a benchmark and as a framework for learning. Participants indicated that these events caused major shocks to the whole food system from producers through to consumers. Vulnerability in relation to access and in relation to pest incursion was noted as resulting in uncertainty and a potential for geo-shift to alternative production sites. The costs of capital investment were mentioned as a risk to adopting practices of mitigation and adaptation.

SECTION FIVE: INTERVENTIONS FOR FOOD SECURITY – CLIMATE CHANGE MITIGATION AND ADAPTATION

Resource management issues, institutional structures and the meso scale of organisational capital such as farmers organisations and rural development groups all offer avenues and pathways to address climate change and food security. Potential vulnerability to climate change is associated with anticipated risk in the medium- to long-term will depend on that system's ability to adapt appropriately in anticipation of those hazards (AEA, 2007). A number of different types of mitigation and adaptation interventions ranging between incremental, transitional and transformational provide intervention strategies that address different time frames. Adaptation strategies include anticipatory and reactive adaptation, private and public adaptation, autonomous adaptation and policy-driven adaptation. It is important to gain an insight into how sectors in food systems (from producers to processors and consumers) adapt to different production options and management strategies. Such knowledge is critical to developing mitigation and adaptation plans for adjusting production and management strategies in the face of expected frequent extreme climatic events.

Changes in rainfall and water availability will have implications for future food production and food availability through altered biosecurity situations, business models and environmental capital in general. Interventions are identified from three key sources of data: literature; survey data; and Expert Panel discussions. Section 5 identifies the climate change mitigation and adaptation strategies with potential application in horticultural and dairy food systems. Three research tools were used to generate this information, first the survey data, then the EP data and finally a synthesis of the two to provide overarching categories. The final section, 6, provides the results of modelling climate change mitigation and adaptation intervention strategies in relation to capacity for a range of scenarios identified as key risks.

MITIGATION OF CLIMATE CHANGE IMPACTS IN DAIRY AND HORTICULTURE

Australian food producers are constrained by the most variable climate in the world (CSIRO and Meteorology 2007, Hennessy *et al.* 2007). Australia's temperatures are projected to rise and rainfalls decline and climate changes will be expressed through extreme events. The vulnerability of food production derives from supply side effects (Garnaut, 2010) with agriculture often operating close to the upper margins of the temperature ranges, and close to the low margin rainfall requirements.

The South West region of Western Australia is considered to have experienced various levels and impacts of climate change since the mid-1970s (Morgan, *et al.* 2008). Changes in rainfall patterns since the 1970s have resulted in a significant decline in the runoff resulting in new hydrologic regime with implications for future surface water supply in the south west of WA (Petrone *et al.* 2010). The projected rainfall decreases in the south-west in winter and spring will be in the range of 30% (Morgan *et al.* 2008).

Potatoes consist of 18.0 per cent of total vegetable production in WA and are mainly concentrated in the higher rainfall areas of the state's South-West (DAFWA 2009). Carrots produced in WA account for 90 per cent of Australia's carrot exports with major markets in Singapore and Malaysia and increasingly to Middle East markets (DAFWA 2009). Water shortages in Eastern Australia have resulted in a decline in vegetable production with WA increasingly being seen as a supplier of vegetables to eastern states markets.

Over a 5-year period milk production in WA has ranged between 377 million litres in 2005/06 to 319 million litres in 2007/08. The number of registered dairy farms has dropped by 31 per cent over this period. Milk production per cow has increased from 5,369 litres to 6,584 litres. Climate change is impacting adversely on feed availability in the WA dairy sector.

The Office of Climate Change identified the last decade (2000–2009) as the hottest on record in Queensland with temperatures 0.58 °C higher than the 1961–1990 average (Whitfield *et al.* 2010). Queensland can expect increased temperatures of between 1.0 °C and 2.2 °C by 2050; a three to five per cent decrease in rainfall in the south-east Queensland region; more frequent hot days and warm nights; less frequent cold days and cold nights; and increased flooding, erosion and damage due to increased severe weather events. It is expected that cyclones will occur further south potentially impacting on south east Queensland more often. Whitfield *et al.* (2010) expect that climate change will result in a decrease of water available to meet agricultural demand due to decreasing rainfall and runoff, and increasing temperature and evaporation.

Horticultural production in SEQ is dominated by commercial scale vegetable systems and a range of sub-tropical fruits and nuts (macadamias, pineapples, strawberries avocadoes and mangoes) are produced on smaller scale farms (Deuter 2008). Temperature change will have a significant impact on this production.

Hotter summer temperatures, increased humidity and increased extremes of heat will lower volume of milk produced and reduce components. In addition, reproduction rate and cow health will be compromised (Miller 2008).

Mitigation and adaptation results from survey

In response to survey questions the EP participants indicated that the most important approach to mitigation in the dairy industry will be through better decision support systems, and water efficiency (Figure 18). In addition they indicated the transport and market infrastructure and associated development of alternative fuels was critical. While none of the categories of mitigation scores less than a 3 mean, carbon offsets, drought policy and ISO accreditation were all important contributors.

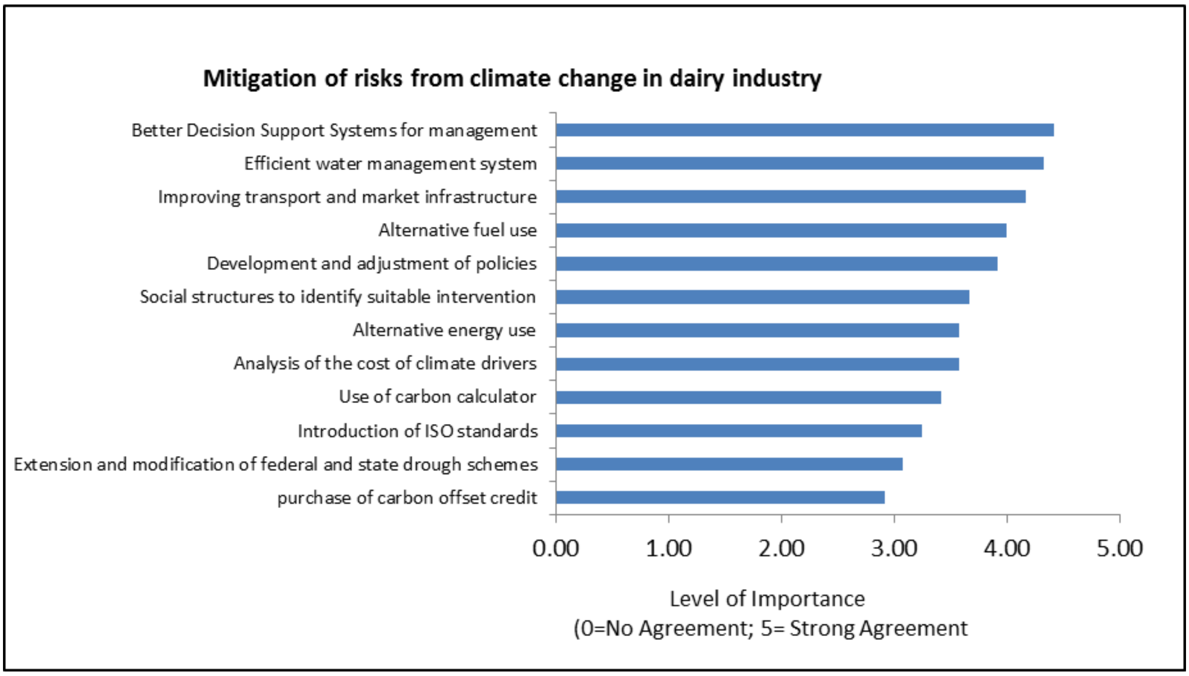


Figure 18 Mitigation of climate change risks in dairy

Mitigation approaches for horticulture focused on water management and climate forecasting, with better decision-support systems seen to be important (

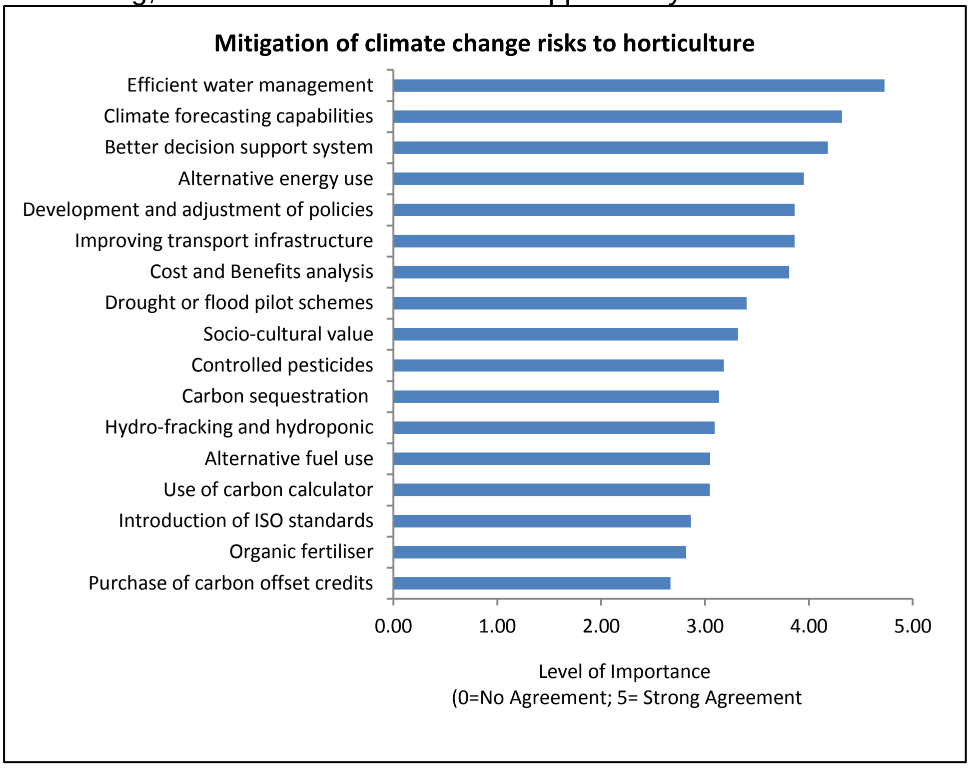


Figure 19). Carbon offsets were seen as less important for horticulture, but other carbon related approaches were included as potential mitigation strategies.

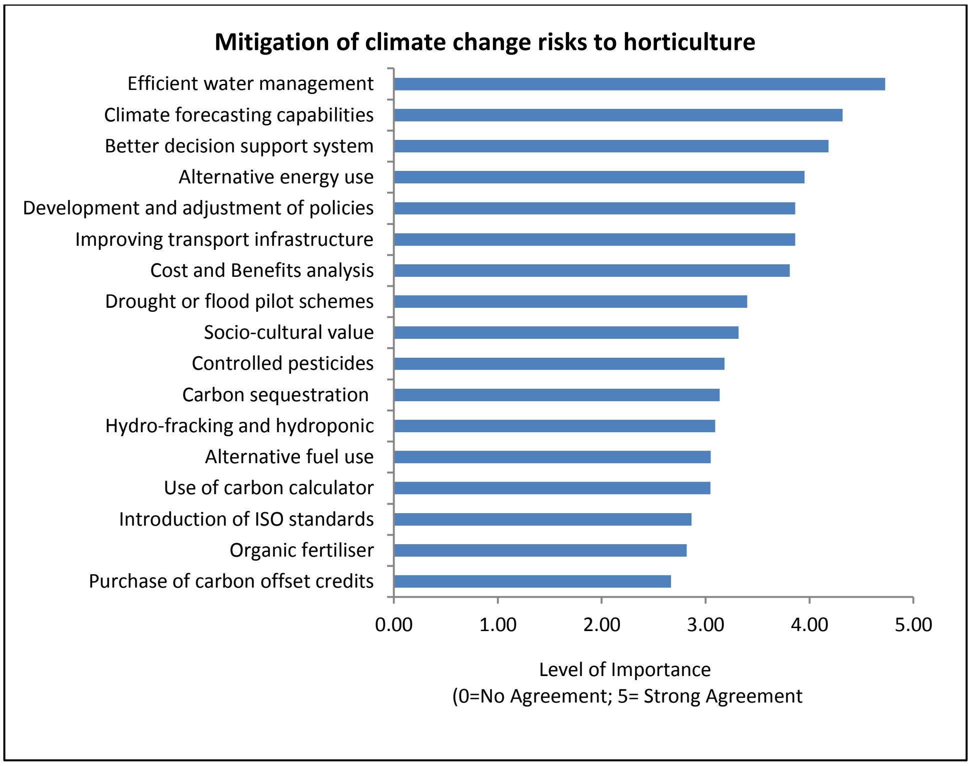


Figure 19 Mitigation of risks from climate change in horticulture

EP participants responses to ranking categories for adaptation to climate change in the dairy industry indicated that temperature management through shading, re-vegetation and more

drought tolerant dairy cattle would be important (Figure 20). The industry indicated a lower preference for re-designing buildings to manage heat levels, and indicated that supplementary power generation on site was also an option.

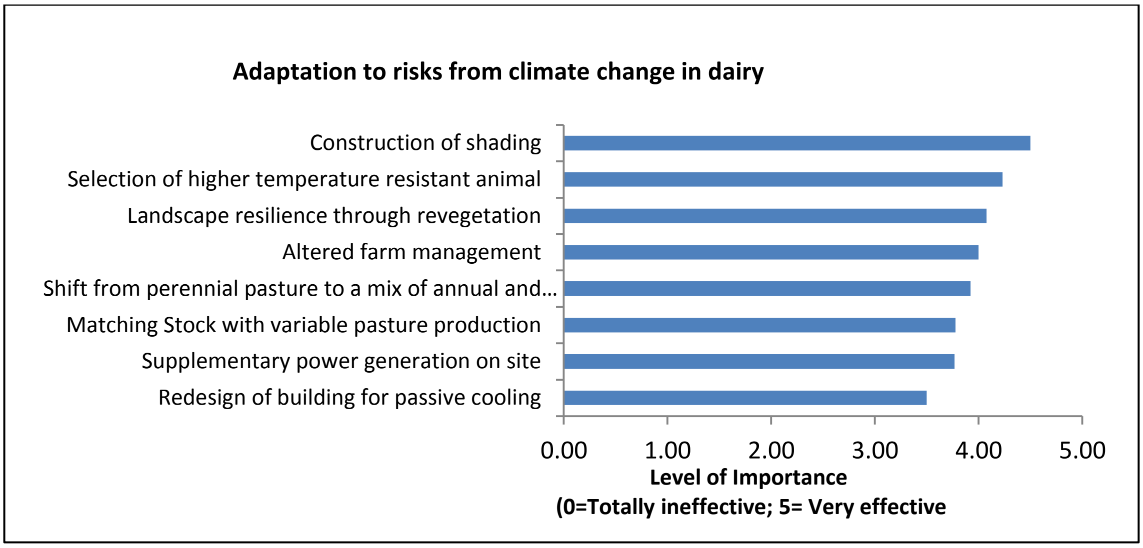


Figure 20 Adaptation to risks from climate change in dairy

The horticulture sector focuses on water, crop management and selection for adaptation strategies (Figure 21). They also ranked supplementary power generation and the use of shading as important.

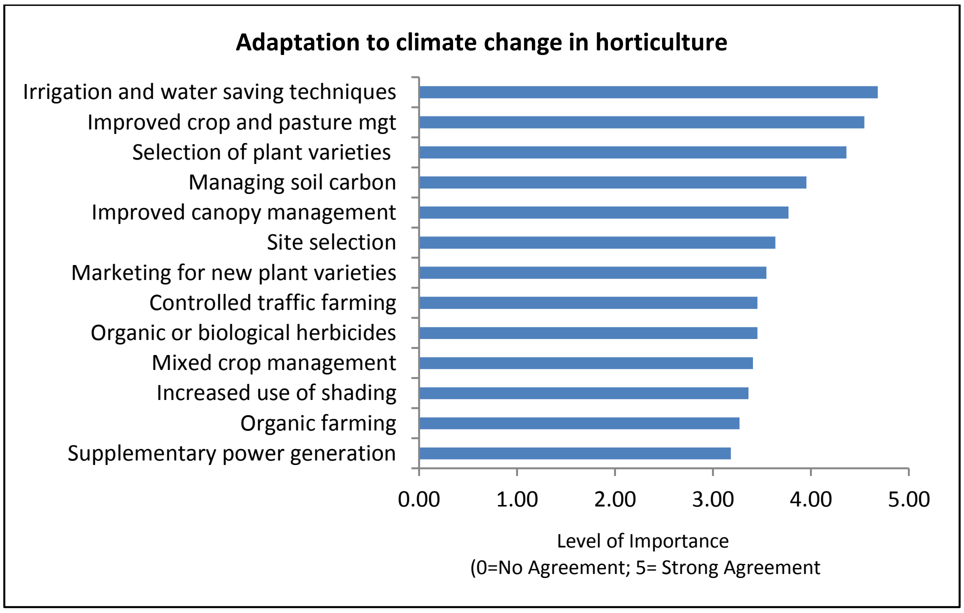


Figure 21 Adaptation to climate change risks in horticulture

In the SW WA EP risks due to climate change would reduce production in marginal horticultural and dairy areas. Water availability, power/ energy requirements to continue production, and the application of technology were also identified as key issues with the potential to impact negatively on dairy and horticultural food-systems. In the SEQ EP risks due to climate change particularly related to extreme events which caused major shocks to the whole food system from producers through to consumers. The costs of capital investment were mentioned as a risk to adopting practices of mitigation and adaptation.

Both the dairy and horticultural sectors choices in mitigation and adaptation strategies reflected their concerns with the risks from climate change on water, power and the costs of

production. Mitigation strategies particularly focused on better decision support systems (including business and climate forecasting), water efficiency and both public and private infrastructure.

Adaptation strategies in dairy and horticulture related particularly to temperature management through shading, re-vegetation, water management and selection of crops and livestock for hotter drier climates.

Mitigation and adaptation results from Expert Panel discussion

In follow up collection of information, the EP discussions were analysed to identify central themes of mitigation and adaptation in each state. Through the workshop activities risks were identified by the collective group. Following this, a series of mitigation and adaptation topics were identified for further development in small working groups. This provided the opportunity for participants to share and discuss specific mitigation and adaptation strategies in more detail. This detail was then combined for further analysis to identify common themes and concepts (Leximancer analysis).

SW WA recommendations for strategies for climate change mitigation and adaptation

The EPs representing the horticultural and dairy food sectors in the SW WA focused on the key theme of ***water*** (connectivity of 100%)(Figure 22). Other themes in the discussion ranked less than 25% included ***food***, ***supply***, ***systems*** and ***production***. The key concept defining these themes was ***water*** (relevance ranking of 100%) with other concepts ranked just above 50% including ***view*** and ***food***.

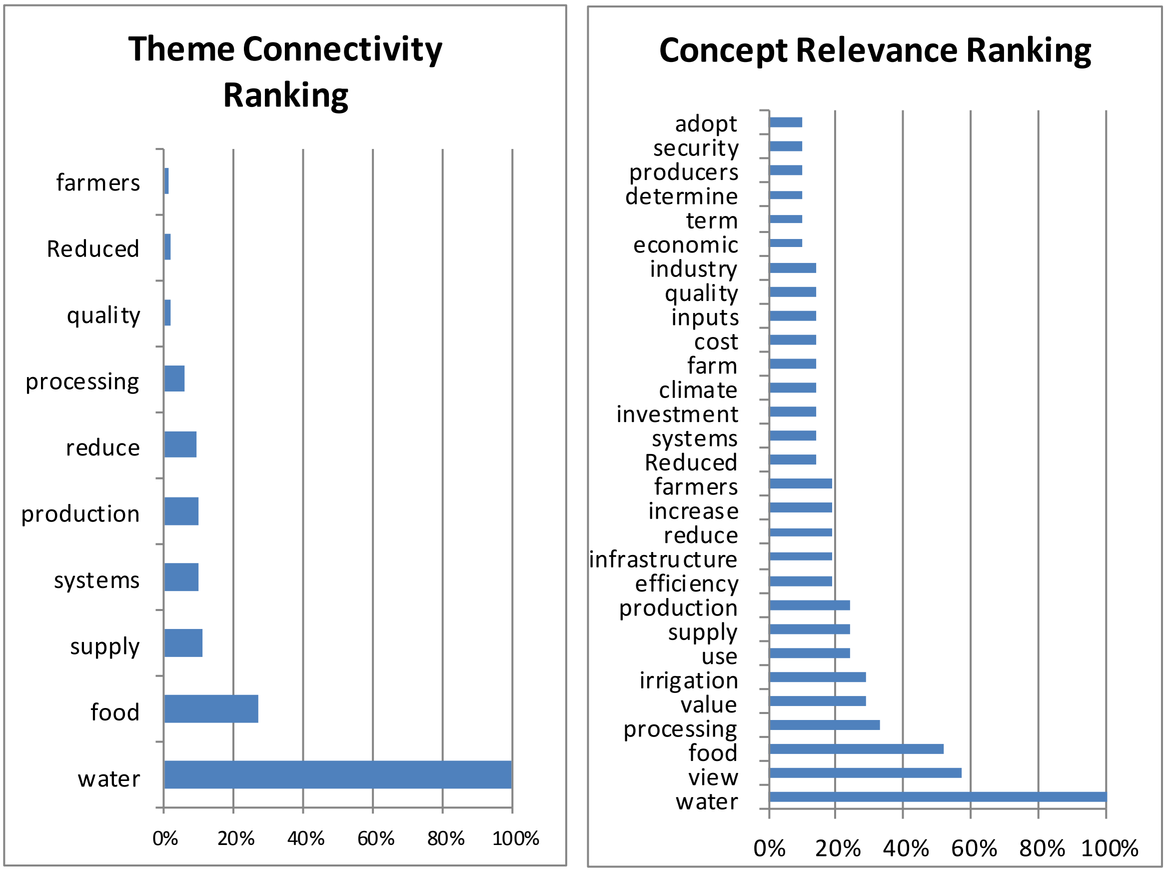


Figure 22 Themes and concepts for SW WA mitigation and adaptation for climate change

These themes reflect those of the survey results focusing mitigation and adaptation on water management (Figure 23). A description of discussion is outlined to indicate the focus within key themes.

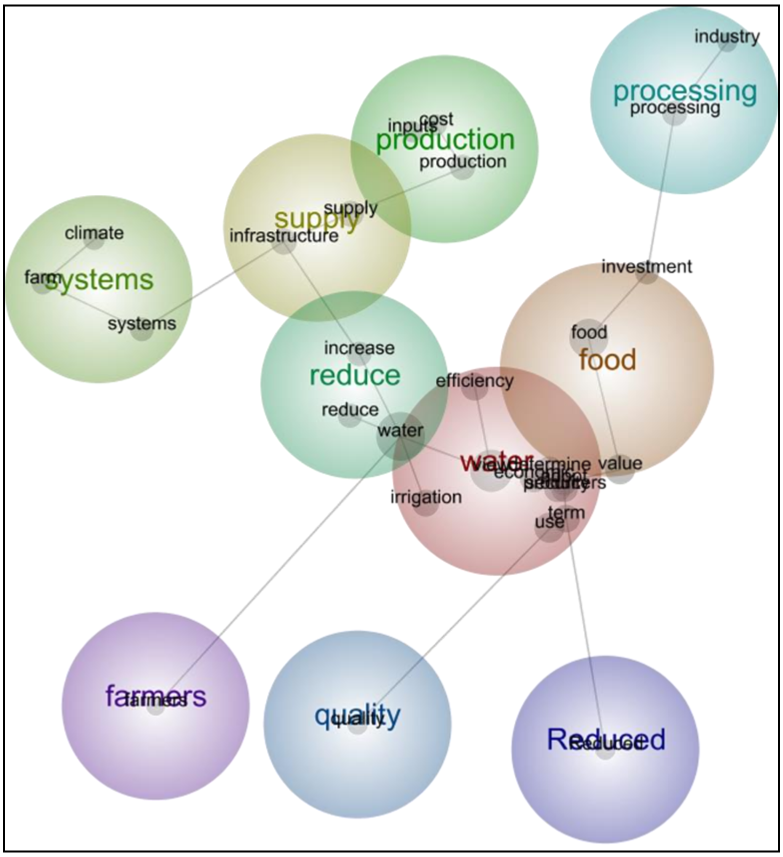


Figure 23 Thematic map of mitigation and adaptation of climate change on food security (SW WA Expert Panel)

The key theme of discussion on mitigation, adaptation and intervention revolved around ***water*** (connectivity ranking of 100%). The concepts defining this theme were ***water***, ***view***, ***use***, ***economic***, ***efficiency***, ***term***, ***determine***, ***producers***, ***security***, ***adopt*** and ***irrigation***. These concepts reflected concerns with reduced rainfall. Adaptation recommended in relation to water efficiency related to value of irrigation and competition for water resources. A strategy to address reduced rainfall and water conservation both on-farm and between farms recommended cooperation between farmers and improved practice on individual farms. Water reform policy that implements economic evaluation for a long-term view using price signals and increased government investment in rural contexts was recommended. Development of institutional structures to improve cooperation between producers and government was recommended for water reform.

Other sub-themes included ***food*** (27%), ***supply*** (11%), ***systems*** (10%) and ***production*** (10%). These themes related to the development of infrastructure to add value to food production, reduce waste and significant investment in infrastructure. Recommendations for infrastructure investment included water, processing precincts, transport, storage, education and training.

Minor themes for adaptation, mitigation and intervention included ***reduce*** (9%), ***processing*** (6%), ***quality*** (2%), ***Reduced*** (2%) and ***farmers*** (1%). These themes advocated mitigation and adaptation strategies for water reform, research and development investment, conservation of natural capital (soils and natural environments) and improved cooperation between farmers.

The overarching recommendation for mitigation and intervention for the management of climate change impacts in dairy and horticulture in the SW WA related to the way in which water is managed, on-farm, within the industry sector and by the policy delivery agencies. Managing reduced rainfall and raising the standards of water conservation were seen to be the responsibility of the private landholder, the business sector and government. These EPs advocated for improved cooperation across these sectors to manage the impacts of climate change in their industries.

SEQ recommendations for strategies for climate change mitigation and adaptation

The EPs representing the horticultural and dairy food sectors in SEQ focused on the key theme of ***Unable*** (connectivity 100%), with sub-themes of ***food*** (30%), ***levies*** (26%), and minor themes of ***events*** (5%), ***land*** (4%), ***industry*** (4%), ***future*** (4%), ***innovation*** (1%) and ***management*** (1%) (Figure 24). The key concepts defining these themes were unable (relevance ranking of 100%), view and structure, with other concepts ranked below 50% including ***local*** and ***food***.

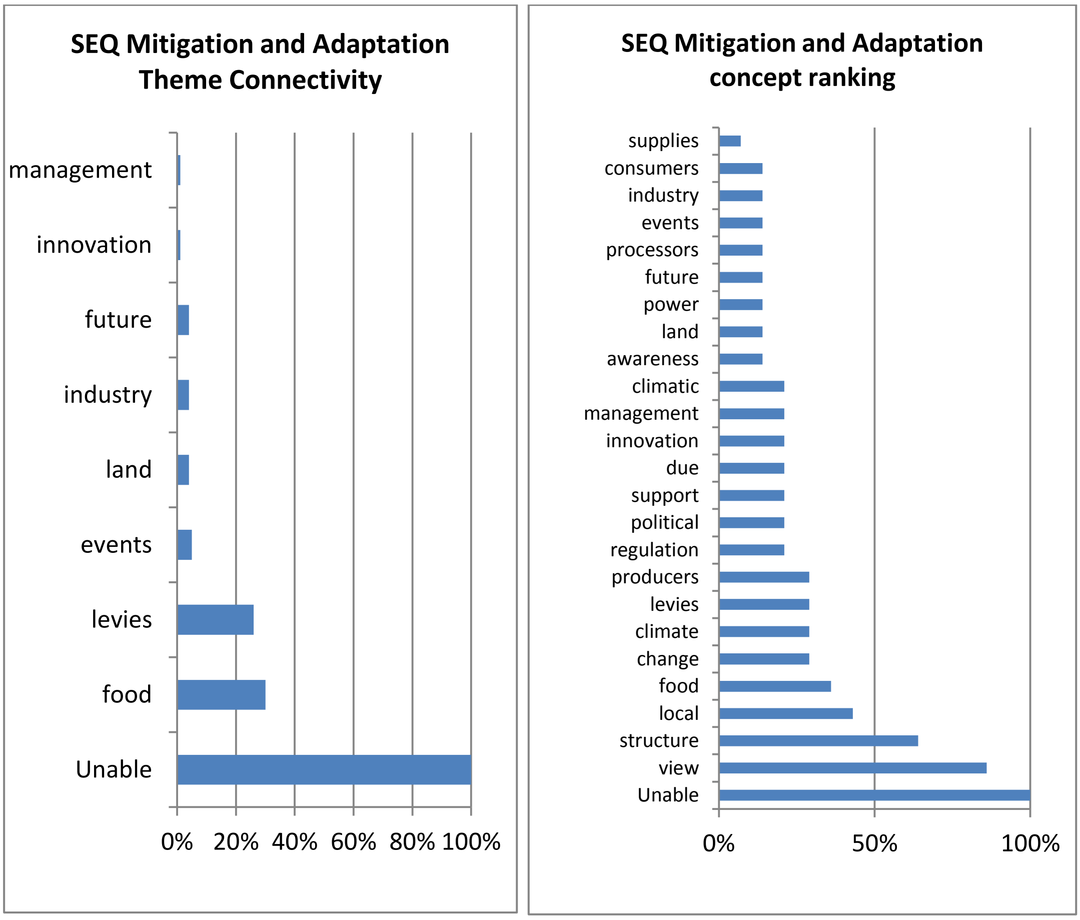


Figure 24 SEQ Mitigation and Adaptation theme connectivity and concept rankings

These themes and defining concepts are portrayed in the thematic map in Figure 25.

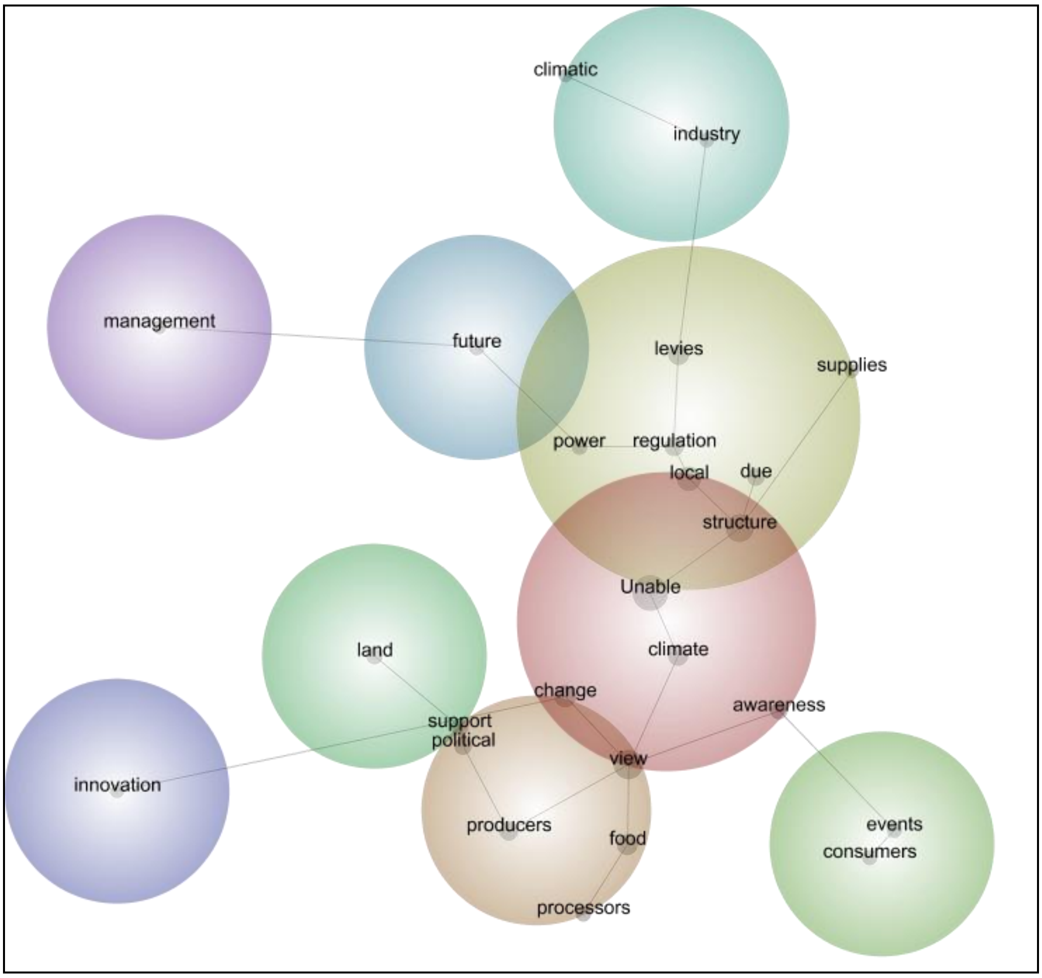


Figure 25 SEQ thematic map of mitigation and adaptation concepts

The thematic map of the SEQ EPs discussion on mitigation and climate change focused on ***Unable***. This theme related an inability to continue in current production approach and poor suitability of crops as climates change. In particular participants indicated that "[c]urrent farming systems may not be suitable to crop type" and that sources of more suitable varieties need to be bred locally (pineapples and strawberries were mentioned as examples). "Changing crops to suit changing climatic conditions (e.g. Feijoas – juice – looking to export; baby bok choy & mini cos lettuce are short turnover" and can be harvested earlier.

This EP indicated that "Government Policy has to change to support and encourage food producers - big or small – government policy must protect all agricultural land in SE Queensland" and undertake "national regulation to reduce market power". In addition, this EP identified the issue of "ag-chemicals not available due to regulation". This hampers producers' ability to react to pests and diseases that have emerged in a changing climate. In concrete terms this EP advocated for "investment in extension/ technology transfer" with "continuous improvement/culture of change innovation" through "R & D for local and future climates (e.g. varietal, resistance)" and "monitoring to detect pests and diseases earlier". There was a concern that "Levy structure not supporting local/regional responses".

This theme indicated a need to "create local awareness to climate variability" through "community awareness building through educating children as consumers are not aware of food security". "Weather events are considered an aberration…. generational barriers (producers)" are a form of resistance to change. These EPs wanted education and "informed discussions about challenges for food systems by community and government (state)" to include promoting "understanding from the consumer's point of view about the risk and costs

for climate change" and understanding of how consumers might make a "contribution to assist the producers and processors or the food suppliers".

The theme ***food*** (30% connectivity) addressed concepts of ***food***, ***producers***, ***political***, ***support*** and ***processors.*** The focus for this theme was on alternative business systems that include "horizontal cooperation at the upstream food supplier" and "community support for agriculture". This theme was about advocating for "cooperatives for small scale primary producers" and "empowering producers to take control of the supply chain to correct the power imbalance of retailers". In political terms, these EPs called for "R/D or agronomic support to ascertain changes to location" and "policy structures to support industries". There was an over-riding concern about the "relationship between produces & processors – with multinationals controlled processing and price" at the expense of viable production systems and investment in mitigation and adaptation in the face of a changing climate.

It is worth reporting on the discussion that emerged through some of the minor themes that had specific messages and recommendations. The theme ***Levies*** (concepts: ***levies***, ***regulation***, ***due***, ***power***, ***supplies***) indicated a lack of support for current industry levy structures: "National levies (internal industry structure) not supportive of local/regional responses" with an indication that "cost differences in Qld dairy related to climatic differences and structural industry issues".

The theme ***land*** concerned the short timeframes currently for agricultural land development: "***Short*** term 5/10 years – ***Ag*** land development management – land use planning, future scenarios included – we need long term 1-/50 years - ***Ag*** land development management" for land use planning to include future scenarios.

These EPs advocated ***innovation*** and ***management*** through "funding for research (applied – developing new technologies and adoption) and incentives for adoption of innovation". In business model terms they wanted to see "adaptation with limits to liability – flexibility – labelling point of origin – creativity/innovation - primary product value adding" and a "continuous improvement/culture of change innovation" based on "investment in extension/technology transfer". These EPs were concerned about the "cost effective use of irrigation" effective "waste management" and in nutrition terms the "conversion to biological from inorganic".

Thematic round-up for mitigation and adaptation in dairy and horticulture

Recommendations for dairy and horticulture in the SW WA related to the way in which water is managed, on-farm, within the industry sector and by the policy delivery agencies. These EPs advocated for improved cooperation across these sectors to manage the impacts of climate change in their industries. In SEQ, the EPs had a range of distinct and separate recommendations for mitigation and adaptation strategies that focused on current production approaches with poor suitability of crops as climates change. They called for R&D investment in crop development to suit changing climatic conditions. The SEQ EPs were critical of government policy of short timeframes currently for agricultural land development calling for protection of "all agricultural land in SEQ". The industry sector was challenged to develop levy structures that support local and regional needs better. In advocating for continuous improvement, investment in R&D was specifically in relation to developing new technologies and approaches to encourage adaptation through incentives for adoption of innovation.

EVALUATING RELATIVE MAGNITUDE OF IMPACT AND LIKELIHOOD OF STRATEGY

Addressing issues of scale from local to global provide a range of contexts for mitigation and adaptation strategies. Mitigation strategies aim to reduce the impact of changes to climate and the associated risks from anthropogenic (human) processes. Adaptation strategies and

actions are those designed to adjust to and limit the potential impacts relating to climate change processes.

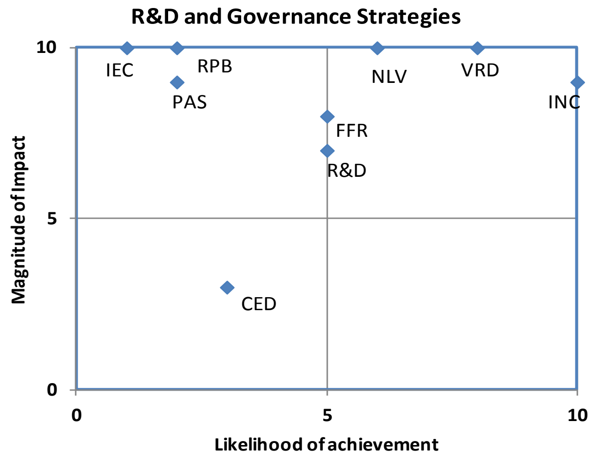
A number of different types of mitigation and adaptation interventions include incremental (step-wise), transitional (effective for particular time frames) and transformational (significant process changes). Adaptation strategies include anticipatory and reactive adaptation, private and public adaptation, and autonomous adaptation and policy-driven adaptation. Mitigation and adaptation approaches can differ in their effectiveness, efficiency and legitimacy (N Adger *et al.* 2005). Understanding the kind of mitigation and adaptation proposed is critical to forming effective plans for climate change.

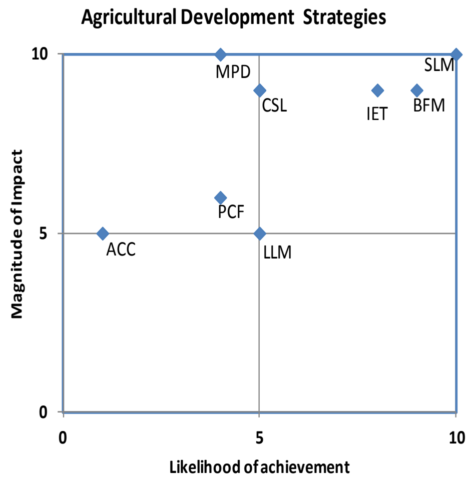
The EPs first identified risks due to climate change on the dairy and horticultural sectors. They then developed detailed mitigation and adaptation strategies (Figures 27, 29, 31 and 33 and Table 4). These strategies were then evaluated for their magnitude of impact and likelihood of implementation. These were also evaluated to show the geographic scale of their potential intervention, as well as identified as incremental, transitional or transformational. The graphs that follow show each of these evaluations for the following categories: R&D; Governance; Agricultural Development; Geo-shift strategies; Water strategies; Infrastructure; Value Chain; On-Farm strategies; and Other strategies.

In the selection of interventions the highest ranking strategies are those in the top right-hand square (

Figure 26). These represent the correlation of highest magnitude of impact and best likelihood of implementation. R&D and Governance strategies recommended by SEQ EPs that scored highest ranking) show industry collaboration (INC), varietal development (VRD) and national levies (NLV) to be the most strategically useful. For strategies in Agricultural Development, the most strategic interventions would include short term land management approaches (SLM), best farm management strategies (BFM), and investment in extension and technology (IET) (

Figure 26).





Notes:

CED	Consumer education
FFR	Funding for research
IEC	Improve ease of compliance
INC	Industry collaboration
NLV	National levies
PAS	Pilot projects for alternative system
R&D	R& D development
RPB	Regulation to enhance power (market) balance
VRD	Varietal development

Notes

ACC	Awareness of climate change
BFM	Best Farm management
CSL	Community support for local agriculture
IET	Investment in Extension/Tech Transfer
LLM	Long-term land management
LSM	Land suitability mapping
MPD	Monitoring to detect pests and diseases earlier
PCF	Promote Cluster Farming
SLM	Short-tem 5-10 years land management

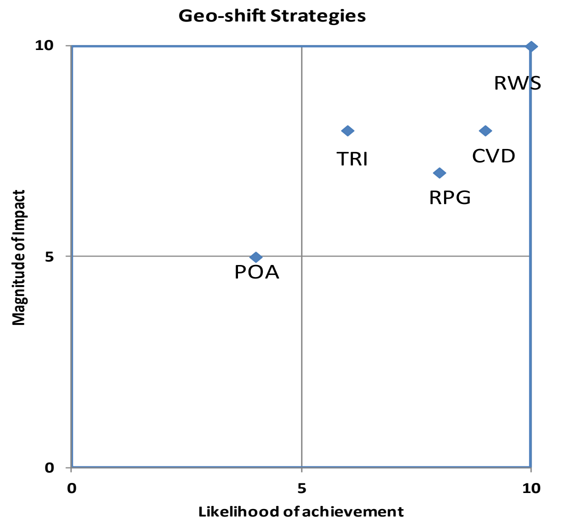
Figure 26 SEQ EP R&D, Governance and Agricultural Development strategy implementation evaluation

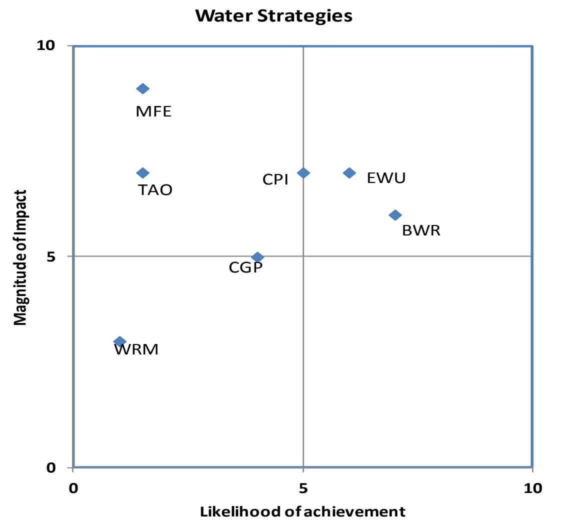
Recommendations for implementing intervention strategies by geo-political scale for R&D, Governance and Agricultural Development strategies (**Error! Reference source not found.**) ndicates the three top ranked interventions of industry collaboration (INC), varietal development (VRD) and national levies (NLV) should be implemented as transformational interventions at regional and national scales respectively. For Agricultural Development, the EPs recommended implementation of the three top ranked strategies - short term land management approaches (SLM), best farm management strategies (BFM), and investment in extension and technology (IET) – as transformational and transitional strategies implemented at local, regional and national scales.

Table 2 SEQ EP Geo-political intervention scales for R&D, Governance and Agricultural Development strategies

Geo-political scale of intervention for Agricultural Development Strategies			
	Incremental	**Transitional**	**Transformational**
Local	SLM, MPD, CSL, BFM, IET, PCF, LSM		LLM, BFM
Regional	MPD, PCF	ACC	LLM, SLM
National	PCF		LLM, SLM
Global	PCF		LLM
Geo-political scale of intervention for R&D and Governance strategies			
	Incremental	**Transitional**	**Transformational**
Local	CED		
Regional	R&D, CED	R&D, VRD	R&D, VRD, FFR, NLV, PAS
National	CED,	R&D, IEC, INC	R&D, RPB, INC
Global			

In SW WA the EPs evaluated Geo-shift and Water interventions ranking the magnitude of impact and likelihood of achievement (Figure 27). Those in Geo-shift that ranked highest were reliable water supply (RWS), crop variety development (CVD), transport infrastructure (TRI) and reliable power generation (RPG). For strategic intervention for Water (Figure 27), the highest ranking strategies were efficient water use (EWU) and best water reticulation systems (BWR). These did not rank particularly high.





Notes:

CVD	Crop variety development
POA	Possible Offset approach
RPG	Reliable Power Generation
RWS	Reliable Water Supply
TRI	Transport Infrastructure

Notes

BWR	Best water reticulation system
CGP	Compliance with government policies
CPI	value/capacity to pay for irrigation water
EWU	Efficient water use
MFE	Market mechanism to enable farmers using efficient system
TAO	Technology adoption by on-farm incentives
WRM	Ownership - resource management

Figure 27 SW WA Geo-shift and Water intervention strategy likelihood and impact evaluations

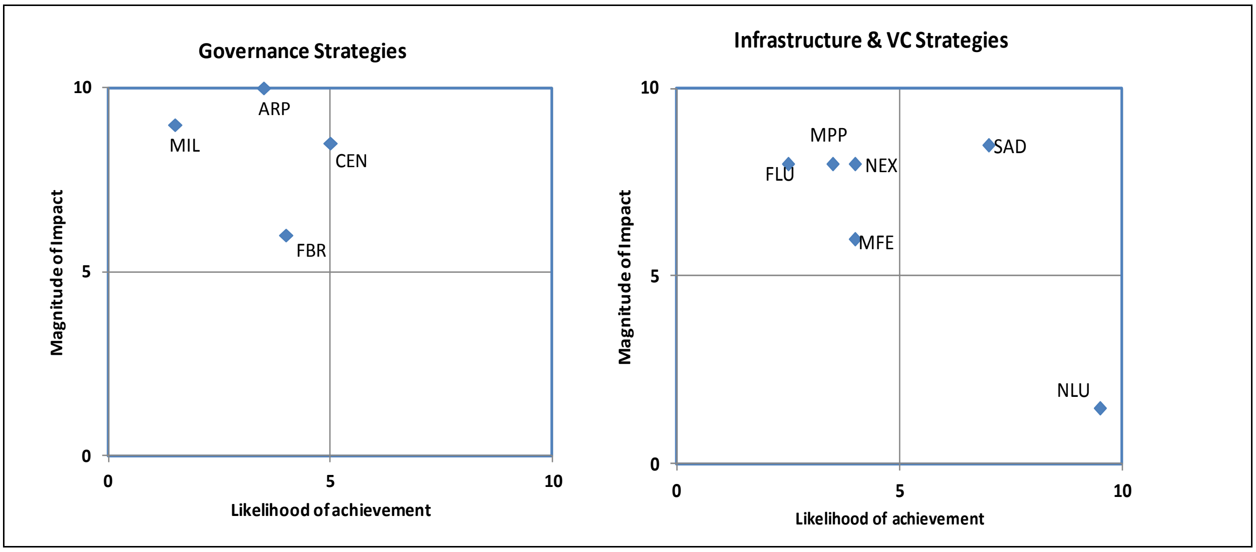
In terms of intervention scale for geo-political and temporal approaches (

Table 3), the Geo-shift strategies of reliable water supply (RWS) were considered transformational at regional scales. Crop variety development (CVD) was considered incremental at global scales. Transport infrastructure (TRI) was considered incremental at regional scale and reliable power generation (RPG) was considered both incremental and transformational at local and regional scales of implementation. For strategic intervention for Water the highest ranking strategies were efficient water use (EWU) to be applied as an incremental measure at local scales and best water reticulation systems (BWR) was considered transformational and applied at national scale.

Table 3 Scale of intervention for Geo-shift and Water strategies in SW WA

Geo-political scale of intervention of the Geo-Shift Strategies			
	Incremental	**Transitional**	**Transformational**
Local			RPG
Regional	TRI, RPG	POA	RWS
National			POA
Global	CVD		
Geo-political scale of intervention for the Water Strategies			
	Incremental	**Transitional**	**Transformational**
Local	EWU		
Regional		TAO	TAO
National	CGP	CPI WRM, MFE	CPI BWR, MFE
Global			

Evaluation of potential impact and likelihood of implementation of Governance strategies by the SW WA EP ranked a low potential (Figure 28). In relation to Infrastructure and Crop Variety interventions, supporting adaptation (SAD) was the only intervention that was worthy of a strategic ranking (Figure 28).



Notes:	
ARP	Adjusting regulatory process
CEN	Creating enabling environment
FBR	Food banking and recycling
MIL	More integrated land use governance

Notes	
SAD	Supporting adaptation
DSD	Designing Storage and distribution facilities
NEX	Enable easier entry and exit in ag production
FLU	Favourable land use policy
NLU	Non land use production system
MPP	Moving/processing to production site

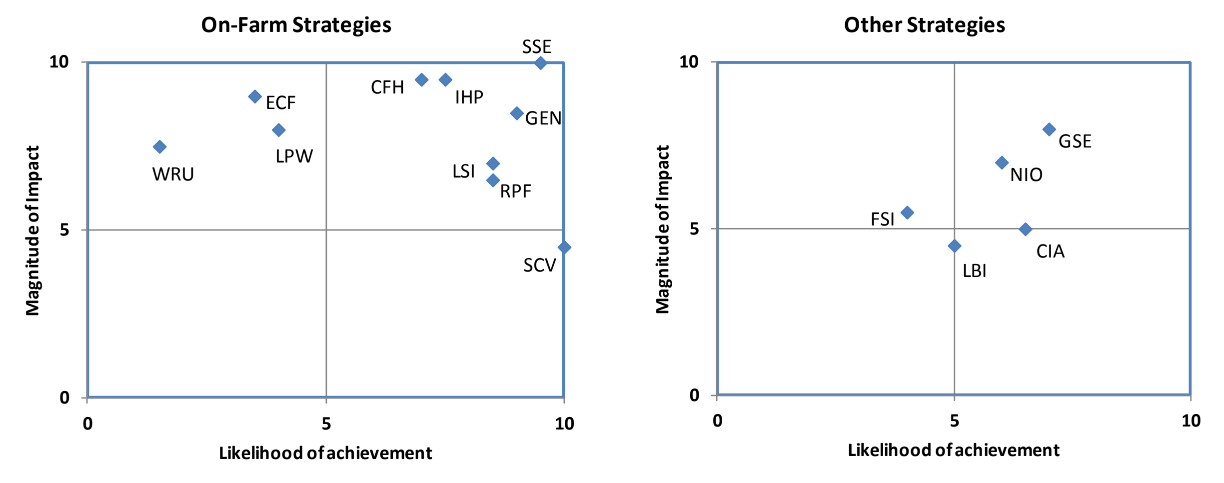
Figure 28 SW WA evaluation of Governance and Infrastructure and Crop Variety development strategies

While scale of intervention is nominated here (Table 4), as the ranking of intervention failed to rank worthy of strategic intervention, they are not discussed.

Table 4 Scale of intervention for SW WA EP Governance strategies

Geo-political scale of intervention for the Governance Strategies			
	Incremental	**Transitional**	**Transformational**
Local	CEN		MIL
Regional	ARP,FBR, CEN		MIL
National	CEN		MIL
Global			MIL

A further ranking of mitigation and adaptation strategies by the SW WA EP included On-Farm and Other strategies (Figure 29). Those strategies that were ranked with the most potential were soil security (SSE), increase input for higher productivity (IHP), genetic engineering (GEN), and the creation of fertiliser for higher productivity (CFH). In addition, other strategies that were ranked with potential for impact in intervention were local sources of input (LSI) and reliable predictions for planning future (RPF). Other strategies that ranked with potential impact (Figure 29) were government support for efficient water use and technology (GSE) and new irrigation opportunities (NIO).



Notes:	
CFH	Create fertiliser for higher productivity
ECF	Eco restoration/carbon farming
GEN	Genetic Engineering
IHP	Increase input for higher productivity
LPW	Long term planning for Water Management
LSI	Local sources of Input
RPF	Reliable predictions for planning future
SCV	Suitable crop varieties
SSE	Soil security
WRU	Water re-use

Notes	
CIA	Community Information & Awareness
FSI	Food Storage & supply Infrastructure
GSE	Govt support for efficient water & technology
LBI	liveability in region & business innovation
NIO	New irrigation opportunity

Figure 29 SW WA EP On-Farm and Other intervention strategies

Strategic implementation of On-Farm and Other strategies identified by the SW WA EPs indicated that the highest ranked as soil security (SSE) was to be implemented at both local

and regional scales as incremental strategies. Genetic engineering (GEN) was considered a transitional strategy to be implemented (or developed) at a global scale. The creation of fertiliser for higher productivity (CFH) was recommended to be implemented at local, regional and national scales as a transitional strategy. Other Strategies that ranked with potential impact (

Table 5) were government support for efficient water use and technology (GSE) to be implemented as a transitional measure at regional scales and new irrigation opportunities (NIO) as a transformational measure implemented at local scales.

Table 5 Scale of implementation for On-Farm and Other Strategies in SW WA

Geo-political scale of intervention for On-Farm Strategies			
	Incremental	**Transitional**	**Transformational**
Local	SSE, LSI	LSI, CFH, ECF, WRU	
Regional	SSE	CFH, ECF, WRU,LPW	
National		RPF, CFH, LPW	RPF
Global		GEN	
Geo-political scale of intervention for other Strategies			
	Incremental	**Transitional**	**Transformational**
Local			NIO
Regional	ILBI	GSE	FSI
National	CIA		
Global			

Recommendations for strategic interventions – likelihood, impact and implementation scales

Key interventions strategies were identified for each state (Table 6).

Table 6 Key intervention strategies identified for SEQ and for SW WA

SW WA	SEQ
Infrastructure and Supply Chain, e.g. storage, transport and distribution infrastructure for highly variable production and for a relocation of farm to a suitable location.	**Supply chain structure/relationships,** e.g. a different model for the union of dairy farmers.
Flexible production system, e.g. easier entry and exit in agricultural production to enable response to fluctuating food supply and demand.	**Alternative Business model**, e.g. diversification of production, group marketing/cluster farming and collaborative/cooperative competition in the value chain through small-scale/large-scale connected food supply chain
Varietal development, e.g. enhanced R & D to develop new plant variety/animals genetic conditions (Dairy) for a suitable climate.	**Crop Variety Development, e.g. c**hanging crops to suit changing climatic conditions (more suited to locality/climate e.g. locally breed pineapples, strawberries.
Developing sources of inputs, technology and management, e.g. alternative/reliable energy, fertiliser, waste and water management.	**Land development/land suitability,** e.g. Short term 5-10 years or long term 1-50 years – for agricultural land development, management and planning with future scenarios
Information and awareness, e.g. kerb wastage and change behaviour in terms of consumer choice	**Community Awareness and education/Social networking,** e.g. create local awareness and Understand consumer view about the risk and costs for climate change and what would be their contribution to assist the producers, processors and the food suppliers.
Water reuse and eco-restoration, e.g. water catchment, desalination and efficient irrigation system	**Best Farm Management,** e.g. minimising tillage, increasing soil cover, efficient irrigation.
Policy/enabling environment for land Use and mutual sustainability of food supply chain/value chain members.	**Regulation/policies: Fostering concept of program to promote cluster farmer**, e.g. around a value chain. Empowering producers to take control of the supply chain. Levy structure to support local/regional responses

The strategies ranked with greatest potential to have an impact and most likely to be implemented had some similarities between the two state contexts. These strategies are summarised here in table form and apply to both contexts in a range of ways (Table 7). Transitional strategies appear most, followed by transformational strategies. There are no transformational strategies identified for the global scale, and no incremental strategies for the national scale.

Table 7 Highly ranked strategic interventions by scale of implementation

	INCREMENTAL	TRANSITIONAL	TRANSFORMATIONAL
LOCAL	• Short-term land management approaches (SLM) • efficient water use (EWU) • soil security (SSE) • local sources of input (LSI)	• best farm management strategies (BFM) • investment in extension and technology (IET) • creation of fertiliser for higher productivity (CFH) • local sources of input (LSI)	• best farm management strategies (BFM) • reliable power generation (RPG • new irrigation opportunities (NIO)
REGIONAL	• transport infrastructure (TRI) • reliable power generation (RPG) • soil security (SSE)	• varietal development (VRD) • creation of fertiliser for higher productivity (CFH) • government support for efficient water use and technology (GSE)	• varietal development (VRD) • reliable water supply (RWS)
NATIONAL		• industry collaboration (INC) • creation of fertiliser for higher productivity (CFH) • reliable predictions for planning future (RPF)	• industry collaboration (INC) • national levies (NLV) • best water reticulation systems (BWR) • reliable predictions for planning future (RPF)
GLOBAL	• crop variety development (CVD)	• genetic engineering (GEN)	

The strategies, that were identified by the workshop participants both in SEQ and SW WA, were grouped in six categories according to broad intervention strategies (Table 8).

Table 8 Categories of strategies identified through impact likelihood graph

CATEGORIES	STRATEGIES IDENTIFIED THROUGH IMPACT-LIKELIHOOD GRAPH
Business models	Community support for local agriculture Market mechanism to enable farmers using efficient system Food banking and recycling Non land use production system Local sources of Input Industry collaboration
Education and awareness	Consumer education Awareness of climate change Supporting adaptation Community information and awareness
Infrastructure	Reliable power generation Reliable water supply Designing storage and distribution facilities Food storage and supply Infrastructure Transport infrastructure
Policy and governance	Value/capacity to for pay irrigation water Improve ease of compliance National levies Regulation to enhance power (market) balance Land suitability mapping Promote cluster farming Possible offset approach Compliance with government policies Ownership - resource management Adjusting regulatory process Creating enabling environment More integrated land use governance Enable easier entry and exit in agricultural production Favourable land use policy Moving/processing to production site Long term planning for water management Reliable predictions for planning future Govt support for efficient water and technology Liveability in region and business innovation (social policy) New irrigation opportunity
Research and development	Funding for research Pilot projects for alternative system R& D development Varietal development Monitoring to detect pests and diseases earlier Crop variety development Create fertiliser for higher productivity Genetic engineering Suitable crop varieties
Technology and Extension	Best farm management Investment in Extension/Tech Transfer Long-term land management Best water reticulation system Efficient water use Technology adoption by on-farm incentives Eco restoration/carbon farming Increase input for higher productivity Soil security Water re-use Short-tem 5-10 years land management

A further exploration of the strategic interventions identified by the EPs was categorised according to the crieteria of TBL sustainability framework of the World Class Food System (Nath and Islam 2010) (Table 9). Scores indicate number of times each strategy was mentioned in the EP process. The most mentioned social criteria were knowledge utilisation and access, supporting innovations and building community awareness. The most mentioned economic criteria were land development and management, value added food processing, farmers and market relationships and production system improvements. For environmental criteria, the most mentioned was carbon footprint reduction, water management, climate change and biodivesity and protection of the natural environment.

Table 9 Prioritisation of intervention strategies according to World Class Food System

Social	Total	Economic	Total	Environmental	Total
Knowledge utilization and access	16	Land development and management	18	Reducing carbon footprint	17
Supporting innovations	14	value added food processing	14	Water management	16
Building Community awareness	12	Farmers and market relationships	13	Climate change and biodiversity	13
Rural development initiatives	9	production system improvement	12	Protecting natural environment	12
Building local links into food systems	8	Cut cost and increase profit	8	Low Impact Farming	8
Facilitating industry support	8	Regulations consistency	8	Wise utilization of resources	7
Educate realising food sustainability	8	food sovereignty	7	Government land use policy	6
Fair competition policy	6	Alternative food habits	7	Waste Management	2
Leadership	5	Facilitating access to market	7	Carbon farming and biodiversity conservation	2
Fair trading regulations	5	Producers security program	6	Pest disease and weeds control	2
Regulations moderations	4	Price and value for money	6	Price based on water usage	2
Ensuring animal welfare	3	small farm economy	5	Water tax modelled after carbon tax	2
managing internal trade rules	2	resource allocation facilitation	4	Lean manufacturing and eco-efficiency through whole value chain	1
Involving community	2	economic diversification	3		
Consumer protection program	1	Policy for technology use	3		
Food inspection program	1	supporting small farmers	3		
Inspection and enforcement	1	Labour welfare	1		
Consumer communications	1	Fair share of returns	1		
Encourage health profession	1	Paying true cost of production	1		
Input bottom line	1	Bridging yield gap	0		
Regulations	1	Increasing community Income	0		

Social	Total	Economic	Total	Environmental	Total
Vocational education and job ready	1	Rationing and food bank	0		
Supply and transport	1	Food aid and ethical consumption	0		
Contemporary agricultural extension service with whole system focus	1	Control dominant food systems	0		
Governance	1				
National food traceability system	0				
Food and grain quality	0				
Ensure good hygiene practice	0				
Human harm reduction	0				
Fat content dimensions	0				
Nutritional value dimensions	0				
Verifications and certifications	0				
Creating employment opportunity	0				
Globalization and technological fixes	0				

There were no environmental criteria missing from the outlined sustainability framework for the World Class Food System (WCFS). However, there were five criteria from the economic components of the WCFS and ten social criteria not mentioned. This is a useful evaluation of the priorities allocated by the range of EP participants contributing to this intervention framework for climate change intervention. While it may be possible to aspire and understand the criteria for a sustainable food system that addresses TBL values, such as the WCFS, it is not always foremost in the considerations of the various food systems with an interest.

SECTION SIX: MODELLING THE INTERVENTIONS

By focusing on the factors/variables through considering a whole food system provides a more effective means of identifying risks incurred through climate change and their impact on food security. Adaptation measures have tended to focus on technical agricultural interventions to reduce food security vulnerability. A food system approach provides a framework to identify strategic interventions beyond agricultural solutions. Thus mitigation and adaptation measures may be better focused through points of intervention identified within a discrete TBL value set with a more immediate policy application (Ingram 2009).

There are three key objectives defined in the research agenda. Each of these objectives comprised research strategies that established and built upon knowledge generated horizontally and vertically. The first objective aimed to ensure participation and selection of expert opinion reflected a food system, and knowledge about climate change impacts on dairy and horticulture. The second objective was to identify risks to horticulture and dairy food-systems and food security generated through human-induced climate change. Once synthesised the risks, mitigation and adaptation interventions provided the basis for modelling scenarios and climate change intervention impacts. The third objective was to develop and test mitigation and adaptation approaches suitable for strengthening vertically linked food-systems through a series of integrated modelling exercises. The results provided a concrete means of evaluating and understanding the implications of different interventions by scale, type of intervention (incremental, transitional, transformational) and within a range of scenarios (identified through the EP Workshops).

This approach helps practice, industry and policy decision-makers recognise interactions and implications of climate change. The final section, 6, provides the results of modelling climate change mitigation and adaptation intervention strategies in relation to capacity, for a range of scenarios identified as key risks.

CAPACITY AND CAPITALS

Capacity has a significant bearing on the success of implementing intervention strategies. To assess capacity, a framework of seven capitals was used to locate values representing the triple bottom line (TBL) (Wardell-Johnson 2011).The data to evaluate the relative perceived importance (Figure 30) of these capitals was derived from a series of questions in the survey data. Three social components reflect the social dimension of the TBL: cultural, human and social capital. Two economic components reflect the economic dimension of the TBL: economic and physical capital. Two ecological components reflect the ecological dimension of the TBL: ecological and environmental capital.

Cultural capital (12%) develops within the family sphere and provides a non-economic means of acquiring qualifications, employment and status. Human capital (19%) is the sum of individual human skills, ability, experience training and knowledge that reflects and consolidates social and cultural capital of the family of origin. Social capital (14%) can have a multiplication effect with positive or negative influence on other forms of capital. It comprises networks of relations of trust and norms of reciprocity and exchange. These social obligations are a collective resource derived through group membership and connections that are convertible to economic capital.

Physical capital (combined here from financial and physical capital) (23%) is convertible to money and institutionalised as property rights. While physical capital in infrastructure, financial capital, tools and equipment and is a potential outcome of social capital. Two component of the ecological dimension of the TBL are environmental capital (16%) which encompasses water, soil, forests, biodiversity and scenery, and holds material value. While natural capital (16%) represents values from the ‘natural’ world that holds symbolic value with partial public good. Natural capital rarely has market value.

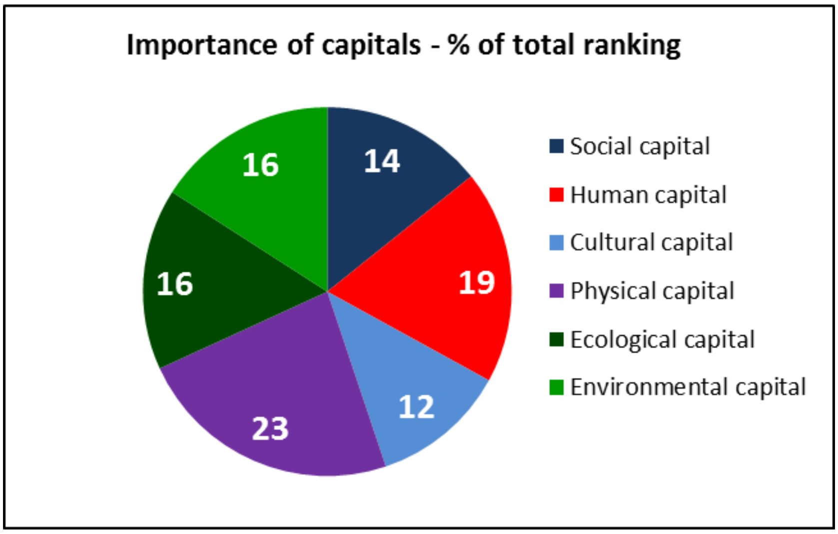


Figure 30 Relative importance of capitals to capacity to mitigate and adapt (n=24)

By understanding the relative allocation of value of capitals comprising the TBL sustainability framework, it becomes possible to indicate the need for certain forms of capacity to intervention for climate change mitigation and adaptation. Once an understanding of the role of capacity is established, this framework provided the basis to test intervention strategies in relation to identified risk scenarios.

STRUCTURAL EQUATION MODELLING

The conceptual framework developed through the literature review and the results of the expert panel workshops was used to develop a generalised conceptual model (as shown in Figure 31). This approach was used to illustrate important factors, variables and their hypothesised relationships related to climate change and food security in horticulture and dairy industry in Australia. The statements of the hypotheses are provided in Table 10. The hypotheses (also shown in Figure 31 as from H1-H3) were developed to test whether or not there were significant links between climate change risk scenarios, adaptive capabilities and the adoption of suitable intervention strategies (mitigation and adaptation) for food security in Australia. Using the approaches of structural equation modelling (SEM), the model assumed a number of interdependent factors related to socio-economic and ecological adaptive capabilities and the relevant risks that may determine/ predict the ability of implementing climate change mitigation and adaptation strategies to improve food security in Australia.

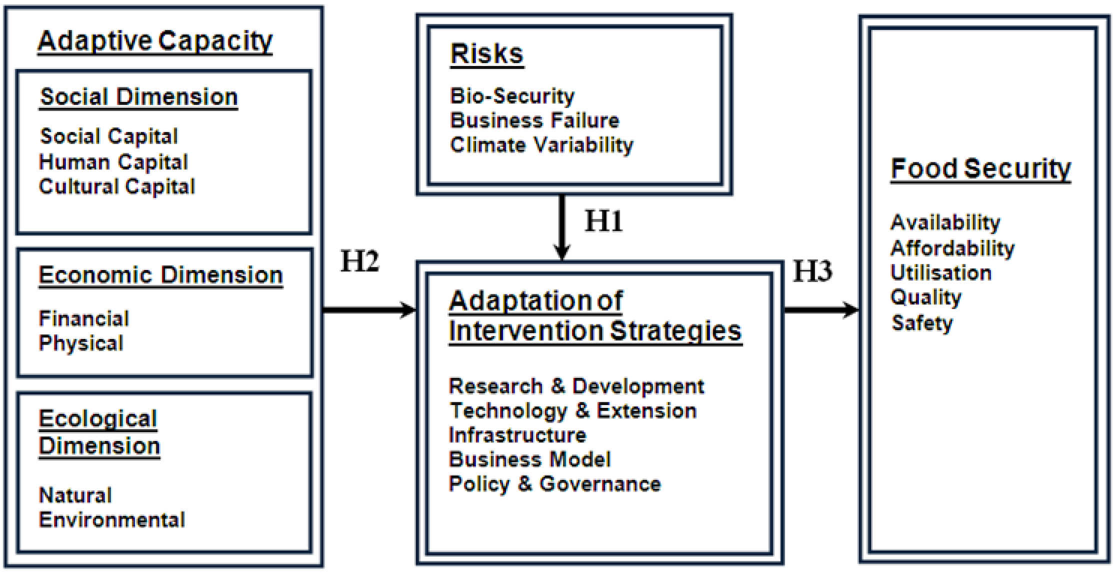


Figure 31 Modelling of the factors and their hypothesised relationship in the food security system

There are four multidimensional factors used in the model: (1) Adaptive Capacity; (2) Risk; (3) Adoption of Intervention Strategies; and (4) Food Security. Each of these factors forms a process of evaluating both influence and contribution to the final objective of food security.

1. **Adaptive Capacity**: The model in **Figure 31** shows that the factor 'Adaptive Capacity' is a macro presentation of individual factors and is formed from three dimensions of capacities, that is Social Dimension, Economic Dimension and the Ecological dimension. These dimensions were defined in the literature review to identify the detail of the socio-economic and environmental vulnerabilities related to climate change adaptation and can indicate the likely success of intervention within a particular sector in the food system. The dimensions (which can be called sub-factors) in the model are used to aggregate different social, economic and ecological capacity indicators. This provides a test for the link between climate change adaptive capacities and the adoption of intervention strategies. In addition, the relative importance of each of the dimensions to the combined adaptive capacity factors can be assessed in the model. Appendix provides the measurement items for the factor 'Adaptive Capacity'.
2. **Risk**: The risk factors were identified through the EP workshops and developed using the variables of three risk scenarios – Bio-security, Climate Variability and Business Failure (Appendix). The scenarios were used to form the macro presentation of risks in climate change and assessed to establish the relative importance overall of the risk factors. The aggregated weights of the risk factor were then assessed to establish their association with the adoption of intervention strategies in food systems.
3. **Adoption of Intervention Strategies**: Similarly, the factor 'adoption of intervention strategies' was developed from a group of five strategies (identified as sub-factors) of adaptation and mitigation, that is Policy and Governance, Research & Development, Infrastructure, Technology and Extension and Business Model (Appendix). However, compared to the formative factors 'Adaptive Capacity' and 'Risk', the factor 'Adoption of Intervention Strategies' was developed as reflective as it is hypothesised an overall latent construct (e.g. intervention strategies) exists and can be indicated or reflected by the group of sub factors. The groupings were used to define the entire domain of the intervention strategies. It is also possible to establish the relative importance of each of the groups in reflecting the factors influencing intervention strategies.

4. **Food Security**. It is important to note that the categories of the strategies and their items are purposefully selected from the literature review and were a representative sample of the six categories identified in the expert panel workshops (Table 6). The selection was based on the survey responses and available data for the purpose of modelling. Moreover, the categories 'Education and Awareness' and 'Industry collaboration' were not included as the items were adequately covered by the factor of Adaptive Capacity. The conceptualisation of these indicators was developed from the literature review, expert panel workshops, and ranking of the issues from the survey.

HYPOTHESISED RELATIONSHIP IN THE MODEL

The study used Structural Equation Modelling (SEM) to estimate a series of interdependent relationships in the model. SEM is a multivariate technique combining aspects of and factor analysis (representing unmeasured concepts – factors – with multiple variables). The hypothesised relationships, as shown in Table 10 are provided in Appendix .

Table 10 Hypothesised relationships in the Model

Factors and their sub-factors	Path	Hypothesized Relationship
Risks **Business failure** **Bio-Security** **Climate variability**	H1	Climate change related risks will positively influence the adoption of suitable intervention strategies in the food security system. Risks → Adoption Strategies
Adaptive Capacity **Social Capital** **Economic Capital** **Ecological Capital**	H2	Adaptive capacities will positively influence the adoption of climate change intervention strategies in the food security system Adaptive capacity → Adoption Strategies
Adoption of Strategies **Policy & governance** **Research & development** **Infrastructure** **Technology and Extension** **Business models**	H3	Adoption of climate change intervention strategies will positively influence the food security system. Adaptation Strategies → Food Security

Hypotheses Testing using PLS based SEM

The study used Partial Least Square (PLSGraph 3.0) based SEM to simultaneously model the structural paths (i.e., theoretical relationships among latent variables) and measurement paths (i.e., relationships between a latent variable and its indicators) in order to accept or reject the hypothesised relationships.

In PLS, the measurement model is estimated showing statistics (i.e., loadings) that assess the validity and reliability of variables and their respective constructs. Second, the results for the structural model are reported showing the relationships (i.e., path coefficients) between the constructs and the explained variance. Thus, PLS shows which assumed predictors have substantive links to outcomes by estimating the relative strength of relationships using the path loading of the predictors. Using the R^2, it also can be judged to what extent variation in one set of variables might help explain variance in another variable of interest. **Figure 32** illustrates the PLS data analysis procedure in the study.

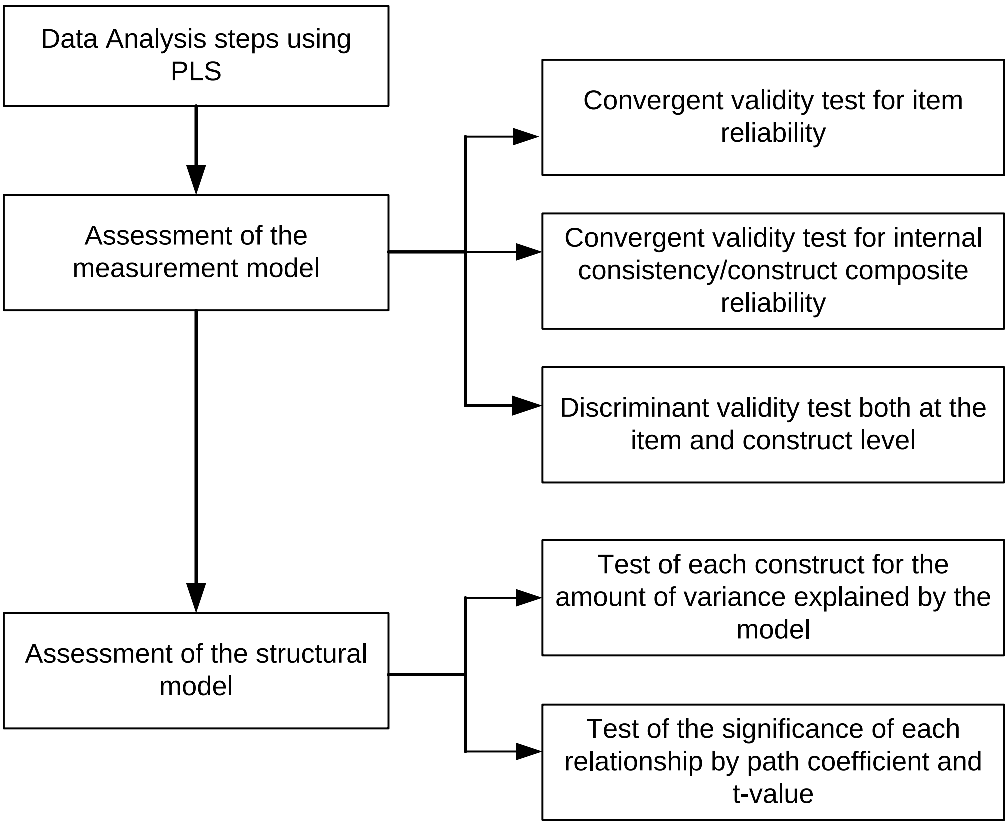


Figure 32 Required Steps of Data Analysis in PLS

Relationships between risk scenarios, adaptive capacity, intervention strategies and food security

The graphical result extracted from PLS bootstrap analysis is presented in Figure 33. It shows the direction and coefficient of each hypothesised path (beta weight) and corresponding t-values. R^2 values also are provided under each of the endogenous constructs (in circles). The standardised path estimates, which can be interpreted in the same manner as the path coefficients in multiple regressions, indicate the magnitude of the impact of an independent factor on a dependent factor.

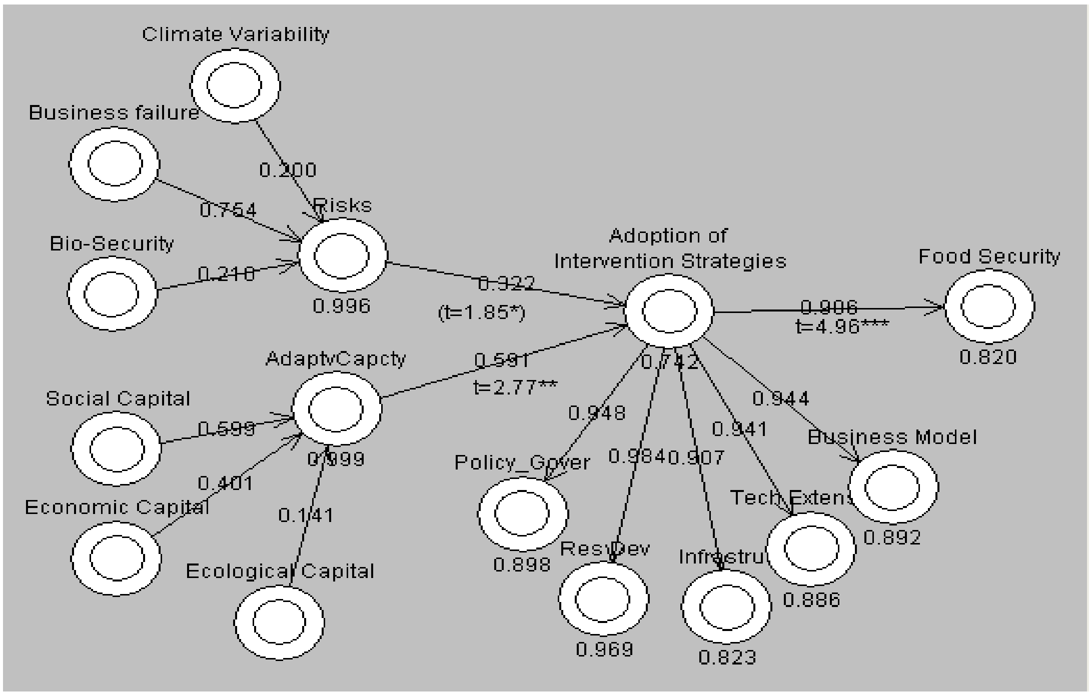


Figure 33 PLS Bootstrap Analyses for the Hypothesised relationships

***Significant at α = 0.000 **Significant at α = 0.005 *Significant at α = 0.05

The PLS bootstrap results are also presented in Table 7. The table reveals that all paths (relationships) were statistically significant and, thereby, support all the hypotheses in the study. In terms of the path loading/path coefficient (beta weight), the result shows that Adaptive Capacity has the strongest influence (β 0.591; t = 2.77; p <0.005) on Adoption of Intervention Strategies, followed by climate change related risks (β 0.322; t = 1.85; p< 0.05). The result also shows, given all the direct and indirect effects, adoption of intervention strategies related to climate change had a very strong positive influence on Food Security.

Table 11 Hypotheses testing: Bootstrap Path Co-Efficient and Their T-Values in the Structural Model

Hypothesis	Hypothesized Relationship	Path Coefficient(β)	t - value	P Value (α)
H1	Risks → Adoption Strategies	0.322	1.85	0.05
H2	Adaptive capacity → Adoption Strategies	0.591	2.77	0.005
H3	Adaption Strategies → Food Security	0.906	4.96	0.000

The explanatory power of the research model can be assessed by observing the R^2 of the endogenous factors in the model (Barclay *et al.* 1995). R^2 value of a latent construct should be at least 0.10 for an acceptable standard. The structural model testing shows that the strongest R^2 value was 0.820 is “Food Security” followed by 0.742 in the adoption of intervention strategies, thus 75 percent of the variance was explained by the proposed model which is the indication of a relatively parsimonious model (Table 12).

Table 12 R2 Values for the Endogenous Construct

Construct	R^2
Adoption of Intervention Strategies	**0.742**
Food Security	**0.820**

Hypotheses Related to Climate Change Risks (H1)

The effect of climate change related risks was explored as an antecedent of the adoption of intervention strategies and it was hypothesised that risks would positively influence the adoption of suitable intervention strategies in the food security system. The results in H1 (Table 11) shows that the path coefficient and t-value of hypotheses H1 (β 0.322; t=1.85, p <0.05) is significant, thereby providing evidence that the level of risks had an impact on the level of adoption of the intervention strategies.

It is important to note that Risks was modelled as a higher order factor consisting of three sub-factors or scenarios of risks - Bio-security Risk, Business Failure and Climate variability which were measured by individual indicators. Analogous to beta weights in a multiple regression, the statistical significance of the weights obtained for each of the scenarios can be used to determine the unique/ relative importance of the scenarios in the holistic Risks concept. The result, as shown in Figure 34 reveals that the risk of Business Failure (β=0.754) has the highest weight and statistical significance, followed by Bio-security (β=0.210) and Climate Variability (β=0.200). Thus, results indicate a greater likelihood that farm businesses may fail, as a consequence of climate change and resulting cost of production, low productivity and margins, unless suitable strategies to build viability and support are adopted.

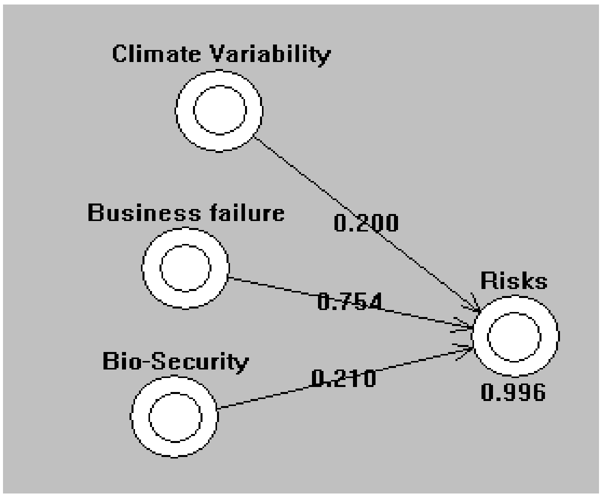


Figure 34 Relative importance of each of the climate change related risk scenarios in the holistic risk concept

Hypotheses Related to Adaptive Capacity (H2)

Hypothesis H2 explored whether or not adaptive capacities will positively influence the adoption of climate change intervention strategies in the food security system. The factor was also developed as a higher-order factor using three dimensions of capabilities – Social dimension, Economic Dimension and Ecological Dimension. The main purpose of this formative model was to extract the beta weight of each of the dimensions to realize their relative contribution in forming the Adaptive Capacity factor and to determine how they

mediated strength of influence on the adoption of intervention strategies. As reported in

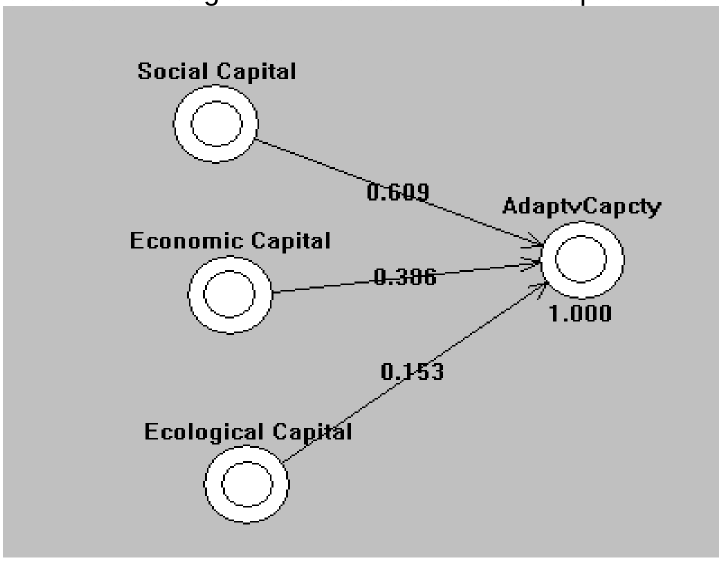


Figure 35, the social dimension showed the highest importance (β=0.609) in forming the adaptive capacity, followed by the economic dimension (β=0.386) and ecological dimension (β=0.153).

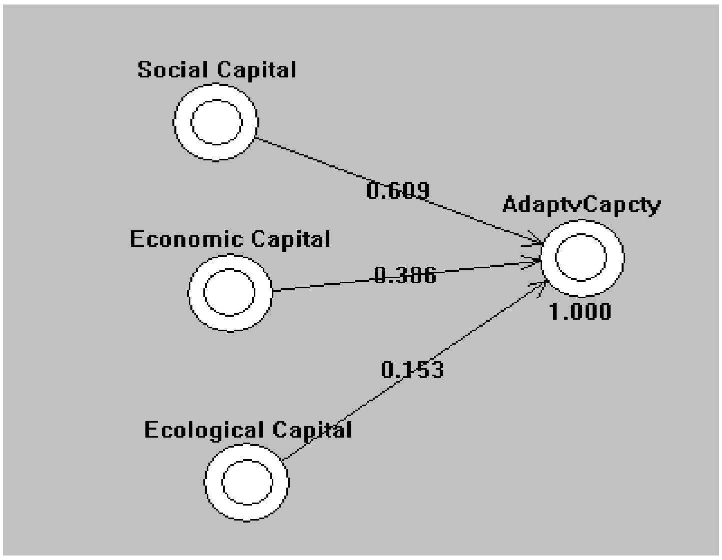


Figure 35 Relative importance of each of Adaptive Capacity in the holistic risk concept

The higher-order effect of the factor Adaptive Capacity was then tested in regard to the Adoption of Intervention Strategies. The result of the structural model, as shown in Figure 32 and Table 12).

Table 12 provided strong evidence for the hypotheses H2 (β= 0.591; t = 2.77; p> 0.005). Thus, it can be said that the strength of adaptive capacities in the food security system significantly influences the adoption of climate change intervention strategies.

Hypotheses Related to Adoption of Intervention Strategies (H3)

The final hypothesis was related to the consequences of the Adoption of Intervention Strategies to the overall food security system in Australia. It was hypothesised that given the effect of Risks and Adaptive Capacities, the Adoption of intervention strategies would positively influence food security relevant to the horticulture and dairy industries. The factor Adoption of Intervention Strategies used a group of five adoption and mitigation strategies, namely: Policy & Governance; Research & Development; Infrastructure; Technology and Extension; and Business model. Unlike the formative model used in Risks and Adaptive Capacity factor, the sub-factors in the intervention strategies were used to reflect/define the domain of intervention strategies. There was strong evidence in these results that all the sub-factors showed highly significant loadings. The beta weight for the hypothesised relationship between food security and intervention strategies (β= 0.906, t= 4.96; p> 0.000) shows strong empirical evidence that Adoption of Intervention Strategies positively influenced the overall food security system.

CONCLUSIONS FOR SEM

The main purpose of the modelling was to provide evidence of the links between climate change risk scenarios, adaptive capacities and the adoption of suitable intervention strategies (mitigation and adaptation) for food security in Australia. The model demonstrates strong evidence of relationships between the climate change risk scenarios and intervention strategies, and between the adaptive capacities (TBL capacities) and intervention strategies. All these relationships have a strong consequence for food security in Australia.

A critical finding emerging from the research was the evidence that communities that are vulnerable to adaptation to climate induced change are vulnerable for a set of socio-economic capacities. The model shows that among the three dimensions of adaptive capacities, the social dimension comprising three social components - cultural, human and social capital - has the strongest influence on the adoption of suitable strategies for climate change intervention. The economic dimension with underlying financial and physical capacities was also found to be important for an effective implementation of the intervention strategies for enhanced food security. A full list of the capacities is provided in Appendix . However, the low impact of ecological capital (representing natural and environmental capacities) is relative to the weight of multiple regression in the context of three different dimensions of TBL capacities and provides direction for future research with more rigorous measures of ecological capacity.

Another important point demonstrated by the risk scenarios was that farm businesses are likely to fail in the absence of suitable adaptation and mitigation strategies. The risks, as listed in Appendix , are the consequence of climate change which adversely impacts the cost of production, productivity and profit margins of the upstream producers.

It is important to note that the model is applicable to all the actors of a food-system who are primarily responsible for the mitigation of and adaptation to climate change for a sustainable food system. As the food systems reflect food availability, access and utilization of food through a supply chain of production, processing, distribution and consumption, the structural model is suitable for testing the multiple causal relationships between adaptive capacity, risks and adaptation intention of all supply chain participants. For example, at the farm producer level, the model can identify details of the socio-economic-environmental capability of producers for climate change adaptation, the risks, and points of intervention for effective mitigation. Also, this modelling can statistically test the strength of socio-economic-environmental capability with potential to influence farmers' decisions for adaptation of

relevant strategies. Similarly, the model can equally explain the adaptive capacity of the other sectors of a food-system, for example policy makers, food processors, retailers and their consumers.

However, as the nature of the study was exploratory, there were some limitations in following all the procedures for developing new measures in this study. Future studies should incorporate more scenarios and variables for adaptation strategies. The model was tested using a holistic approach of the horticulture and dairy industries which may be equally applicable for modelling and testing in other food systems.

Assessing interventions in relation to climate change risk scenarios

The main purpose of the modelling was to provide evidence of the links between climate change risk scenarios, adaptive capacities and the adoption of suitable intervention strategies (mitigation and adaptation) for food security in Australia. The model demonstrated strong evidence of relationships between the scenarios of climate change and business failure, socio-economic-ecological capacities and adoption of climate change intervention strategies. All these relationships have a strong consequence for food security in Australia. However, as the nature of the study was exploratory, there were some limitations in following all the procedures for developing additional measures in this study. The model was tested using a holistic approach of the horticulture and dairy industry which may be equally applicable for modelling and testing in other food systems. Future studies may well incorporate more scenarios and variables of the adaptation strategies as identified from our Expert Panel workshops.

MODELLING PRIORITY INTERVENTION STRATEGIES

In the earlier sections important factors and variables were identified and their relationships with climate change and food security estimated by using the SEM approach. In this section an attempt was made to measure priority rankings of climate change adaptation and mitigation strategies. To achieve the goal of regional food security an understanding of the relative importance of climate change adaptation and mitigation strategies are necessary. The achievement of these objectives and criteria at different levels and dimensions of a regional food system is necessary for rational planning and resource allocation in decision making.

Analytical Hierarchy Process Modelling

Based on the model structure and results of the SEM an Analytical Hierarchy Process (AHP) modelling approach was used to develop a hierarchy of objectives that were required to be fulfilled through the implementation of a number of alternative adaptation and mitigation strategies for achieving the goal of regional food security. The AHP modelling allows the modelling of complex problems by incorporating both objectives and sub-objectives as considerations in the decision process. This is achieved through the application of hierarchical processes with goals, objectives, sub-objectives and alternatives. See Appendix for a brief overview of an AHP modelling and measurement process. Figure 36 shows this hierarchy.

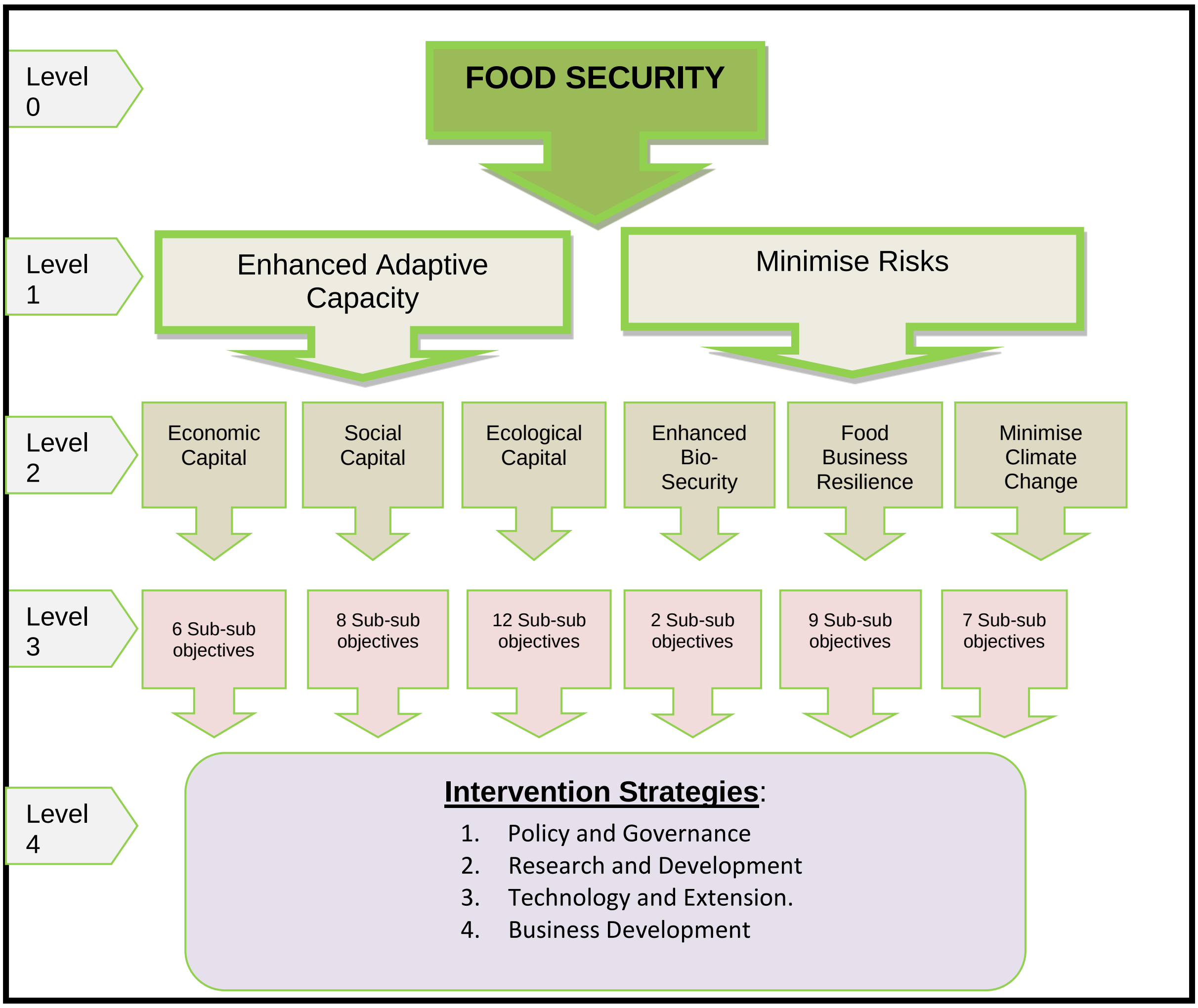


Figure 36 Food Security goal and intervention strategy model

Level 0 of the hierarchy represents the goal of 'Food Security' which is defined to include food 'affordability', 'availability', 'utilisation', 'quality' and 'safety'. We considered that the food security goal could be achieved through the achievement of two major objectives. These were: a) Enhanced Adaptive Capacity (EAC) and b) to Minimise Risk (MR) from climate change. These two major objectives are shown in level 1 of the hierarchy in Figure 36. Level 2 of the hierarchy provides the objectives of the key components of the two major objectives shown in Level 1. These were enhancement of Economic, Social and Ecological capitals that are necessary for EAC. On the other hand enhancement of the Bio-Security (BS), Food Business Resilience (FBR) and Climate Change Impact Minimisation (CCIM) measures are necessary components of MR. Level 3 of the hierarchy provides the lowest level objectives of the food security goal that are basic components to address through four groups of intervention strategies i.e. Policy and Governance, Research and Development, Technology and extension, and Business development are shown in level 4. The hierarchical detail components of objectives and sub-objectives are given in Appendix and the components of the four intervention strategies are given in Appendix 11.

DATA, MODEL ESTIMATION AND RESULTS

The correlation estimates of the SEM are used as data to derive ratio-scale in order to measure relative importance of each of the adaptation and mitigation strategies (in Level 4, Figure 36) with respect to each of the lowest level objectives (in Level 3). Similarly, the relative importance of each of the lowest level objectives (in Level 3) with respect to their corresponding objectives in Level 2 was measured. This process continued to the measure

of relative importance of the two major objectives (i.e. EAC and MR) with respect to the goal of food security.

Relative importance of objectives and sub-objectives in the hierarchy

In terms of ratio-scale, the relative importance of the individual objective components from Level 3 to Level 1 with respect to their upper level objectives and the goal are presented in Figure 37 to Figure 39. Figure 37 reveals that the two top level objectives, EAC and MR are considered to be equally important in the face of climate change for achieving the goal of food security. Enhancement of Social Capital is the most important of the capitals, followed by Economic Capital, Ecological Capital ranking lowest importance.

With respect to the MR objective, Food Business Resilience (in terms of helping food industries achieve greater productivity and market access) was revealed to be significantly important to minimising the risk of climate change. The sub-objectives of Enhanced Bio-Security (such as protection of biodiversity, minimisation of pests and diseases) and Minimise Climate Change Impact (in terms of bush fire, soil salinity) received equally lower importance.

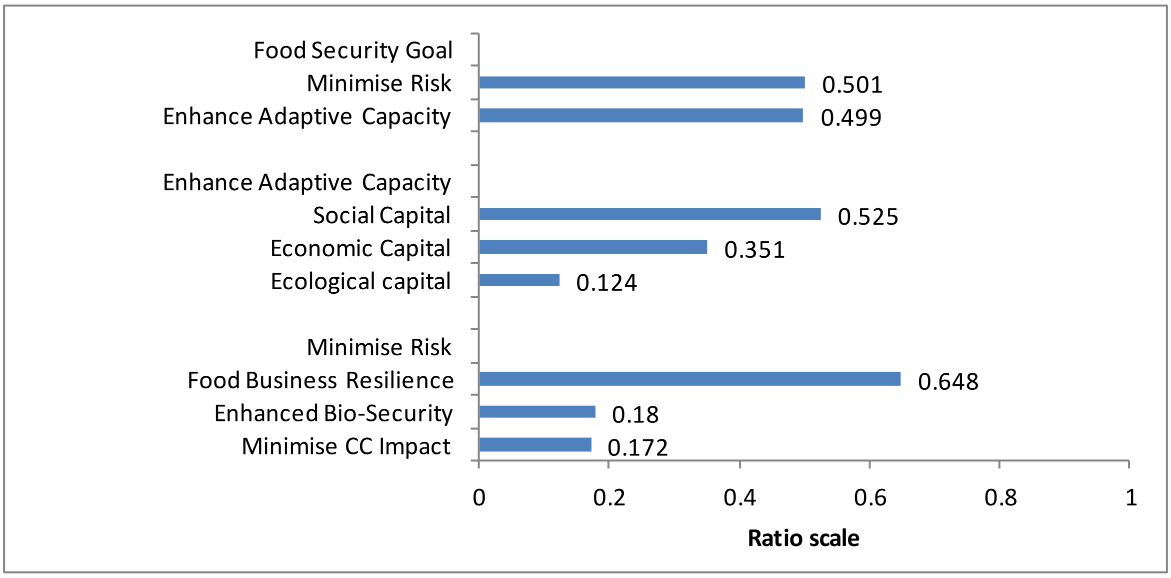


Figure 37 Relative Importance of the Level 1 and 2 components with respect to food security goal and the top two objectives

Within the Social Capital sub-objective, support for online social communication, formal education and maintenance of good health for example, were relatively important components (Figure 38). For the Economic Capital sub-objective adequate income to adopt new techniques and for achieving Ecological Capital goals, good quality vegetation and biodiversity ranked highest.

Although Enhanced Bio-Security was revealed to be of relatively low importance with respect to minimise risk, effective measures to protect biodiversity received absolute importance compared to pest and disease control measures (Figure 39).

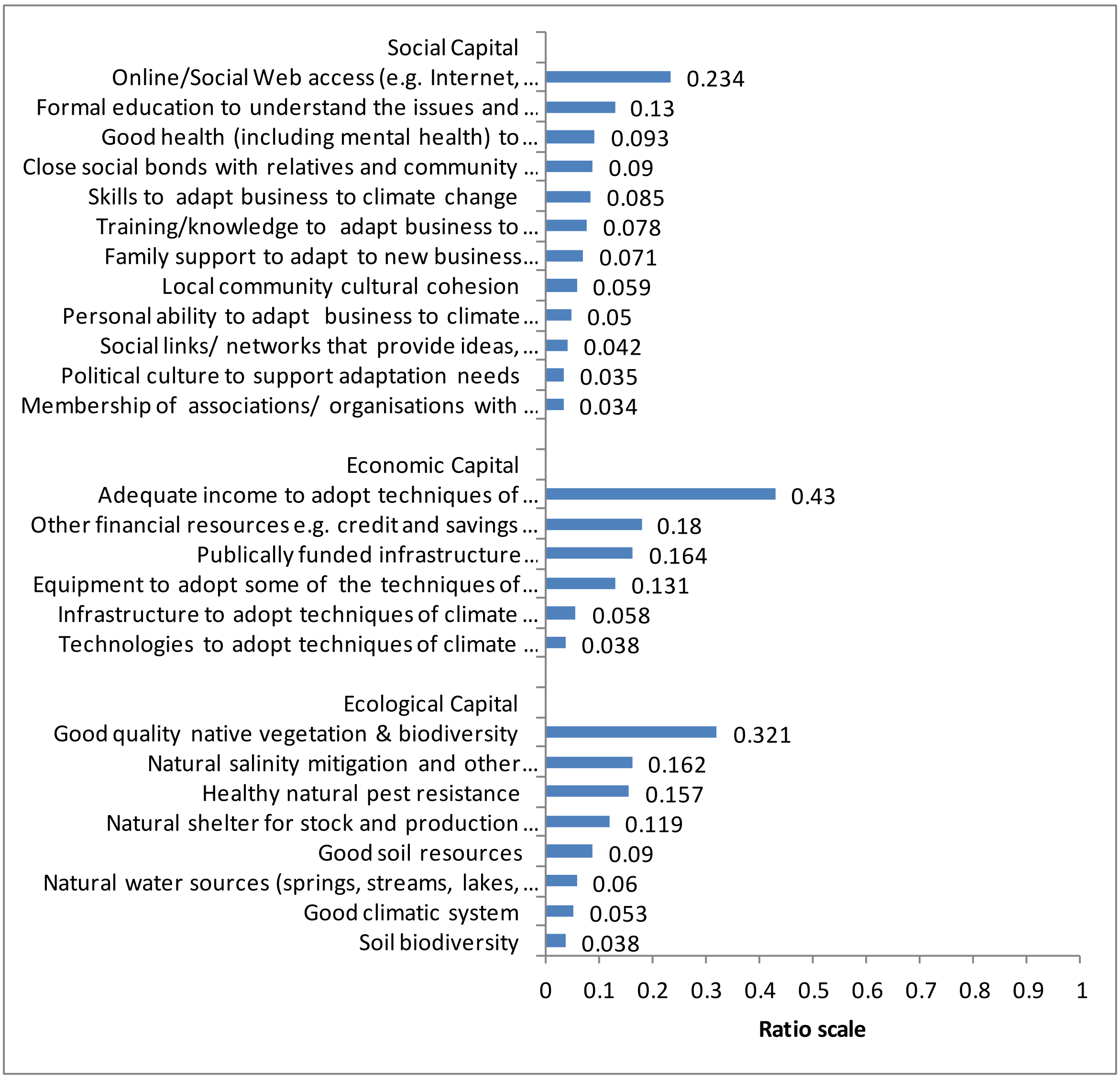


Figure 38 Relative Importance of the Level 3 components with respect to enhanced adaptive capacity objectives

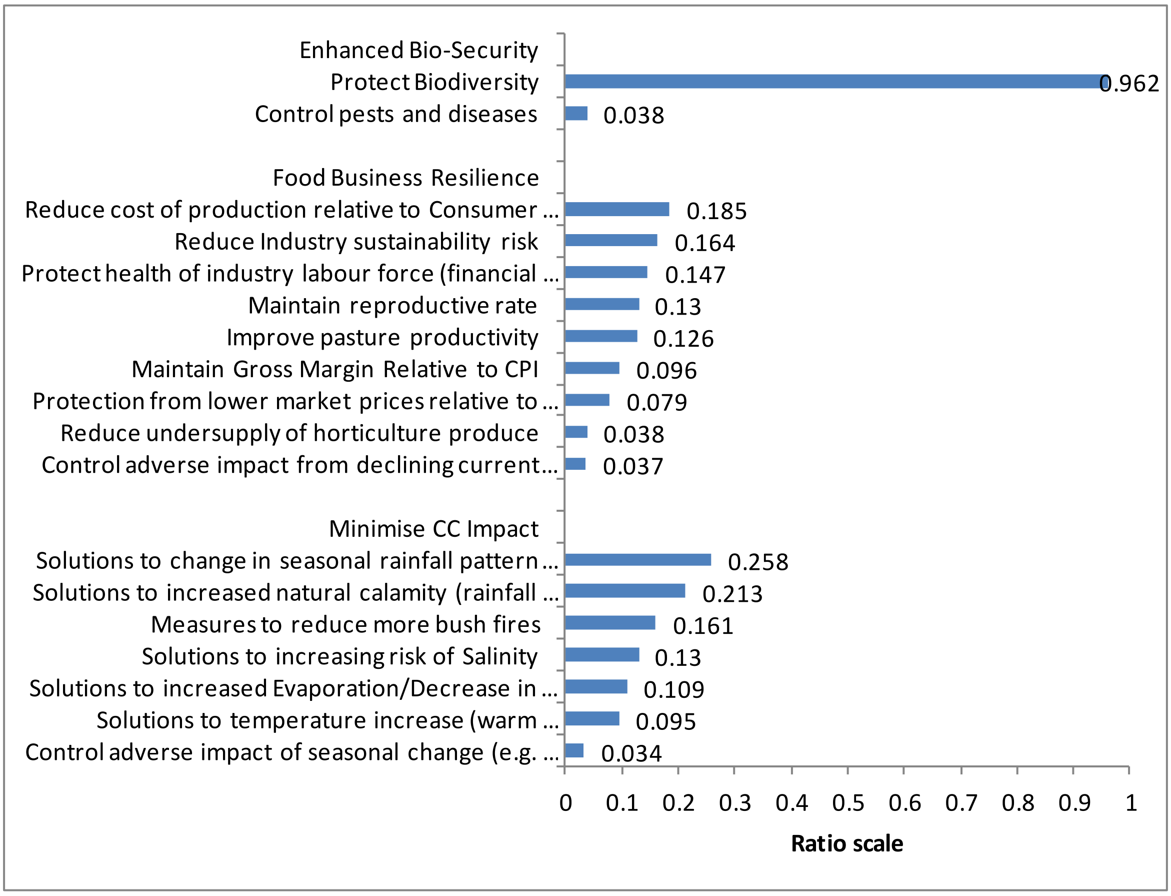


Figure 39 Relative Importance of the Level 3 components w.r.t risk minimisation objectives.

Relative importance of strategic alternatives

The data on the relative importance of objectives and sub-objectives in the hierarchy were loaded to Expert Choice software and the priority rankings of the climate change adaptation and mitigation strategies were estimated with respect to the goal and the objectives hierarchy. The synthesised priority rankings in terms of ratio-scale are shown in Figure 40 for the goal and Level 1 objectives.

This result suggests that to enhance adaptive capacity of food systems to sustain food security in Australia, policy and governance oriented strategies such as skill development, and land development policy are to be given priorities. On the other hand, to minimise food security risk from climate change, technology development and extension oriented strategies for sustained productivity and income growth of food systems should be given priority.

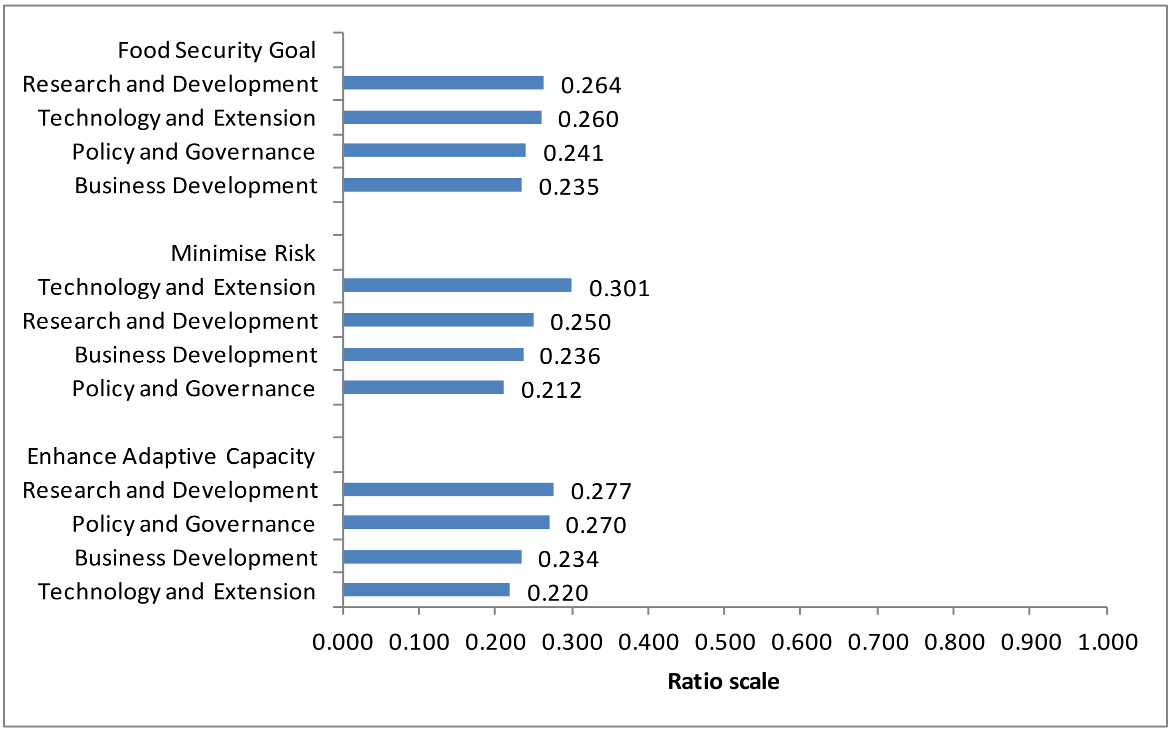


Figure 40 Relative Importance of alternative strategies with respect to food security goal and the top two objectives

Synthesis of the social, economic and ecological capital components of the EAC objective reveals that for social capital enhancement all four alternative strategies are important. The Policy and Governance strategy was the most important (see top part, Figure 41). These components do not contribute to Ecological Capital enhancement more than to Economic Capital enhancement.

Synthesis of the Bio-Security, Food Business Resilience and Minimise Climate Change Impact components of the MR objective (Figure 41) indicated that Technology and Extension was the most important strategy to achieve the Bio-Security objective. Research and Development is also important. The implication of this result is that relatively more resources are to be allocated on Technology and Extension and Research and Development for pests and disease control and protection of biodiversity to achieve the Bio-Security objective.

The Business Development Strategy ranked highest for the Food Business Resilience (see middle part, Figure 41) while it ranked lowest for the Bio-security (top part, Figure 41) and Minimise Climate Change Impact (bottom part, Figure 42) sub-objectives. This result suggests that careful economic analysis is relatively important for Food Business Resilience compared to Bio-security and Minimise Climate Change Impact components of the Minimise Risk objective.

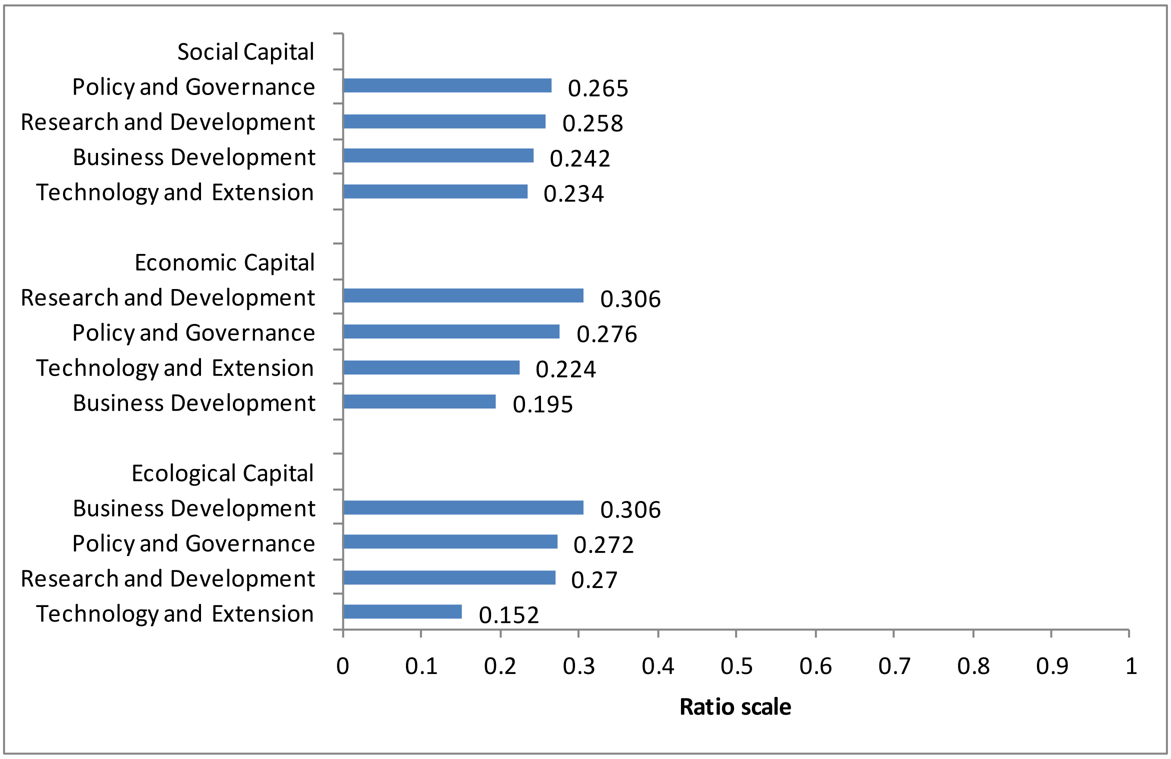


Figure 41 Relative Importance of alternative strategies with respect to the sub-objectives of the enhanced adaptive capacity objective

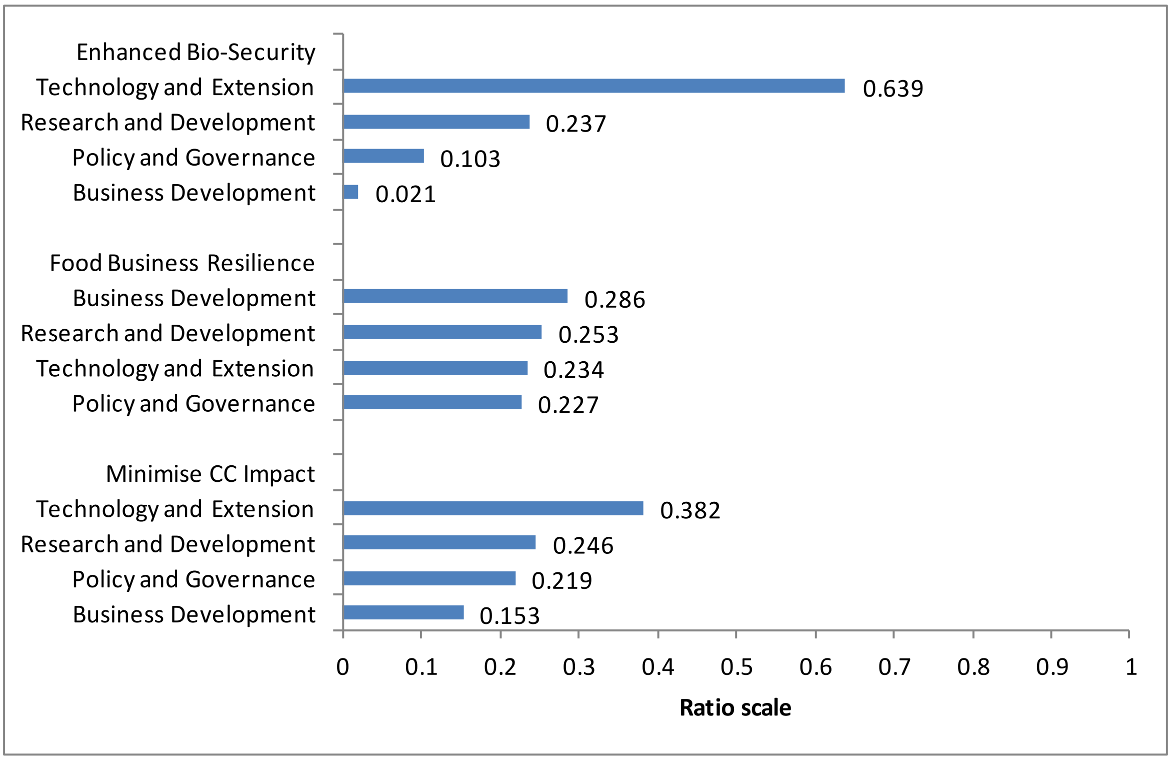
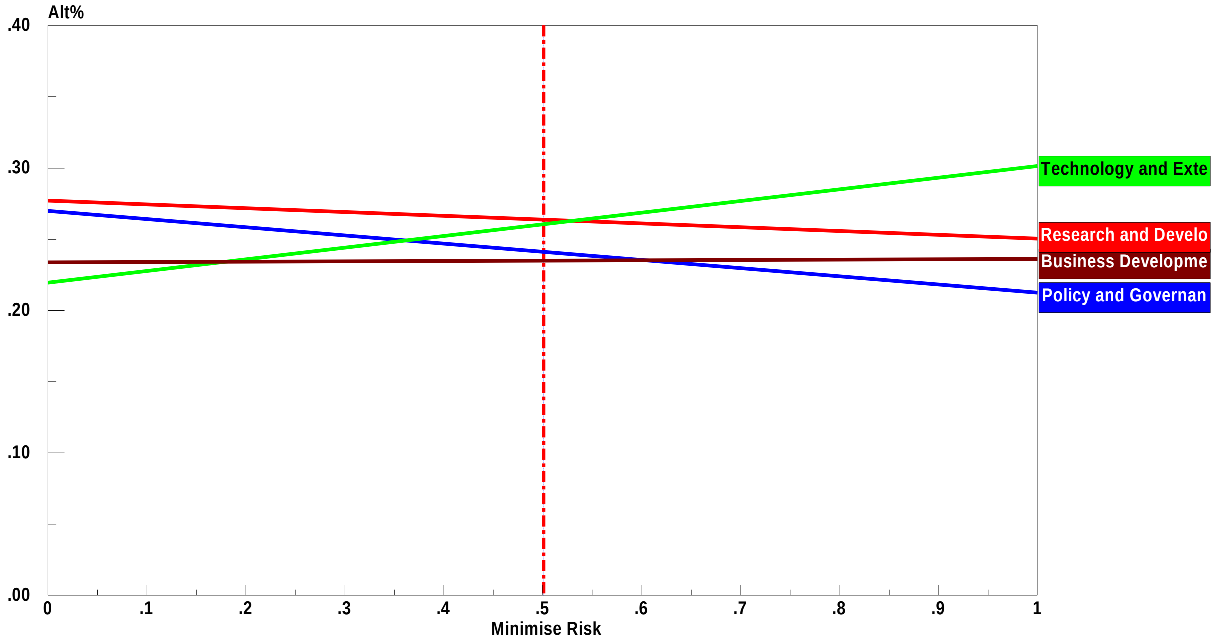


Figure 42 Relative Importance of alternative strategies with respect to sub-objectives of the risk minimisation objective

Sensitivity analysis of objectives

Performance sensitivity of the MR and EAC objectives with respect to the four groups of strategic alternatives are analysed in Figure 43, Figure 44 and Figure 45. In these figures the horizontal axis is the ratio-scale measures of objectives and the vertical axis on the left is the relative importance of the strategies. In Figure 43 the sensitivity of Minimise risk objective (higher group priority) with respect to the four groups of strategies is presented. With its current priority of 0.501 the Research and Development strategy ranked first.



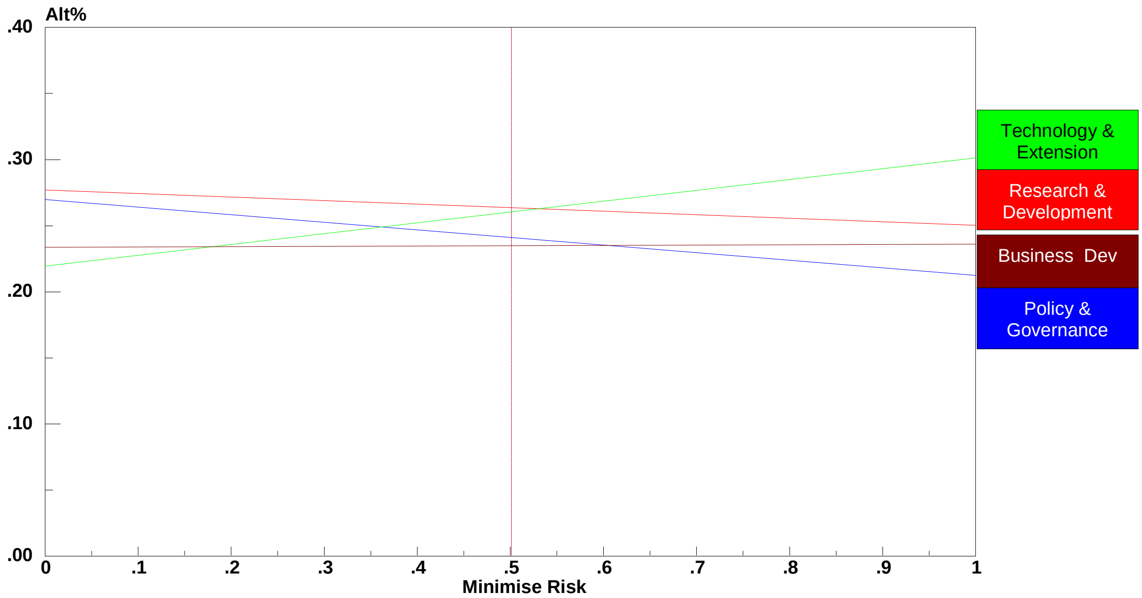


Figure 43 Gradient sensitivity for Minimise Risk objective with respect to Food Security goal

The sensitivity of the Social Capital sub-objective (highest group priority in EAC objective) (Figure 44) with respect to the four strategy groups was ranked highest with its current priority of 0.53as the R&D strategy. This indicates that to enhance social capital

development for achieving increased adaptive capacity to climate change, R&D strategy is most important. However, if priority increases beyond 0.80 policy and development strategy become the most important.

Sensitivity analysis for the Economic Capital and Ecological Capital (not shown) also indicated that R&D strategy remains important for a large range of priority ratio-scale.

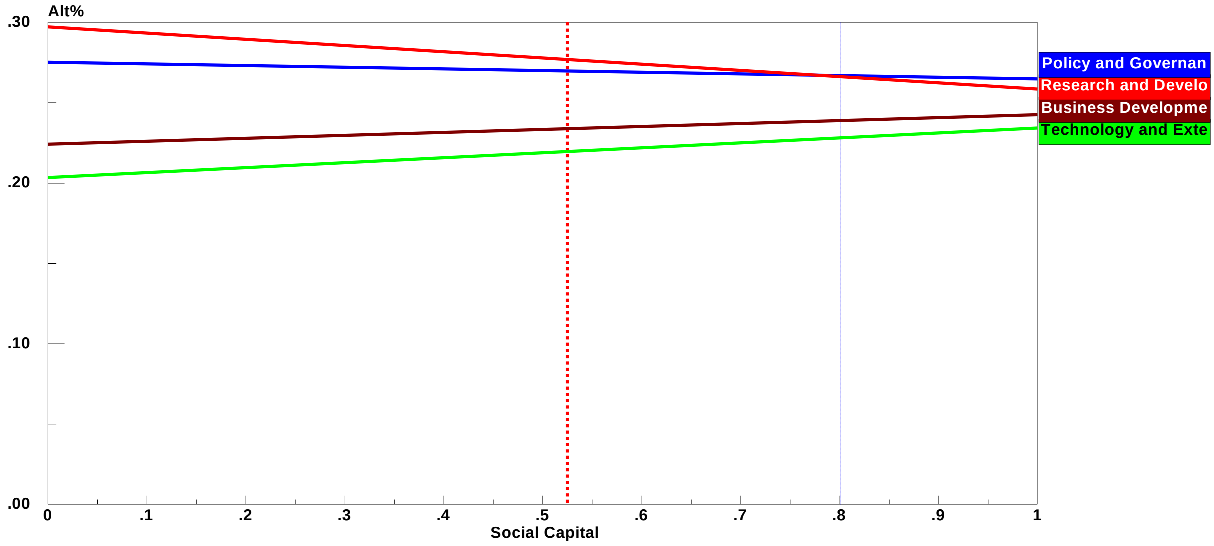


Figure 44 Gradient sensitivity for Social Capital with respect to EAC objective

The Food Business Resilience component of the Minimise Risk objective has the highest group priority of 0.6.5 where Technology and Extension strategy ranked highest (Figure 45). Sensitivity analysis for the Bio-Security and Minimise Climate Change Impact (not shown) also revealed that Technology and Extension strategy was highly important for a large range of their priority ratio-scale to achieve the Minimise Risk objective for the goal of food security.

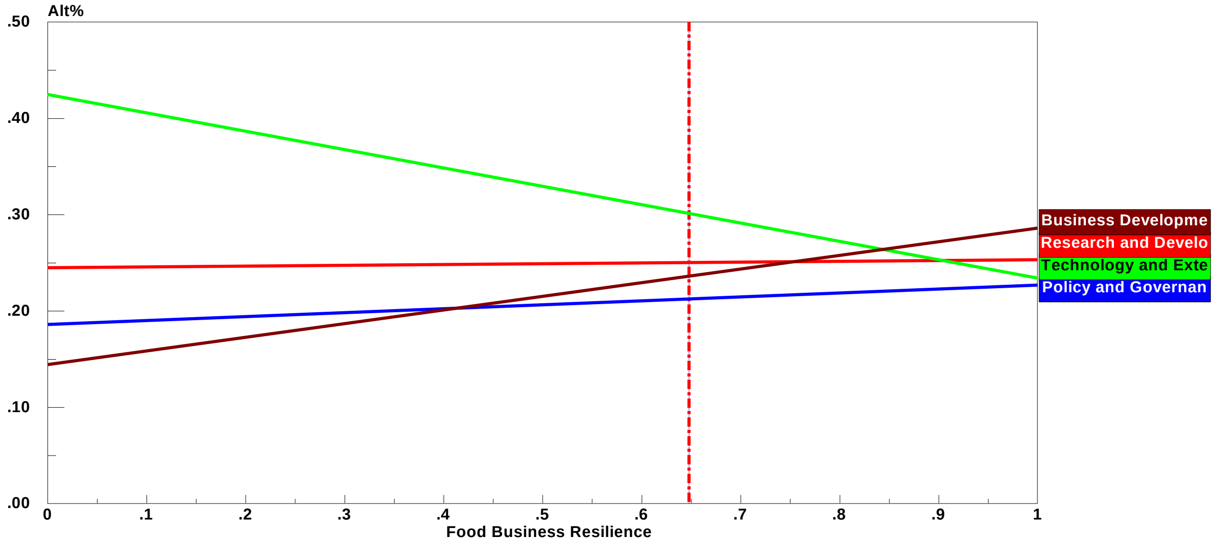


Figure 45 Gradient sensitivity for the Minimise Risk objectives

PRIORITIES FOR INTERVENTIONS

The structural equation modelling approach shows that there was a strong link between climate risks, adaptive capacities and adoption of intervention strategies. The model shows, among the three dimensions of adaptive capacities, the social dimension comprising of three social components: cultural, human and social capital have the strongest influence on the adoption of suitable strategies for climate change intervention. The economic dimension with underlying financial and physical capacities was also found to be very important for an effective implementation of the intervention strategies for enhanced food security. The risk scenario shows that the risk factors adversely impact on the cost of production, productivity and profit margin of the upstream producers.

A further analysis based on the Structural Equation modelling results through an Analytical Hierarchy Process (AHP) modelling approach was applied to understand the relative importance of climate change adaptation and mitigation strategies with respect to achievements of the goal of food security for improved planning and resource allocation in decision making.

In this analysis, Enhanced Adaptive Capacity and Risk Minimisation ability of the food industry stakeholders were considered to be the most important two objectives for Australian food security. The modelling results revealed that both these objectives were equally important for food security. However, when the stakeholders preferred to allocate more importance to Enhanced Adaptive Capacity of the food system more policy and governance oriented strategies such as skill development, land development policy were to be given priorities. On the other hand, if more importance was given to minimising food security risk from climate change then technology development and extension oriented strategies for sustained productivity and income growth of the agri-food industry should be given priority. Overall however, Research and Development strategies, for alternative energy use capacity, plant variety development, effective climate forecasting ranked the highest.

This intergrated modeling approach identified key variables from industry and the international literature to act as the evidence for understanding options and intervention consequences. Significant investment will be necessary in the future to guarantee food security at both local and global scales. The results of this modelling provide strong evidence for investment that has great potential to achieve the goal of food security in the face of climate change.

INTERVENING FOR FOOD SECURITY: CONCLUSIONS FOR CLIMATE PROOFING HORTICULTURAL AND DAIRY FOOD SYSTEMS

Food is central not only to health and wellbeing for individuals and communities, but critical to cultures and political stability. The complexity of global interactions around food and food related activities play a significant role in changing environments and the world's climate through water, carbon, nitrogen, biodiversity, soils and landcover. Food has a way of both generating capital and in turn undermining the natural capital upon which food security is based (Misselhorn 2012). Food security has come to include notions of availability, access, utilisation and stability of supply with nutritional security as integral to the definition. Effective food systems are noted to provide equity in market access and adequate R&D support for agricultural producers globally catering to both the poor and rich farmers operating both at small and large scales (Franklin 2012, Vermeulen *et al.* 2012). Food-systems are based on direct links between producers of food and the consumers of food and include production, processing, distribution, marketing, retailing, consumption and waste disposal (Donovan and McWhinnie 2011). Misselhorn et al (2012) indicate that effective food systems provide the basis for equity in human development.

Though more food is now produced per capita, access is still inadequate despite increasing production (Franklin 2012). Predicted population growth over the next 50 years will raise food demand globally, which is complicated by environmental changes such as climate, biodiversity, water availability, land use, atmospheric and other pollutants, and sea-level rise. The Universal Declaration of Human Rights adopted over sixty years ago has not yet guaranteed access to sufficient, safe and nutritious food. The measure of food policy effectiveness can no longer be based solely on 'value-for-money' but must include practices that integrate broader issues (Lang 2009). The vulnerability of food production derives from supply side effects (Garnaut, 2010). Much of Australian agriculture operates close to the upper margins of the temperature ranges at which agriculture is undertaken successfully, and close to the low margins of rainfall requirements. Viability of the Australian rural economy is intrinsically linked to food production, and food security and the future of food in a changed climate must address core socio-economic and environmental issues that include institutional frameworks, training, technology, biosecurity, nutrition and business models.

Adaptation to the impact of climate change on food production, processing and consumption is hampered by fragmented knowledge derived through disparate case studies and contesting interests (Hofmann *et al.* 2011). While an extensive body of knowledge is evident in a general review of research across a wide range of disciplines and interests, results have emerged from discrete and sometimes incommensurate knowledge frameworks. The complex interactions of environmental, economic and social factors define the form and means of sustainability (Head *et al.* 2011, Nelson *et al.* 2010). In the past the practice was primarily to evaluate food-systems from an economic or agricultural production perspective (Stimson *et al.* 2006) but increasingly the triple-bottom-line criteria of sustainability dictates evaluation of the success of a food system (Islam, Nath *et al.* 2011).

Food security raises a number of critical issues for food systems to address. The context and scale of food production is critical within governance and societal frames. Social expectations, human health and sustainability principles are critical to food systems practices particularly where biosecurity and environmental protection are contributing factors. The development of climate change and mitigation and adaptation approaches must address a range of social scales and social structures through both policy intervention and incentives. Decision-support models for integrating and testing potential approaches require the integrative tools of a trans-disciplinary practice to address the complex inter-relationships between economic viability, social resilience and ecological integrity.

FOOD SYSTEMS AND FOOD SECURITY IN GLOBAL CONTEXT

Intervening in climate change for agricultural production will have different implications for the global north and the global south depending both on strategies for mitigation and adaptation, and the context of place and business model. Four distinct contexts for food security must be considered within a food systems model all with implications for Australian agricultural production. Local food systems sustain local populations, and agricultural production communities and markets are distinct from these. Global industrial food systems may be linked but are most often distinct from developing economy food systems. Three key areas for the future development of food policy relate to the simplification of regulatory systems that minimise bureaucratic layers in order to effectively address climate change adaptation and mitigation strategies. The process of food policy development must by necessity allow a consistent and integrated approach in existing vertical and horizontal governance arrangements. This should ensure the integration of regional and local scales of food security beyond the import-export focus of commodity and industrial food systems (Slade 2012).

This research explored the impacts and potential interventions of climate change on food security in a process of six steps. The first step explored the literature on food security using definitions and parameters to develop a conceptual framework that spans global geo-political scale but refers to the production practices of food systems in local context. The value positions and moral underpinnings of people contributing to decisions in horticulture and dairy were identified to understand the social framing that defines responses to climate change. Surveys and Expert Panel workshops provided a way of bringing voices and sectors together to explore issues of climate change, and to identify strategic interventions for horticulture and dairy. Perceptions of climate change risk were identified and developed further in relation to potential mitigation and intervention strategies. Climate change mitigation and adaptation strategies potential application in horticultural and dairy food systems were linked to a range of climate risk scenarios. These intervention strategies were assessed along with the capacity they depend on through a series of modelling exercises to identify those with greatest potential, and the factors that will result in successful mitigation and adaptation.

INTRACTABLE AND COMPLEX ISSUES – DEVELOPMENT OF TOOLS TO EVALUATE MITIGATION AND ADAPTATION APPROACHES THAT ADDRESS SOCIAL, ECOLOGICAL AND ECONOMIC DIMENSIONS OF FOOD SECURITY

Addressing the complex and intractable issues of climate change and food security required the development of a set of key research tools to integrate knowledge frameworks and work across disciplinary boundaries. These research tools were developed with the explicit intent of demonstrating the potential of integrated disciplinary frameworks, but also to allow a testing of cumulative knowledge developed through discrete processes. These tools included a simplified identification of the social structures with pertinence to a food system (and thus food security) (identifying expert voices and social catchments). Other social science tools included the identification of value positions within dairy and horticultural food systems (discourse frameworks). These value positions define both limits to problem identification, in addition to limits to the application of solutions. These social science tools were dependent on the development of survey and focus group processes practiced with the rigour intrinsic to social science disciplinary practices.

Gathering data was the domain of each of the three key sustainability discipline areas: economics, ecology and social science. Data was gathered through extensive literature review of an international literature on food security and climate change; surveys; and focus group methods applied through Expert Panel Workshops. The first key integration outcome was the effective testing and application of a capacity model drawn from a framework of

capitals (Wardell-Johnson 2011) which in application represented the critical dimensions of triple-bottom-line sustainability.

IDENTIFYING CAPACITY TO INTERVENE IN THE IMPACT OF CLIMATE CHANGE ON FOOD SECURITY

Capacity has a significant bearing on the success of implementing intervention strategies. A framework of seven capitals included three social components (cultural, human and social capital), two economic (economic and physical capital) and two ecological components (ecological and environmental capital). These capitals account for capacity to implement climate change mitigation and adaptation strategies.

Capacity provided the key starting point to identify the implications of climate change risk for food security, in addition to identifying primary modelling steps in identifying constraints and opportunities, and, developing mitigation and adaptation interventions. Each of these models drew on empirical data identified and synthesized through the literature, survey and focus group processes. Integrating three key modelling processes used a stepwise process drawing on behavioural, statistical and business modelling through the theoretical models of Theory of Reasoned Action, Theory of Planned Behaviour and Diffusion Innovation Theory. Structural Equation, Value Chain, Supply Chain modelling approaches suitable for strengthening vertically linked food-systems, were used.

This integrated modelling allows insights into requirements for and implications of strategic interventions. These models were complemented by structural equation modelling (SEM) to identify process relationships between risk, capacity and interventions to climate change for food security. The SEM used four multidimensional latent factors used in the model: (1) Adaptive Capacity; (2) Risk; (3) Adoption of Intervention Strategies; and (4) Food Security. Each evaluating both influence and contribution to the final objective of food security. Partial Least Square (PLS) bootstrap results showed all paths (relationships) to be statistically significant supporting all the hypotheses in the study.

The results of SEM provided the basis for Analytical Hierarchy Process modelling which identified strategic interventions and tested for outcomes based on a range of possibilities in application. This integrated process identified key risks emanating from climate change for food security, in addition to identifying key relationships between capacity and mitigation and adaptation interventions. Choices for policy, planning and development for industry as well as for governance processes were tested and identified to provide an evidence-based strategic approach for climate proofing food security. The results effectively integrated a range of risk factors and climate change interventions pertinent to achieving economic viability, ecological integrity and social resilience, but more importantly tested the interactive processes between and across each of these dimensions.

The comparative contexts not only of agricultural food production sectors in dairy and horticulture, but also of governance and climatic regions provided insights with potential and effective application to other food systems.

IDENTIFYING POTENTIAL SOLUTIONS THROUGH THE RANGE OF POSITIONS

Key insights into the range of philosophical positions taken in relation to the impact of climate change on food security were evident in the experts representing each of the industry sectors in each state. Each of these socio-political positions provides an insight into different framings that might be useful in identifying solutions to the impact of climate change on food security. The framing rests on an identification of the relationships between ideals, ideology and practice in possible and potential solutions. The moral and value framing indicated that technology has a role to play and that the oil crisis has significant implications for food systems. Rising temperature will have a consequence for food production and

agriculture has some impact on ecological integrity. In general, experts did not feel that Australia holds a significant responsibility for providing for global food needs.

Climate change was identified through extreme weather events, seal level rises and declining rainfall. Key issue identified by the panels was the relationship between introduced plants and animals and climate change, biosecurity. Nearly 80% of responses indicated confidence that the dairy and horticultural sectors will have the capacity to adapt to climate change. Formal scientific sources and the internet were identified as key information resources on climate change indicating both formal expertise and capacity for scientific engagement in these panels of experts. In identifying potential risks presented by climate change for food security there were differences between dairy and horticultural sectors. Bush fires were perceived to be more of an issue for the horticultural sector and rainfall and lower market prices were risks identified by the dairy sector.

The panels almost equally represented each of the potential six paradigms on how food production landscapes are valued. Each of these six discourse frameworks allows for a distinct set of issues and solutions to be possible. Thus the empirical evidence gathered through the surveys and focus group workshops represented a comprehensive set of positions and possibilities for interventions for climate change. As well as a comprehensive representation of moral values framings identified through the discourse frameworks, a good cross section of representation of occupations and sectoral representation in the horticultural and dairy food systems provided empirical input through the surveys and focus group workshops. Occupations included academics, agronomists, CEOs, public servants, economic development officers (industry and government), extension officers (industry and government), facilitators, farmers, industry development officers, policy officers, town planners.

IDENTIFYING RISKS

In the SW WA EPs risks due to climate change for food security were identified through changes in food production requirements reducing production in marginal horticultural and dairy areas. An anticipated reduction in the volume of food produced was indicated as an impact on food quality and availability. The consequent flow on to rural communities was indicated to pose a significant threat to social cohesion. Requirements for water and energy resources to continue production as well as current constraints to innovation and application of technology were seen as a potential impact on both the dairy and horticultural sectors.

In the SEQ EP extreme events resulting from climate change were identified as a key risk to food security and food production. Vulnerability of horticulture in relation to pest incursion was noted as resulting in uncertainty and a potential for geo-shift to alternative production sites. The costs of capital investment were mentioned as a risk to adopting practices of mitigation and adaptation.

Key risk scenarios to food security were identified as biosecurity, business failure and climate variability. Risks to biodiversity and increased pests and diseases represented a measure of biosecurity risk. Declining product variety and health of the industry labour force (both financial and mental) were seen to be exacerbating lower market prices and reduced reproductive rates (dairy). These potential risks resulting in business failure indicated a potential for lower industry sustainability. Climate variability perceived to result from adverse impacts of season changes to growth and crop production in horticulture. The dairy sector indicated that climate variability would pose a risk to cattle through increased temperature and water shortages (in SW WA) and local flooding (in SEQ).

IDENTIFYING INTERVENTIONS

Interventions identified by the EPs were categorised according to the criteria of TBL sustainability framework. Key social interventions were knowledge utilisation and access,

supporting innovations and building community awareness. Key economic interventions were land development and management, value added food processing, farmers and market relationships and production system improvements. Key environmental interventions were carbon footprint reduction, water management, protection of biodiversity and the natural environment.

Mitigation interventions suggested by the EPs in the dairy sector were:

- improved decision support systems
- water efficiency
- improved transport and infrastructure
- alternative fuel and energy development
- appropriate and focused policy and adjustment of existing policies
- identifying social structures that allow climate change interventions
- a range of carbon related policies and incentives and ISO standards.

Mitigation interventions suggested by the EPs in the horticulture sector were:

- water efficiency
- climate forecasting and improved decision support
- alternative energy and fuel development
- policy development and adjustment
- transport infrastructure improvements
- identifying socio-cultural values associated with horticultural food systems
- controlled pesticides and organic approaches
- ISO standards
- a range of carbon mitigation approaches through offsets, sequestration and calculation.

Interventions in climate change through adaptation in the dairy sector that were recommended included:

- shading, passive cooling and heat-adapted stock development programs
- revegetation and pasture development programs
- supplementary power generation options
- and altered farm management strategies.

Interventions in climate change through adaptation in the horticulture sector were recommended to include:

- water management
- crop and plant variety development adjusted to changed climates
- site selection, shading and improved canopy management
- organic and biological approaches in addition to precision farming techniques
- management of soil carbon
- and supplementary on-site power generation.

Interventions were identified in socio-geographical scale of local, regional, national and global, and were designated as incremental, transitional or transformational. Key local

interventions operating at incremental scales related to short term land management approaches through water use efficiency and soil security. Transitional interventions operating in regional contexts were identified to be varietal development and development higher productivity through fertiliser development. Policy interventions at this level applied to water use efficiency and technology development and application. Transformational interventions at the national scale related to industry collaboration and the development of national levies with specific reference to water systems and planning and forecasting.

The intervention strategies identified as holding the most potential for impact and the highest likelihood for implementation were categorised as business models, education and awareness, infrastructure development, policy and governance, research and development, and technology and extension. A comprehensive list of intervention strategies within each of these categories is provided in the report (Table 3) which serves as advice for policy development both in the industry and governance sectors.

The capacity model representing seven different capitals (Wardell-Johnson 2011) represented the critical dimensions of triple-bottom-line sustainability. Survey results indicated that a combination of financial and physical capital scored the highest ranking for importance with human capital, environmental and natural capital as significant. In addition, social and cultural capital was considered critical by the experts to provide capacity to address mitigation and adaptation needs in relation to climate change. This capacity formed the core capability for modelling to test potential and implications for addressing core climate change risks for food security and associated adoption of intervention strategies to deal with risk.

IDENTIFYING RELATIONSHIPS BETWEEN CAPACITY, RISK AND INTERVENTION OUTCOMES

Adaptive capacity was identifies in each of the three TBL dimensions: the social, economic and ecological differentiated through seven forms of capital. Three risk scenarios were identified to form the basis for testing potential interventions against. These risk scenarios were bio-security, climate variability and business failure. Adopting intervention strategies were identified to be dependent on policy and governance, research and development, infrastructure, technology and extension, and business models. These categories formed the basis for modelling the relative influence and contribution of capacity and intervention for food security in the face of climate change. The three components of intervention, risks, adaptive capacity and adoption formed distinct structural equation modelling for testing hypotheses.

The results of the structural equation modelling provide key insights into the importance of adaptive capacity. Adaptive capacity has the strongest influence on the potential for intervention strategies to be adopted. Given the importance of adaptive capacity food security is less likely to be impacted by climate change if adoption of intervention strategies is successful. Climate change has the greatest potential to impact on business systems indicating a greater likelihood that farm business will fail as a consequence of climate change due to costs of production, low productivity and margin, without policy interventions to develop and support capacity. Within the dimension of adaptive capacity the social dimensions of capital were indicated to most positively influence the adoption of intervention strategies.

The most significant positive influence on food security was the adoption of intervention strategies. Communities that are vulnerable to climate induced change are vulnerable for a set of socio-economic capacities. The model shows, among the three dimensions of adaptive capacities that the social dimension comprising three social components - cultural, human and social capital - has the strongest influence on the adoption of interventions for climate change.

The SEM modelling provided evidence of the links between climate change risk scenarios, adaptive capacities and the adoption of suitable intervention strategies (mitigation and adaptation) for food security in Australia. The results demonstrate strong evidence of relationships between climate change risk and intervention strategies. There is also evidence of relationships between TBL adaptive capacities and intervention strategies with consequences for food security in Australia.

Key results provide evidence that communities that are vulnerable to climate change are vulnerable through their socio-economic capacities. These SEM results show that the social dimensions of cultural, human and social capital have the strongest influence on the adoption of intervention strategies. Results show that the economic dimensions of financial and physical capacities are also important for effective implementation of intervention strategies to enhance food security. Future research further investigating the impact of the ecological capital based on improved measures may reveal added importance for ecological capacity.

The results of the SEM are applicable equally across a supply chain of production, processing, distribution and consumption, providing a means for testing the interactions of casual relationships between adaptive capacity, risks and adaptation intention of the food system participants. This approach to identifying points of intervention provides an evidence based means of explaining the adaptive capacity of related sectors including policy makers and the research sectors.

IDENTIFYING PRIORITIES

The final modelling process (AHP) was used to test potential intervention scenarios. This is a particularly useful tool for decision-support in deciding on prioritisation in the investment in policy (both industry and governance) to maintain adaptive capacity in food systems. Further evaluation to prioritise development of strategies for effective management of climate change related implications for food security were conducted through an Analytical Hierarchy Process (AHP) modelling approach. This approach was based on four broad categories: policy and governance, research and development, technology and extension and business development. These categories and variables served as the dimensions to test relative importance of intervention strategies through Expert Choice Modelling.

Based on the SEM indicating that the three dimensions of adaptive capacities, the social dimension comprising of three social components - cultural, human and social capital -has the strongest influence on the adoption of suitable strategy for climate change intervention. In addition, accounting for the underlying capacity of the economic dimension to provide effective implementation of the intervention strategies for enhanced food security, the AHP was used to conduct a further analysis to understand the relative importance of climate change adaptation and mitigation strategies for better planning and resource allocation in decision making.

Two major objectives of achieving food security were identified through the results of the SEM to be enhanced adaptive capacity and the minimization of risk due to climate change. Enhanced adaptive capacity relates to the TBL social, economic and ecological dimensions. Risk minimization related to biosecurity, food business viability and minimizing the impacts of climate change. These objectives were identified with the potential to be achieved through intervention strategies implemented through policy and governance, research and development, technology and extension and business development. Enhanced adaptive capacity particularly through social capital was revealed as the most important objective. Minimising risk to achieving food business viability was revealed as significantly important to minimizing the impact of climate change. Key variables within the social capital enhanced adaptive capacity objective related to online social communication, formal education and maintenance of good health.

The key priorities to ensure enhanced adaptive capacity to sustain food security requires policy and governance strategies focused on skills development and land development (site selection and geo-shift options). If the priority is to minimise risks to food security then strategies related to climate change technology development and extension will sustain productivity and income growth.

A key result from this prioritization modelling identified enhanced adaptive capacity to rest on building resilience in social capital which facilitates all four alternative approaches to climate change management in relation to food security. In terms of minimizing risk from the impact of climate change on food security, technology and extension, as well as research and development were critical to achieving bio-security outcomes (pest and disease control and protection of biodiversity). Linked to this are business development strategies to build food business resilience which contributes to biosecurity and minimised risk through climate change.

Building resilient food systems and thus enhancing food security rests on developing enhanced adaptive capacity. Enhanced adaptive capacity was identified to rest on building and maintaining social capital. To effectively minimize risks from climate change to food security requires technology development and extension to sustain productivity and income growth. Investment in research and development should focus on alternative energy, plant variety development and climate forecasting for effective decision-support.

This evaluation of strategic intervention in relation to the impact of climate change on dairy and horticulture provides evidence as the basis for the development of strategic climate change interventions tailored to maximise impact on food security through dairy and horticultural food systems.

This report provides detailed insights into the relationships between risks incurred through changing climates for food security. In addition these risks are comprehensively assessed and evaluated in relation to strategic implementation of interventions. These interventions were evaluated for relative importance given a changing policy environment. This research combined social science, economics and ecological knowledge from two states, two contrasting food production systems and a range of interests that span from local food producers to global food business interests. This integration of disciplines and practices has allowed a unique insight into the issues facing global food security, but more importantly the rich opportunities for positive change that might result from treating food as a triple-bottom-line system with global accountability and local innovation.

Agriculture in responding to climate change must now optimise practices to address not only productivity, but also rural development, environmental and social justice (Pretty *et al.* 2010). Increasingly the interaction between economic, social and environmental costs drive decision-making in food production (Misselhorn *et al.* 2012). The research identified strategic interventions to promote food security and maintain resilience in local food systems, agricultural production communities and markets, global industrial systems, with relevance to developing world food systems. Climate change mitigation and adaptation interventions were defined to reflect a rich conceptualisation drawing from the Australian context, but also acknowledging the moral context of global association.

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Appendix 1 EXPERT PANEL BACKGROUND PAPER

"Creating a climate for food security:

the business, people & landscapes in food production"

EXPERT PANEL BACKGROUND PAPER

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RESEARCH BACKGROUND

Balancing human and environmental needs is urgent where food security and sustainability are under pressure from population increases and changing climates. Requirements of food security, social justice and environmental justice exacerbate the impact of agriculture on the supporting ecological environment. A UK Government report on the future of the global food-system (Government Office for Science 2011) identified maintenance of biodiversity and ecosystem services in agricultural systems as a key challenge. A report to the Australian Prime Minister (PMSEIC 2010) indicated predicted changes in climate and population will necessitate food import to meet Australian domestic requirements.

Predicted population growth over the next 50 years will raise food demand globally higher, which is complicated by environmental changes such as climate, biodiversity, water availability, land use atmospheric and other pollutants and sea-level rise. The Universal Declaration of Human Rights adopted over sixty years ago has not yet guaranteed access to sufficient, safe and nutritious food. More food is now produced per capita but access to food is still inadequate despite increasing production (Misselhorn *et al.* 2012).

Adaptation to the impact of climate change on food production, processing and consumption is hampered by fragmented knowledge derived through disparate case studies and contesting interests (Hofmann *et al.* 2011). While an extensive body of knowledge is evident in a general review of research across a wide range of disciplines and interests, results have emerged from discrete and sometimes incommensurate knowledge frameworks.

This food-systems and food security research draws on climate change literature to provide systematic identification of risks and approaches to adaptation in food production, processing and consumption. The focus will be on literature that relates to building resilience in food-systems and accounting for climate change mitigation and adaptation in regional economies. Sources of literature included grey literature; research literature; and agency reports.

DEFINING A FOOD SYSTEM

A food-system includes different socio-geographical scales such as local, community, regional, national and global (Islam, Nath *et al.* 2011). Regardless of scale the success of a food-system may be evaluated using distinct overarching sets of criteria. In the past the practice was primarily to evaluate food-systems from an economic or agricultural production perspective (Stimson *et al.*, 2006) but increasingly the triple-bottom-line criteria of sustainable development dictates evaluation of the success of a food system (Islam, Nath *et al.* 2011).

The elements contributing to identifying a food-system are diverse and include all the activities required in feeding a population ranging from primary agricultural production to food consumption (Koc and Dahlberg 2004;Kloppenburg, Lezberg *et al.* 2000). Food-systems are based on direct links between producers of food and the consumers of food and include production, processing, distribution, marketing, retailing, consumption and waste disposal (Heller 2003; (Donovan and McWhinnie 2011).

Ingram (2009 p.419) (noted that the food system concept was not new with several frameworks for analysing food systems in use but with the few existing models focused on one disciplinary perspective or one component of the system. These models included food chains, food cycles, food webs and food contexts, in addition to nutrition. Other approaches outlined by Ingram (2009) used a cultural economy model for identifying power in commodity systems, and other approaches were based on a political economy perspective (ie (Lawrence, Richards *et al.* 2012). Some approaches to identifying food-systems were defined by a socio-ecological framework (such as (Fraser, Mabee *et al.* 2003) to identify vulnerability within a physical landscape.

Models of food systems, if they are to be useful in understanding the impact of climate change, need to be useful in identifying the processes that may offer points of policy intervention (governance), mitigation, or adaptation strategies in an inherently cross-level and cross-scale setting (Misselhorn, Aggarwal *et al.* 2012).

Misselhorn *et al.* (2012 p. 12)) note that equitable food systems ensure adequate amounts of nutritious food that is “affordable and accessible to all at all times”. In addition, effective food systems are noted to provide equity in market access and adequate R&D support for agricultural producers globally catering to both the poor and rich farmers operating both at large and small scales (Misselhorn, Aggarwal *et al.* 2012; Vermeulen, Zougmoré *et al.* 2012). Misselhorn et al (2012) indicate that effective food systems provide the basis for equity in human development.

Differentiating between food-systems provides the means firstly of identifying relevance of scale, and secondly application of intervention approaches (either mitigation or adaptation). Food-systems in a production and consumption sense have been defined by Islam, Nath *et al.* (2011) as: conventional food systems, global food systems, community food systems, organic food systems, cooperative food systems, and slow food systems.

The social, geographical location and economic needs contribute to differences between food systems. Islam, Nath *et al.* (2011) indicate a range of factors that motivate producers which in turn impact on social expectations, environmental conditions and the economy.

Each of these food-systems have different links and processes in operation and are evaluated for purposes of adaptation and mitigation differently. Misselhorn *et al.* (2012) indicated that the value of using a food-systems approach to address issues of food security includes:

- identifying the range of actors and interests that should be involved in dialogue for improving food security
- providing a framework capable of addressing multiple socio-economic vulnerabilities
- identifying points of intervention to limit potential food insecurity.

Strong indications from global food analysis suggests that innovation and adaptation in the capacity to produce and distribute food is essential to address forecast changes to population demography and patterns in economic development. The debates about priorities in agro-food production systems reflect a range of sentiments and meanings that are addressed more directly through a broader focus on food security (Fish, Lobley & Winter 2012).

FOOD SECURITY

Food sustains health and wellbeing for individuals and communities, defining cultures and framing global interactions. Thus food defined here as operating within a food-system binds individuals and extends as a vital link across socio-geographic scale. This very broad framing ensures that food security is also considered in a wide range of contexts with equally broad implications.

A standard definition from the 1996 World Food Conference (in Timmer 2010) defines food security as being met "when all people at all times have physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life" (p2). This definition rests on food security meeting three requirements (1) sufficient quantity and quality of food that might be supplied through either domestic production or through import; (2) individual and household access to foods providing a nutritious diet; and (3) sufficient water, sanitation and health care to ensure available food may be utilised to meet these requirements. In other definitions, food security is defined by the UK Government within a wider geopolitical frame as "ensuring the availability of, and access to, affordable, safe and nutritious food, sufficient for an active lifestyle, for all, at all times" (Defra 2009a: 6 in Fish, Lobley & Winter 2012).

Food security has come to include notions of availability, access, utilisation and stability of supply with nutritional security as integral to the definition. Food security is affected by water quality, storage, disease as well as socio-cultural norms of food preparation and consumption. These food related activities play a significant role in changing environments and the world's climate through water, carbon, nitrogen, biodiversity, soils and landcover in turn undermining the food systems and natural capital upon which food security is based (Misselhorn 2012). Food security is thus not only dependent on the production of enough calories to meet global population requirements but also impacts on the capacity to produce.

In the narrowest framing food security is enough food available at global, national, community and household levels to meet dietary energy requirements and acting as a proxy for national self-sufficiency. In a broader framing food security recognises the socio-cultural elements of preference that are socially and culturally acceptable to religious and ethnical requirements. In addition, food security may be differentiated between transitory supply that is periodically insecure and permanent food insecurity where there is a long-term lack of access to sufficient food (Pinstrup-Andersen 2009).

Debates defining the discussion on food security relate the contested relationship between scale of production and capacity to meet TBL sustainability criteria. This debate extends beyond the pragmatic and technological potentials for production expansion to embrace notions of social and environmental justice, both within the context of production and extended to a global view of equity (Fish, Lobley & Winter 2012). Fish, Lobley & Winter (2012) provided strong evidence for the engagement of UK food producers through an analysis of farmer understandings of food security which show that while perceptions are conditioned by the context of a farming situation, notions of safety and traceability are considered as important as guaranteed supply to national and global markets. In general results indicate a strong need to reconcile concerns for sustainability with production to address the "failings of a highly industrialised and globalised agro-food system" (p. 10). Fish, Lobley & Winter(2012) indicate that domestic

resilience in food supply, and thus food security, was thus built not only on "patterns of economically and socially viable local farming", but also on the potential to realise "greater productive potential in an environmentally sustainable, way". p.?

In extending the debate around food security from food production in an agricultural context, to the broader global context of food needs, the emphasis shifts from increasing food production to increasing access to food thus integrating processes of food availability and food utilisation (Ingram 2011). This shift in focus from production to access and equity highlights the holistic conceptualisation of food security which considers multiple aspects of food security and food systems to include a wider range of research challenges that engage not only with the biophysical sciences, but by necessity also with the humanities, social and economic sciences (Ingram 2011).

The analysis of food security includes a wide range of socioeconomic 'drivers' that interact in a combination of local and non-local origins. Ingram (2011) indicates that resilience of local food systems is prone to external as well as internal stresses. Global-level influences such as climate change, trade agreements, and world food and energy pricing affect local and regional food systems in addition to local factors such as property rights, local market policy and the state of natural resources. Contemporary food systems are inherently cross-level and cross-scale (Ericksen, Ingram & Liverman 2009).

Ingram (2011) identifies key research requirements in agronomic research as: "(i) to understand better how climate change will affect cropping systems…; (ii) to assess technical and policy options for reducing the deleterious impacts of climate change on cropping systems while minimizing further environmental degradation; and (iii) to understand how best to address the information needs of policy-makers and report and communicate agronomic research results in a manner that will assist the development of food systems adapted to climate change (Ingram *et al.* 2008, p 418 in Ingram 2011 ?). In addition, other activities related to food processing, packaging, distribution, retailing and consumption are identified as of key importance in considering food security.

This broader focus, according to Ingram (2009), "helps to identify the actors involved, the roles they play, and the many and complex interactions amongst them". This focus brings challenges in addressing environmental change requiring research into the translation of seasonally based plot-level approaches to larger spatial and temporal levels that better identify solutions to food security issues.

Ingram (2009) identifies three key considerations necessary to meet food security needs:

- food availability encompassing production, distribution and exchange
- access to food which includes affordability, allocation and preference
- food utilisation which addresses nutrition, social value and food safety.

CLIMATE CHANGE SCENARIOS FOR SOUTH EASTERN QUEENSLAND

The Office of Climate Change has identified that the last decade (2000–2009) was the hottest on record in Queensland with temperatures 0.58 °C higher than the 1961–1990 average (Whitfield, Oude-Egberink *et al.* 2010). This report went on to suggest that Queensland regions can expect increased temperatures of between 1.0 °C and 2.2 °C by 2050; a three to five per cent decrease in rainfall in the south-east Queensland region; more frequent hot days and warm nights; less frequent cold days and cold nights; and increased flooding, erosion and damage in coastal areas due to increased numbers of severe weather events. It is expected that cyclones will occur further south potentially impacting on south east Queensland more often.

Whitfield, Oude-Egberink *et al.* (2010) expect that climate change will increase the difficulty in supplying water to meet agricultural demand due to decreasing rainfall and runoff, and increasing temperature and evaporation. Laves (2008) concurs and suggests that industries that depend on irrigation to remain viable will be vulnerable to decreased water availability in the northern part of the region. He further concludes that support will be needed to assist producers to reduce vulnerability and to adopt sustainable agriculture practices based on applied climate change knowledge. The climate change adaptation process he suggests will be vital to the success of the agricultural industry.

Coupled with these impacts increases in mean annual temperature will lead to shorter growing seasons for some crops as well as increasing the decomposition of soil organic matter, the depletion in soil fertility (native N stocks), decline in soil structure and reduced soil cover (Grace 2008). Grace (2008) argues that on farm management of soil carbon and nitrogen use efficiency will play an overriding role in adapting to climate change.

Horticultural production in SEQ is dominated by commercial scale vegetable systems with Lockyer Valley primarily growing temperate crops during the mild SEQ winter. A range of sub-tropical fruits and nuts (macadamias, pineapples, strawberries avocadoes and mangoes) are produced on smaller scale farms (Deuter 2008). Deuter (2008) considers that temperature changes are likely to be the key aspect of climate change forcing adaptation. Together with variable rainfall patterns this is likely to lead to increased pest and disease pressures and changes to fruit development (ripening and post-harvest) which has the potential to influence market access opportunities (Deuter 2008). While initially deleterious to traditional food systems in SEQ the ability to produce more 'tropical' produce (e.g mangoes) may assist with any changes to current production systems.

Livestock respond to increasing temperature by drinking more and eating less. Heat stressed cattle will as a result decrease body weight and increase body temperature. Hotter summer temperatures are already impacting on dairy cows with the number of days where the Temperature Humidity Index (THI) is greater than 72 each year increasing from 2000-2004 relative to the 1961-1990 mean (185 days) in SE QLD/NNSW (Miller 2008). With predicted increased extremes of heat it is likely that without adaptive practice THI levels exceeding 72 will have a more significant impact on milk production (lower milk volume and reduced components), reproduction (lower conception rate) and cow health (increase in ticks, buffalo fly, eye cancers) (Miller 2008).

IN CONSIDERATION

A range of critical issues relates to discussions about food systems and related food security:

- human health
- biosecurity for production and for environmental protection
- industrial, commodity and local scale agricultural production and enterprise
- adaptation policy and related practice
- mitigation of climate change impacts in relation to food systems
- social capital and adaptation (micro, meso and macro scales addressing individual, community, society and governance)
- social expectations and food systems
- sustainability principles and practice across food systems
- climate change impacts on horticultural and dairy production systems
- policy interventions and incentives (such as carbon accounting systems)
- social structures and social catchments in development of mitigation and adaptation approaches
- integrative tools for trans-disciplinary practice
- models to integrate and test potential approaches for intervention and decision-support

Viability of the Australian rural economy is intrinsically linked to food production and food security requiring systematic evaluation of climate change adaptation strategies for agricultural productivity in:

Institutional frameworks that support food-systems;

Training and access to technology in vertically linked food-systems;

Biosecurity and nutritional access;

Socio-cultural values in changed food-systems.

This food-systems research uses climate change literature to identify risks and adaptation. This research has two contrasting agricultural production areas as context (SW-WA and SE-Qld). These areas represent two of Australia's most rapidly changing landscapes of socio-cultural values, population growth, and changing food production capacity. Contrasting governance offers insights for a range of mitigation and adaptation policies and practices. Limits to adaptation are understood through projections in climate change and global economic context of each food-system with potential application in regional mitigation and adaptation strategies for other places. Research focus is the south west Western Australia (SW-WA) (contributes ≈$6billion to WA's economy) and south east of Queensland (SE-Qld) (contributes over $6billion to Qld's economy).

Research into food systems and the mitigation and impacts of climate change requires trans-disciplinary approaches combining social science, economics and land-management. Specialist input representing contexts from production to international points of export that include governance and research are necessary to understand points of potential mitigation and adaptation interventions to manage the impacts of climate change.

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Appendix 2 NCCARF FOOD SECURITY AND CLIMATE CHANGE ADAPTATION EXPERT PANEL WORKSHOP

EXPERT PANEL WORKSHOP – Running Sheet

Lunch — **Time**

1. **Welcome and Introduction** (Angela) — 1:00
   a. Project Team Introductions — 1:20
   b. Introduce themselves – name organisation, position and area/s of interest/ expertise in food security and climate adaptation
   c. Introduction to the Research (Angela)
2. **Round table** (Angela – facilitates , Brian Scribe)
   Key Question:
   How do you think climate change will impact on food security?
3. **Small group workshopping** on impacts in nominated areas of interest (Angela)
   Key Question
   What are the key issues and likely impacts on SQ WA Food Systems? — 1:45
   Nominate whether each issues is a constraint or opportunity
4. **Report back** (Top 3 issues/ impacts) and individual reflection (Angela)
5. **Small Group Workshop** (Brian)
   Task 1. - Identify points of mitigation, adaptation and intervention strategies in areas of interest and assign relative position on graph provided. — 2:00
   Key Questions
   What is the relative magnitude of impact of each strategy?
   What is the likelihood that the desired consequence can be achieved from the strategy?
   Task 2 -Starting with the highest priority strategies form the process above classify each strategy incremental, transitional or transformational and identify at what scale (local, regional, national, glol on the table provided. — 2:30

Afternoon Tea- Get afternoon Tea when served and take back to table — 2:50

6. **Report back & individual reflection** (Brian)
7. **Prioritisation of World Class Food System** (Angela)
   Brief overview of model
   Task: Review the draft elements of the world class food system conceptual model and identify omissions or enhancements you think could be made using post it notes provided.
   In the buff pink section identify what you consider to be the most important (highest ranked) are (using a maximum of 3 gold and 3 red stars) :
   a. Adaptation in a social context - gold star
   b. Mitigation in a social context - red star
   c. Adaptation in an economic context - gold star
   d. Mitigation in an economic context - red star
   e. Adaptation in an environmental Context - gold star
   f. Mitigation in an environmental Context - red star — 3:30
8. **Round table - Evaluation** (Brian)
   Key Questions
   What was useful about the process?
   Would you suggest we change something if we are to do it again?
   What have you learnt?
9. **Individual Reflection**
   If only one action was to be taken from today what should it be?
10. 4:40 **Reporting for workshop & Close** (Angela)
    - Synthesis and analysis of qualitative and quantitative results of workshop & survey
    - Report for participants (each Expert)
    - Reporting for NCCARF requirements
    - Papers and conferences.

Glossary of Terms

Adaptation – adaptation strategies and actions are those designed to **adjust to and limit the potential impacts relating to hazard and risks arising from extreme weather events, climatic variability, climate change and sea level rise.**

Adaptation is generally considered an evolving, long-term dynamic process in which the building of the adaptive capacity of stakeholders is crucial.

Food Security - The 1996 World Food Conference suggested that food security was achieved "when all people at all times have physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life". Ingram(2009) identifies three key considerations to meet food security needs:

- Food availability encompassing production, distribution and exchange
- Access to food which includes affordability , allocation and preference
- Food utilization which addresses nutrition, social value and food safety.

Fish et al (2012) includes concerns regarding sustainability and suggests security is also reliant on domestic resilience in food supply which is built on "patterns of economically and socially viable local farming …. in an environmentally sustainable way".

Incremental Strategies – Incremental strategies are those where it is logical to take a step-wise approach. In this approach it is considered that the issue can be addressed by starting a process and building on first steps as knowledge, commitment and solutions develop over time.

Mitigation - Mitigation strategies aim to reduce the size of changes to climate and the associated risks by **reducing the amount of greenhouse gases emitted by anthropogenic (human) processes.**

Transitional Strategies – In a climate change context transitional strategies are those which you undertake realising that they will only be effective for a limited period of time or within a specific set of climate change variables. Transitional strategies are those which aim to promote action now as a bridge to new (e.g. transformational) strategies in the future.

Transformation Strategies – Transformation strategies break from the 'status quo' in response to significantly different operating environment. Transformation strategies are generally required where the change to the system is so large that existing process (e.g food production systems) can't cope with the new conditions.

APPENDIX 3 FOOD SECURITY AND CLIMATE CHANGE SURVEY

"Creating a climate for food security: the business, people & landscapes in food production"

is research being conducted in Western Australia and SE Queensland by

Angela Wardell-Johnson, Nasir Uddin, Nazrul Islam, Tanmoy Nath and Brian Stockwell

University of the Sunshine Coast, DAFWA and DAFFQld.

Balancing human and environmental needs is urgent where food security and sustainability are under pressure from population increases and changing climates. Requirements of food security, social justice and environmental justice exacerbate the impact of agriculture on the supporting ecological environment.

Viability of the Australian rural economy is intrinsically linked to food production and food security requiring systematic evaluation of climate change adaptation strategies for a continued growth in agricultural productivity by engaging concerned stakeholders in decision making.

Food systems in SW of WA and SE Qld form the context for this research into the impact of climate change on food production and food security. Key areas of food systems include institutional frameworks, technology, bio-security and nutrition formed both from socio-cultural and economic values.

In this research integrated social and economic modeling will engage decision-makers in the process of developing methods for adaptive practice. This iterative action-research process will provide immediate generation and transfer of expert knowledge through Expert Panels to account for climate change mitigation and adaptation. The results will identify adaptive practices necessary to maintain food security, social justice and environmental justice through a triple-bottom-line evaluation process.

NCCARF undertakes a program of Synthesis and Integrative Research to provide decision-makers with information they need to manage the risks of climate change. Outputs from this area of activity have direct relevance for the requirements of policymakers, and in this project will be delivered in an interactive format.

This research is funded through a nationally competitive National Climate Change Adaptation Research Facility (NCCARF) grant in the Integrative and Synthesis research Program 3a: Ensuring secure food supplies for Australia under climate change: NCCARF Project S3A FS2.

The **Expert Panel Workshops** will engage a range of key individuals and interests to discuss the future of food production, processing and consumption in the SW of WA and in SEQ Qld.

This workshop is one of eight expert panel workshops that will identify influences and dynamics that have implications for the future of the food sectors in SW of WA and SEQ Qld.

Each workshop will contribute to research prioritisation, decision-making and policy development aimed at meeting Australia's future agenda for production, processing and consumption of fresh food. At the same time the interests and expectations of the population dependent on food from these landscapes is accounted for.

The results will provide the basis of a framework that guides climate change adaptation and mitigation action to integrate activities of government, industry and research and consider community values and expectations.

This framework aims to support viability in agriculture and to promote ecological, economic and social resilience in landscapes and communities.

All information provided through this research will remain **confidential** to the research team. Information will be coded to form aggregated data with only general information on sectors. This provides participants with the opportunity to be clear in their responses without fear of exposure. **Participant details** will be provided separately for receiving a **summary** of the research results.

Reporting to the wider community will be as a joint effort between members of the NCCARF Food Security and Climate Change research team. In addition, academic papers will provide the results from this work to the wider academic community.

This study has been cleared by human **ethics committees** of the University of the Sunshine Coast in accordance with the Australian National Health and Medical Research Council's guidelines. Participation in this study can be discussed with project staff contactable on the phone numbers provided here.

Further discussion with an officer of the University not involved in the study, is through contacting the Ethics Officer at University of the Sunshine Coast on phone 07 5459 4574 or email humanethics@usc.edu.au or in writing by mail to University of the Sunshine Coast, Locked Bag 4, MAROOCHYDORE DC QLD 4558.

Please return the survey via email before the workshop use highlighting to indicate your choices, or hardcopy at the workshop.

Participation in this survey will require up to 20 minutes of your time.

Please note:

- Taking part is voluntary and you can withdraw at any time without any consequences.
- Your withdrawal will not affect you in any way. Should you wish us to destroy the records we will do so.
- This interview and questionnaire are confidential and your privacy is respected at all times.
- Any information that could identify you will be removed.
- The researcher has signed a confidentiality form and cannot share information about you with any person outside the research team.
- All information will be stored confidentially in a locked cabinet at University of the Sunshine Coast for 7 years. After this time the information will be destroyed.

Program contacts are:

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"Creating a climate for food security: the business, people & landscapes in food production" - a survey.

1. ***Australia is responsible for meeting global food needs under circumstances of decreased food supply and increased poverty.***

Please indicate your level of agreement with the statement: 0 = don't agree and 4 = agree strongly

0 = Don't agree	**1**	**2**	**3**	**4 = agree strongly**

a. What key factors relate to increasing food production in SW/ SEQ agricultural landscapes to meet local and global needs? ***Indicate by circling either constraint or opportunity.***

ONE	Constraint	Opportunity
TWO	Constraint	Opportunity

2. ***Agricultural practice impacts negatively on ecological integrity and environmental quality.***

Please indicate your level of agreement with the statement: 0 = don't agree and 4 = agree strongly

0 = Don't agree	**1**	**2**	**3**	**4 = agree strongly**

a. What key factors relate to minimising impact of agriculture on the natural/ ecological environment? ***Indicate by circling either constraint or opportunity.***

ONE	Constraint	Opportunity
TWO	Constraint	Opportunity

3. ***The global oil crisis has implications for food production and transport.***

Please indicate your level of agreement with the statement: 0 = don't agree and 4 = agree strongly

0 = Don't agree	**1**	**2**	**3**	**4 = agree strongly**

a. What key factors relate to the production, processing and transport of food in SW/ SEQ?

ONE	Constraint	Opportunity
TWO	Constraint	Opportunity

4. ***Human-induced changes in climate will result in temperature increase & rainfall decrease requiring political and practice adaptation strategies for food systems.***

Please indicate your level of agreement with the statement: 0 = don't agree and 4 = agree strongly

0 = Don't agree	**1**	**2**	**3**	**4 = agree strongly**

What key political or practice factors relate to the capacity for SW/SEQ food systems to adapt?

ONE	Constraint	Opportunity
TWO	Constraint	Opportunity

5. ***The development and adoption of new technologies will overcome climate and peak oil constraints on food production, processing and supply.***

Please indicate your level of agreement with the statement: 0 = don't agree and 4 = agree strongly

0 = Don't agree	**1**	**2**	**3**	**4 = agree strongly**

a. What key factors relate to the development and use of new technologies ***(ranging from moral and knowledge-related to funding)?***

ONE	Constraint	Opportunity
TWO	Constraint	Opportunity

Personal socio-economic, environmental values and characteristics related to regional capacity to adapt to climate change.

Please indicate level of IMPORTANCE: 0 = not important and 5 = very important

Adaptive Capacity (Social dimension)

6. Social Capital

Membership of associations/ organisations with interests in climate change risks, adaptation and mitigation	0	1	2	3	4	5
Close social bonds with relatives and community that encourage cooperative actions for adaptation	0	1	2	3	4	5
Social links/ networks that provide ideas, information and resources to address climate change impact	0	1	2	3	4	5
Online/Social Web access (e.g. Internet, facebook and twitter) providing links to ideas, information and resources to address climate change issues	0	1	2	3	4	5
Other (please name)	0	1	2	3	4	5

7. Human Capital

Skills to adapt business to climate change	0	1	2	3	4	5
Training/knowledge to adapt business to climate change	0	1	2	3	4	5
Personal ability to adapt business to climate change	0	1	2	3	4	5
Good health (including mental health) to address the risks of climate change and required adaptation	0	1	2	3	4	5
Formal education to understand the issues and requirements for climate change adaptation	0	1	2	3	4	5
Other (please name)	0	1	2	3	4	5

8. Cultural Capital

Local community cultural cohesion	0	1	2	3	4	5
Family support to adapt to new business environment	0	1	2	3	4	5
Political culture to support adaptation needs	0	1	2	3	4	5
Other (please name)	0	1	2	3	4	5

Adaptive Capacity (Economic dimension)

9. Physical/Technological and Financial Capital

Infrastructure to adopt techniques of climate change adaptation/mitigation intervention	0	1	2	3	4	5
Equipment to adopt some of the techniques of climate change adaptation/mitigation intervention	0	1	2	3	4	5
Technologies to adopt techniques of climate change adaptation/mitigation intervention	0	1	2	3	4	5
Adequate income to adopt techniques of climate change adaptation/mitigation intervention	0	1	2	3	4	5
Other financial resources e.g. credit and savings to adopt techniques of climate change adaptation/mitigation intervention	0	1	2	3	4	5
Publically funded infrastructure (telecommunications, roads, power etc)	0	1	2	3	4	5
Other: (please name)	0	1	2	3	4	5

Adaptive Capacity (Ecological dimension)

10. Ecological/Natural Capital

Natural water sources (springs, streams, lakes, rainfall)	0	1	2	3	4	**5**
Good quality native vegetation & biodiversity	0	1	2	3	4	**5**
Good climatic system	0	1	2	3	4	**5**
Soil biodiversity	0	1	2	3	4	**5**
Other (please name).	**0**	**1**	**2**	**3**	**4**	**5**

11. Environmental Capital

Good soil resources	0	1	2	3	4	**5**
Healthy natural pest resistance	0	1	2	3	4	**5**
Natural shelter for stock and production landscapes	0	1	2	3	4	**5**
Natural salinity mitigation and other environmental services	0	1	2	3	4	**5**
Other (please name).	**0**	**1**	**2**	**3**	**4**	**5**

12. What climate change adaptation or mitigation in the horticulture and dairy sector will positively impact on the overall food system?

Please rate your agreement 0 = no agreement, 1 = some agreement, 5 = strong agreement

Enhanced environmental sustainability	0	1	2	3	4	5	Alternative food habits	0	1	2	3	4	**5**
Low impact Farming	0	1	2	3	4	5	Food aid and ethical consumption	0	1	2	3	4	**5**
Reducing carbon footprint	0	1	2	3	4	5	Enhanced food safety quality	0	1	2	3	4	**5**
Increasing community Incomes	0	1	2	3	4	5	Enhanced food quality	0	1	2	3	4	**5**
Access to Markets	0	1	2	3	4	5	Health and Nutritional value	0	1	2	3	4	**5**
Value added food processing	0	1	2	3	4	5	Inspection & enforcement of adaptation/mitigation policies	0	1	2	3	4	**5**
Purchasing power	0	1	2	3	4	5	Energy intake	0	1	2	3	4	**5**
Farmers and market relationships	0	1	2	3	4	5	Building social cohesion through community support	0	1	2	3	4	**5**
Land development and management	0	1	2	3	4	5	Enhanced food affordability	0	1	2	3	4	**5**
Labour welfare	0	1	2	3	4	5	Food preference options	0	1	2	3	4	**5**
Enhanced food security	0	1	2	3	4	5	Building local production links/options into food system	0	1	2	3	4	**5**
Enhanced food production	0	1	2	3	4	5	Innovation programs	0	1	2	3	4	**5**
Food distribution/Resource allocation	**0**	**1**	**2**	**3**	**4**	**5**	**Other: (please name)**	**0**	**1**	**2**	**3**	**4**	**5**

13. In terms of Social, Economic and Environmental performance , how would you rank the SW-WA /SE-Qld horticulture industry as a 'world class' agri-food system? *[including production, processing, distribution, retailing and consumption]*

Please Rate your agreement: 0 = no agreement, 1 = some agreement, 5 = strong agreement

Social	0	1	2	3	4	**5**
Economic	0	1	2	3	4	**5**
Environmental	**0**	**1**	**2**	**3**	**4**	**5**

14. In terms of Social, Economic and Environmental performance , how would you rank the SW-WA /SE-Qld dairy industry as a 'world class' agri-food system? *[including production, processing, distribution, retailing and consumption]*

Please Rate your agreement: 0 = no agreement, 1 = some agreement, 5 = strong agreement

Social	0	1	2	3	4	**5**
Economic	0	1	2	3	4	**5**
Environmental	**0**	**1**	**2**	**3**	**4**	**5**

15. How do you think climate change can be **recognised**?

Temperature increase	**Rainfall decline**	**Sea-level rises**	**Extreme weather events**	**Melting ice-caps**	**Other**

16. Do you believe that horticulture & dairy can adapt to the likely effects of climate change? YES NO DON'T KNOW

Please explain:

17. How should dairy/ horticulture adapt to climate change?

18. Who do you think is responsible for solving problems to do with climate change?

Individuals	☐	Government agencies	☐
The community	☐	Federal government agencies– which ones?	☐
Society	☐	State government agencies – which ones?	☐
Local environmental officers	☐	Local Government– which ones?	☐
Non-Government organisations– which ones?	☐	University/ tertiary/ research sector	☐
The business sector	☐	**Other:** (please name)	☐
Industry/ commercial sector bodies– which ones?	☐		

19. What are the most urgent environmental issues faced in production landscapes?

Rate each of the following categories where 3 = very urgent and 1 = quite urgent

Declining air quality	☐	Loss of native bushland	☐	Loss of soil quality	☐
Declining water quality	☐	Salinity	☐	Soil erosion	☐
Loss of plants and animals	☐	Protection of endangered species	☐	Introduced plants and animals	☐
Climate change	☐	High herbicide/ pesticide loads	☐	Other: (please name)	☐

20. Rate your agreement with these ideal characteristics associated with country landscapes:

0 = no agreement, 1 = some agreement, 2 = agreement, 3 = strong agreement.

Country Landscapes should be…

… a business asset for the production of agricultural resources	0	1	2	3
… an enterprise that provides resources to sustain the nation	0	1	2	3
… a landscape of many uses and communities	0	1	2	3
… a landscape of small farmers, rural communities and businesses	0	1	2	3
… a landscape of environmental stewardship	0	1	2	3
… a landscape of critical ecological systems	0	1	2	3

21. Rate your agreement with these statements indicating the way in which people manage and use country landscapes:

0 = no agreement, 1 = some agreement, 2 = agreement, 3 = strong agreement.

Country landscapes are used for…

… people serious about doing good business	0	1	2	3
… people prepared to use science as a basis for sound agriculture	0	1	2	3
… people who live in the countryside for its beneficial values	0	1	2	3
… people involved in looking after country heritage and landscapes	0	1	2	3
… people working within the limits of natural and ecological values	0	1	2	3
… people looking after the needs of ecological systems that sustain the planet	0	1	2	3

22. Rate your agreement for how people think of themselves in country landscapes:

0 = no agreement, 1 = some agreement, 2 = agreement, 3 = strong agreement.

People who live in country landscapes think of themselves as...

… people who work in the global business of agricultural production	0	1	2	3
… people who use best practice in agriculture	0	1	2	3
… diverse communities who live in harmony with nature	0	1	2	3
… farming communities with a range of activities in support of country values	0	1	2	3
… people who look for the best way of living in the landscape without impacting on nature	0	1	2	3
… people vested with the responsibility of looking after vital planetary systems	0	1	2	3

HORTICULTURE SECTOR QUESTIONS

23. ***What are the major risks that climate change brings to the horticulture industry.*** ***Please rate agreement: 0 = no agreement, 1 = some agreement, 5 = strong agreement***

Undersupply of horticulture produce	0	1	2	3	4	5	Adverse impact from declining current product variety	0	1	2	3	4	**5**
Increased natural calamity (decreased rainfall /water shortage/ drought/ storm intensity/ local flooding)	0	1	2	3	4	5	Increased cost of production above the Consumer Price Index (CPI)	0	1	2	3	4	**5**
Change in seasonal rainfall pattern (decrease in summer/winter rainfall)	0	1	2	3	4	5	Decrease Gross Margin Relative to CPI	0	1	2	3	4	**5**
Adverse impact of seasonal change (e.g. growth and production of crops)	0	1	2	3	4	5	Lower market prices relative to CPI	0	1	2	3	4	**5**
Increased evaporation/ Decrease in surface cover	0	1	2	3	4	5	Industry sustainability might be at risk	0	1	2	3	4	**5**
Temperature increase (warm climate/more days over 35^{0c})	0	1	2	3	4	5	Biodiversity will be challenged	0	1	2	3	4	**5**
More bush fires	0	1	2	3	4	5	Declining health of industry labour force (financial & mental)	0	1	2	3	4	**5**
Increased pests and diseases	0	1	2	3	4	5	Other	0	1	2	3	4	**5**
Risk of increasing salinity	**0**	**1**	**2**	**3**	**4**	**5**							

24. ***Please identify and rate the adaptation techniques to minimise risks due to climate change in horticulture industry.***
0 = totally ineffective, 1 = mildly effective, 5 = very effective

Improvements in irrigation and water saving techniques (water reuse, use of controls and water supply valves)	0	1	2	3	4	5	Mixed crop management (mixed cropping - livestock)	0	1	2	3	4	**5**
Improved crop and pasture management	0	1	2	3	4	5	Environment friendly pest & disease management (organic & biological herbicides)	0	1	2	3	4	**5**
Improved Canopy Management	0	1	2	3	4	5	Ongoing Marketing Program for new plant varieties	0	1	2	3	4	**5**
Increased use of shading (trees / shading construction to reduce wind erosion)	0	1	2	3	4	5	Supplementary or complete power generation on site	0	1	2	3	4	**5**
Selection of plant varieties (using plant characteristics and phenological matching climates, seasonal change)	0	1	2	3	4	5	Organic farming initiatives	0	1	2	3	4	**5**
Site selection (relocation/ purchasing of land less susceptible to CC)	0	1	2	3	4	5	Controlled traffic farming (minimising tillage)	0	1	2	3	4	**5**
Managing soil carbon & moisture level	**0**	**1**	**2**	**3**	**4**	**5**	**Other (please name)**	**0**	**1**	**2**	**3**	**4**	**5**

25. *Please identify and rate the mitigation intervention to minimise risks and consequences to the horticulture industry.*

0 = no agreement, 1 = some agreement, 5 = strong agreement

Socio-cultural values and social structure to identify intervention/ adaptation technique	0	1	2	3	4	5	Alternative fuel use (biodiesel, ethanol, vegetable oil)	0	1	2	3	4	**5**
Climate forecasting capabilities (improvement of seasonal forecasts)	0	1	2	3	4	5	Alternative energy use (e.g. solar, wind)	0	1	2	3	4	**5**
Improving transport and market infrastructure to support adaptive farming, production and transportation	0	1	2	3	4	5	Controlled pesticide use	0	1	2	3	4	**5**
Better Decision Support Systems for farm management	0	1	2	3	4	5	Use of organic fertilizer	0	1	2	3	4	**5**
Efficient water management (irrigation system maximisation)	0	1	2	3	4	5	Carbon sinks/sequestering (e.g. planted trees)	0	1	2	3	4	**5**
Development and adjustment of policies with new climatic condition	0	1	2	3	4	5	Use of carbon calculator for the products	0	1	2	3	4	**5**
Extension and modification of Federal and State Drought/flood relief schemes	0	1	2	3	4	5	Purchase of carbon offset credits	0	1	2	3	4	**5**
Introduction of ISO standards to farming enterprises that acknowledge climate change adaptive management strategies	0	1	2	3	4	5	Hydro-fracking and hydroponic techniques to reduce energy costs and fertiliser costs	0	1	2	3	4	**5**
Cost/benefit Analysis for a particular intervention type	**0**	**1**	**2**	**3**	**4**	**5**	**Other (please name)**	**0**	**1**	**2**	**3**	**4**	5

DAIRY INDUSTRY SECTOR QUESTIONS

26. What are the major risks and consequences of climate change for the dairy industry?

Please Rate agreement: 0 = no agreement, 1 = some agreement, 5 = strong agreement

Low pasture productivity	0	1	2	3	4	5	Increasing risk of Salinity	0	1	2	3	4	**5**
Increased natural calamity (rainfall changes/water shortage/more drought/increased storm intensity/local flooding)	0	1	2	3	4	5	Increased cost of production above the Consumer Price Index (CPI)	0	1	2	3	4	**5**
Change in seasonal rainfall pattern (decrease in summer/winter Rainfall)	0	1	2	3	4	5	Decrease Gross Margin Relative to CPI	0	1	2	3	4	**5**
Increased Evaporation/Decrease in surface cover	0	1	2	3	4	5	Lower Market Prices relative to CPI	0	1	2	3	4	**5**
Temperature increase (heat Stress/more days over 35^{0c}	0	1	2	3	4	5	Industry sustainability might be at risk	0	1	2	3	4	**5**
Reduced reproductive rate	0	1	2	3	4	5	Biodiversity will be challenged	0	1	2	3	4	**5**
More bush fires	0	1	2	3	4	5	Declining health of the industry worker (financial and mental health)	0	1	2	3	4	**5**
Increased Pests and Diseases	**0**	**1**	**2**	**3**	**4**	**5**	**Other (please name)**	**0**	**1**	**2**	**3**	**4**	**5**

27. Please identify and rate the adaptation techniques that will minimise climate change risks and consequences for the dairy industry.

0 = totally ineffective, 1 = mildly effective, 5 = very effective

Adjustment of stock /Matching stock with variable pasture production	0	1	2	3	4	**5**
Selection of animal lines that are resistant to higher temperatures	0	1	2	3	4	**5**
Construction of shading and spraying facilities/Summer housing for dairy cattle	0	1	2	3	4	**5**
Increasing Landscape resilience through revegetation and rehydration	0	1	2	3	4	**5**
Shift from perennial pastures to a mix of annual and perennial pastures	0	1	2	3	4	**5**
Supplementary or complete power generation on site	0	1	2	3	4	**5**
Altered farm management (e.g. rotational grazing, alteration of forage types, matching stocking, supplementary feed, mixed crop management)	0	1	2	3	4	**5**
Redesign of building for passive cooling	0	1	2	3	4	**5**
Other (please name)	**0**	**1**	**2**	**3**	**4**	**5**

28. Please identify and rate mitigation intervention to minimise climate change risks and consequences for the dairy industry.

0 = no agreement, 1 = some agreement, 5 = strong agreement

Socio-cultural values and social structure to identify intervention/ adaptation technique	0	1	2	3	4	**5**
Improving transport and market infrastructure to support adaptive farming, production and transportation	0	1	2	3	4	**5**
Better Decision Support Systems for farm management	0	1	2	3	4	**5**
Efficient water management system	0	1	2	3	4	**5**
Development and adjustment of policies with new climatic condition	0	1	2	3	4	**5**
Extension and modification of Federal and State Drought schemes	0	1	2	3	4	**5**
Introduction of ISO standards to grazing enterprises that acknowledge climate change adaptive management strategies	0	1	2	3	4	**5**
Analysis of the costs of climatic drivers	0	1	2	3	4	**5**
Alternative fuel use (e.g. biodiesel, ethanol, vegetable oil)	0	1	2	3	4	**5**
Alternative energy use (e.g. solar, wind)/ methane capturing and using for power and electricity generation	0	1	2	3	4	**5**
Use of carbon calculator for per animal emission	0	1	2	3	4	**5**
Purchase of carbon offset credits	0	1	2	3	4	**5**
Other 1……………………………………………………………………	**0**	**1**	**2**	**3**	**4**	**5**

Questions for Producers

29. Your intention to adapt to climate change.

0 = no agreement, 1 = some agreement, 5 = strong agreement

I shall change my farm management to minimise the risks of climate change	0	1	2	3	4	**5**
I shall develop alternative power/fuel generation on site	0	1	2	3	4	**5**
I intend to take some adaptive measure in the next 12 months	0	1	2	3	4	**5**
I shall use improved water management system	0	1	2	3	4	**5**
I shall ensure that my business operates within environmental/ecological principles	0	1	2	3	4	**5**
I shall use existing government policies and initiatives to mitigate climate change impacts	0	1	2	3	4	**5**
Other (please name)	**0**	**1**	**2**	**3**	**4**	**5**

In this section please tell us a little more about yourself:

1. What is the main ***language*** you speak at home?

2. If not Australia what country were you born in?

1.	
2.	

3. Where have you ***lived most*** in the past five years?

Place: (name place)	☐	In regional town in Australia (please name)	☐	Overseas (please name)	☐
In a rural area elsewhere in Australia	☐	In nearest large city (please name)	☐	Other: (please name)	☐
In a rural area outside Australia (please name)	☐	In another city (please name)	☐		

4. Which ***industry*** do you work in?	(please name)				
5. What is your main ***occupation***?	(please name)				
6. ***Gender***?	FEMALE ☐	MALE ☐			
7. What is your age bracket?	**18 – 24**	**25 – 39**	**40 - 64**	**65 - 79**	**80+**

8. What are your most important ***sources of information*** and communication about climate change and the agricultural industry?

Family	☐	Local commercial suppliers/ shop owners	☐
Friends	☐	Consultants	☐
Neighbours	☐	Insurance agents	☐
TV/ Radio	☐	Industry or commercial sector bodies	☐
The Internet	☐	Local Government	☐
Newspapers and magazines	☐	State government agencies	☐
Government agencies	☐	Federal government information	☐
Landcare/ Catchment officers	☐	University/ tertiary/ research sector	☐
Non-Government organisations	☐	Other: (please name)	☐

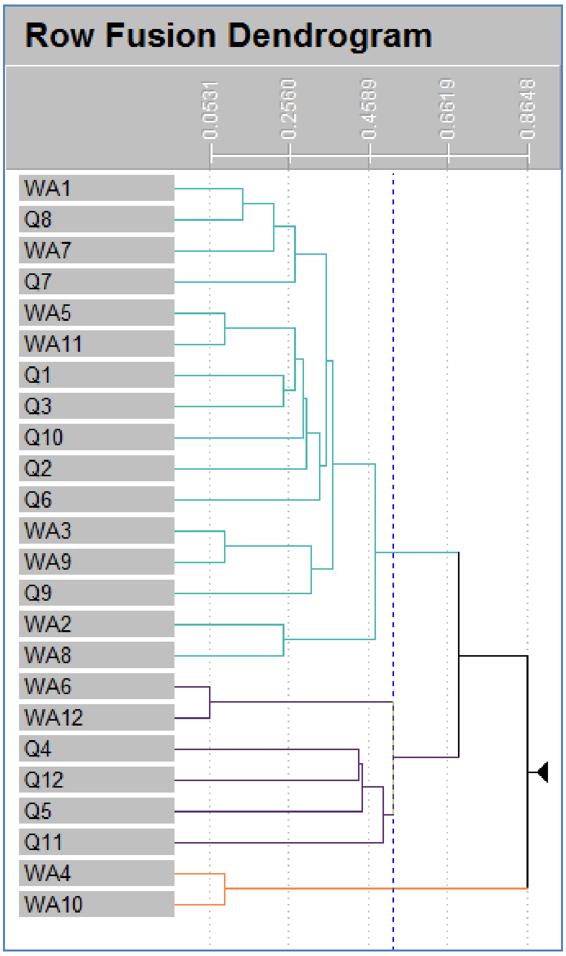
9. Have you ***subscribed to*** newspapers/ newsletters/ journals/ other industry related publications in recent years?

Past 12 months	
Past 5 years	
Past 10 years +	

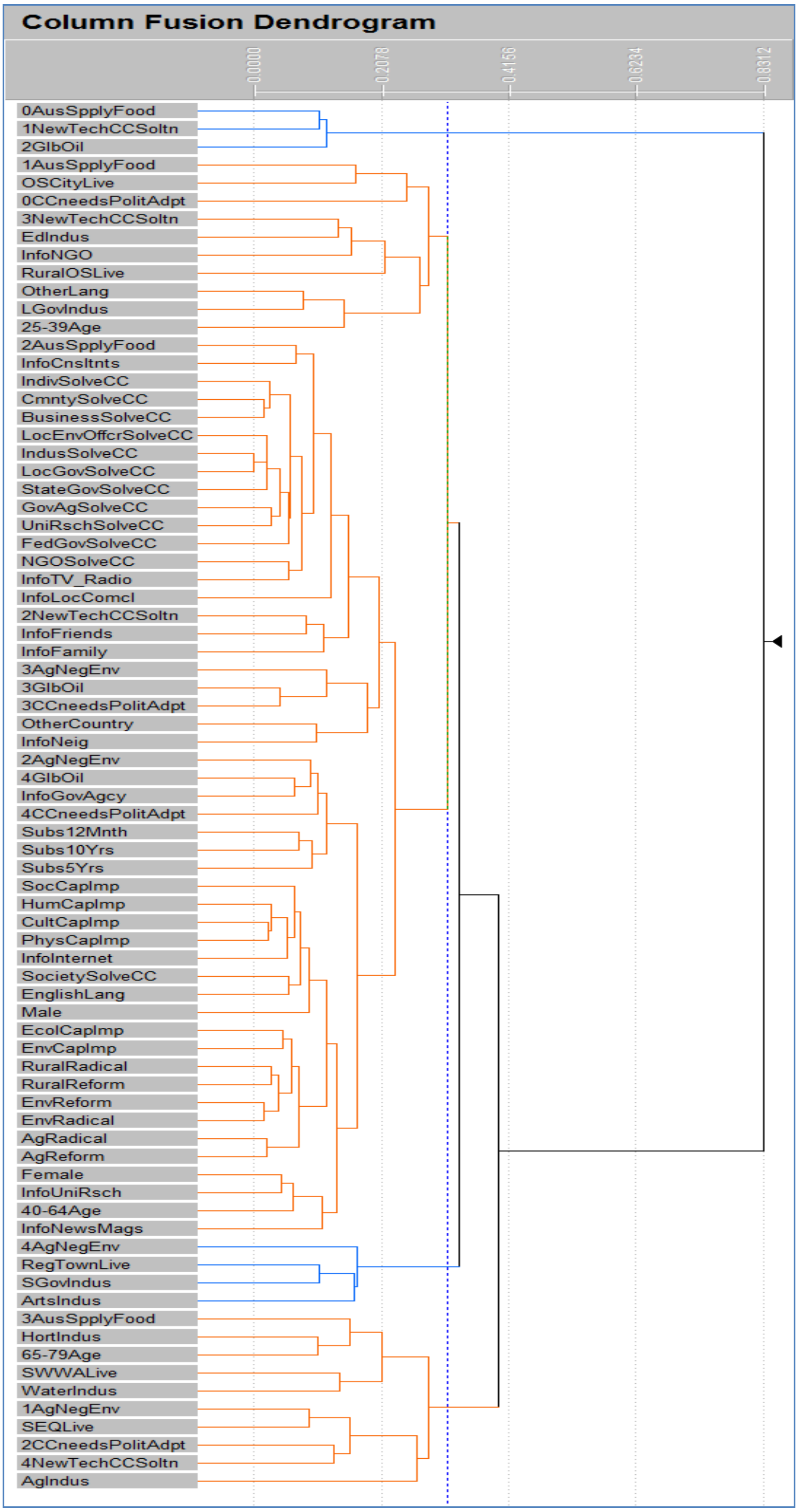
That completes the survey, thanks for your input.

APPENDIX 3 TWO WAY TABLE SHOWING SOCIAL ASSEMBLAGES AND VALUE FRAMEWORKS

APPENDIX 4 EP PROFILE ROW & COLUMN FUSION DENDROGRAMS



APPENDIX 5 COLUMN FUSION DENDROGRAM OF VALUE FRAMES FOR EPS



APPENDIX 6 MEASUREMENT ITEMS FOR THE FACTOR ADAPTIVE CAPACITIES

Formative Factor: Adaptive Capacity	
Sub-factors	Measure
Social Dimension	***Social Capital***
	Membership of associations/ organisations with interests in climate change risks, adaptation and mitigation
	Close social bonds with relatives and community that encourage cooperative actions for adaptation
	Social links/ networks that provide ideas, information and resources to address climate change impact
	Online/Social Web access (e.g. Internet, facebook and twitter) providing links to ideas, information and resources to address climate change issues
	Human Capital
	Skills to adapt business to climate change
	Training/knowledge to adapt business to climate change
	Personal ability to adapt business to climate change
	Good health (including mental health) to address the risks of climate change and required adaptation
	Formal education to understand the issues and requirements for climate change adaptation
	Cultural Capital
	Local community cultural cohesion
	Family support to adapt to new business environment
	Political culture to support adaptation needs
Economic Dimension	***Physical/ Technological and Financial Capital***
	Infrastructure to adopt techniques of climate change adaptation/mitigation intervention
	Equipment to adopt some of the techniques of climate change adaptation/mitigation intervention
	Technologies to adopt techniques of climate change adaptation/mitigation intervention
	Adequate income to adopt techniques of climate change adaptation/mitigation intervention
	Other financial resources e.g. credit and savings to adopt techniques of climate change adaptation/mitigation intervention
	Publically funded infrastructure (telecommunications, roads, power etc)
Ecological/Natural Dimension	***Natural Capital***
	Natural water sources (springs, streams, lakes, rainfall)
	Good quality native vegetation & biodiversity
	Good climatic system
	Soil biodiversity
	Environmental Capital
	Good soil resources
	Healthy natural pest resistance
	Natural shelter for stock and production landscapes
	Natural salinity mitigation and other environmental services

APPENDIX 7 MEASUREMENT ITEMS FOR THE FACTOR RISKS – SCENARIOS: BIOSECURITY, BUSINESS FAILURE, CLIMATE VARIABILITY

Formative Factor: Risks	
Sub-factors	Measure
Bio-security	Biodiversity will be challenged
	Increased pests and diseases
Business failure	Adverse impact from declining current product variety
	Declining health of industry labour force (financial & mental)
	Decrease Gross Margin Relative to Consumer Price Index (CPI)
	Increased cost of production above the CPI
	Industry sustainability might be at risk
	Low pasture productivity
	Lower market prices relative to CPI
	Reduced reproductive rate
	Risk of increasing salinity
	Undersupply of horticulture produce
Climate variability	Adverse impact of seasonal change (e.g. growth and production of crops)
	Change in seasonal rainfall pattern (decrease in summer/winter rainfall)
	Increased evaporation/ Decrease in surface cover
	Increased natural calamity (decreased rainfall / water shortage/ drought/ storm intensity/ local flooding)
	More bush fires
	Temperature increase (warm climate/more days over 35^{0c})

APPENDIX 8 MEASUREMENT ITEMS FOR THE FACTOR ADOPTION OF INTERVENTION STRATEGIES

Reflective Factor: Adoption of Intervention Strategies	
Sub-factors	Measure
Business Models	Analysis of the costs of climatic drivers
	Cost/benefit Analysis for a particular intervention type
	Purchase of carbon offset credits
	Use of carbon calculator for the products
Infrastructure	Supplementary or complete power generation on site
	Improving transport and market infrastructure to support adaptive farming, production and transportation
Policy & Governance	Better Decision Support Systems for farm management
	Carbon sinks/sequestering (e.g. planted trees)
	Controlled pesticide use
	Development and adjustment of policies with new climatic condition
	Extension and modification of Federal and State Drought schemes
	Introduction of ISO standards to grazing enterprises that acknowledge climate change adaptive management strategies
Research & development	Environment friendly pest & disease management (organic & biological herbicides)
	Ongoing Marketing Program for new plant varieties
	Selection of animal lines that are resistant to higher temperatures
	Selection of plant varieties (using plant characteristics and phonological matching climates, seasonal change)
	Site selection (relocation/ purchasing of land less susceptible to CC)
	Alternative energy use (e.g. solar, wind)
	Alternative fuel use (biodiesel, ethanol, vegetable oil)
	Socio-cultural values and social structure to identify intervention/ adaptation technique
Technology & Extension	Adjustment of stock /Matching stock with variable pasture production
	Altered farm management (e.g. rotational grazing, alteration of forage types, matching stocking, supplementary feed, mixed crop management)
	Controlled traffic farming (minimising tillage)
	Improved Canopy Management
	Improved crop and pasture management
	Improvements in irrigation and water saving techniques (water reuse, use of controls and water supply valves)
	Increased use of shading (trees / shading construction to reduce wind erosion)
	Managing soil carbon & moisture level
	Mixed crop management (mixed cropping - livestock)
	Organic farming initiatives
	Shift from perennial pastures to a mix of annual and perennial pastures
	Efficient water management system
	Hydro-fracking and hydroponic techniques to reduce energy costs and fertiliser costs
	Use of organic fertilizer

APPENDIX 9 MEASUREMENT ITEMS FOR THE FACTOR FOOD SECURITY

Reflective Factor: Food Security
Measure
Enhanced environmental sustainability
Low impact Farming
Reducing carbon footprint
Increasing community Incomes
Access to Markets
Value added food processing
Purchasing power
Farmers and market relationships
Land development and management
Labour welfare
Enhanced food security
Enhanced food production
Food distribution/Resource allocation
Alternative food habits
Food aid and ethical consumption
Enhanced food safety quality
Enhanced food quality
Health and Nutritional value
Inspection & enforcement of adaptation/mitigation policies
Energy intake
Building social cohesion through community support
Enhanced food affordability
Food preference options
Building local production links/options into food system
Innovation programs

APPENDIX 10 DETAIL STRUCTURAL COMPONENTS OF THE FOOD SECURITY AND INTERVENTION STRATEGY MODEL

Table 1. Detail structural components of the Food Security and intervention strategy model

Level 1 (Objectives)	Level 2 (Sub-Objectives)	Level 3 (Sub-sub-objectives)
Enhanced Adaptive Capacity	1. Economic Capital	1. Adequate income to adopt techniques of climate change adaptation/mitigation intervention
		2. Equipment to adopt some of the techniques of climate change adaptation/mitigation intervention
		3. Infrastructure to adopt techniques of climate change adaptation/mitigation intervention
		4. Other financial resources e.g. credit and savings to adopt techniques of climate change adaptation/mitigation intervention
		5. Publically funded infrastructure (telecommunications, roads, power etc)
		6. Technologies to adopt techniques of climate change adaptation/mitigation intervention
	2. Ecological Capital	1. Good climatic system
		2. Good quality native vegetation & biodiversity
		3. Good soil resources
		4. Healthy natural pest resistance
		5. Natural salinity mitigation and other environmental services
		6. Natural shelter for stock and production landscapes
		7. Natural water sources (springs, streams, lakes, rainfall)
		8. Soil biodiversity
	3. Social Capital	1. Close social bonds with relatives and community that encourage cooperative actions for adaptation
		2. Family support to adapt to new business environment
		3. Formal education to understand the issues and requirements for climate change adaptation
		4. Good health (including mental health) to address the risks of climate change and required adaptation
		5. Local community cultural cohesion
		6. Membership of associations/ organisations with interests in climate change risks, adaptation and mitigation
		7. Online/Social Web access (e.g. Internet, facebook and twitter) providing links to ideas, information and resources to address climate change issues
		8. Personal ability to adapt business to climate change
		9. Political culture to support adaptation needs
		10. Skills to adapt business to climate change
		11. Social links/ networks that provide ideas, information and resources to address climate change impact
		12. Training/knowledge to adapt business to climate change

Table 1. Cont'd.

Level 1 (Objectives)	**Level 2 (Sub-Objectives)**	**Level 3 (Sub-sub-objectives)**
Minimise Risk	1. Enhanced Bio-Security	1. Control pests and diseases
		2. Protect Biodiversity
	2. Food Business Resilience	1. Control adverse impact from declining current product variety
		2. Improve pasture productivity
		3. Maintain Gross Margin Relative to CPI
		4. Maintain reproductive rate
		5. Protect health of industry labour force (financial & mental)
		6. Protection from lower market prices relative to CPI
		7. Reduce cost of production relative to Consumer Price Index (CPI)
		8. Reduce Industry sustainability risk
		9. Reduce undersupply of horticulture produce
	3. Minimise Climate Change Impact	1. Control adverse impact of seasonal change (e.g. growth and production of crops)
		2. Measures to reduce more bush fires
		3. Solutions to change in seasonal rainfall pattern (decrease in summer/winter Rainfall)
		4. Solutions to increased Evaporation/Decrease in surface cover
		5. Solutions to increased natural calamity (rainfall changes/water shortage/more drought/increased storm intensity/local flooding)
		6. Solutions to increasing risk of Salinity
		7. Solutions to temperature increase (warm climate/more days over 350c)

APPENDIX 11 ADAPTATION AND MITIGATIONS INTERVENTION STRATEGIES CLASSIFIED INTO 4 BROAD GROUPS

Broad Groups	Adaptation and Mitigation Intervention Strategies
Policy and Governance	1. Better Decision Support Systems for farm management (reduction of carbon emissions) 2. Carbon sinks/sequestering (e.g. planted trees) 3. Controlled pesticide use 4. Development and adjustment of policies with new climatic condition 5. Extension and modification of Federal and State Drought/flood relief schemes 6. Improving transport and market infrastructure to support adaptive farming, production and transportation 7. Introduction of ISO standards to farming enterprises that acknowledge climate change adaptive management strategies 8. Supplementary or complete power generation on site
Research and Development	9. Alternative energy use (e.g. solar, wind) 10. Alternative fuel use (biodiesel, ethanol, vegetable oil) 11. Climate forecasting capabilities (improvement of seasonal forecasts) 12. Environment friendly pest & disease management (organic & biological herbicides) 13. Ongoing Marketing Program for new plant varieties 14. Selection of plant varieties (using plant characteristics and phenological matching climates, seasonal change) 15. Site selection (relocation/ purchasing of land less susceptible to CC) 16. Socio-cultural values and social structure to identify intervention/ adaptation technique
Technology and Extension	17. Controlled traffic farming (minimising tillage) 18. Efficient water management (irrigation system maximisation) 19. Hydro-fracking and hydroponic techniques to reduce energy costs and fertiliser costs 20. Improved Canopy Management 21. Improved crop and pasture management 22. Improvements in irrigation and water saving techniques (water reuse, use of controls and water supply valves) 23. Increased use of shading (trees / shading construction to reduce wind erosion) 24. Managing soil carbon & moisture level 25. Mixed crop management (mixed cropping - livestock) 26. Organic farming initiatives 27. Use of organic fertilizer
Business Development	28. Cost/benefit Analysis for a particular intervention type 29. Purchase of carbon offset credits 30. Use of carbon calculator for the products

APPENDIX 12 ANALYTICAL HIERARCHY PROCESS

Analytical Hierarchy Process (AHP) is first introduced by Saaty (1990) in early 1970s as a useful multi criteria decision making (MCDM) tool. Since then AHP has found its way inti various decision areas. Although as a technique not firmly rooted in utility theory, AHP, for the most part, has remained outside the main stream of decision analysis research. The practical nature of the method, suitable for solving complicated and elusive decision problems, has led to applications in highly diverse areas and has created a voluminous body of literature (Zahedi (1986).

One of the main advantages of Saaty's AHP is its simplicity compared to previous decision support methods.

- Allows decision makers to model a complex problem
- Shows the relationships of the goal, objectives (criteria), sub-objectives, and alternatives.
- Defines uncertainties and other *influencing* factors
- Enables decision-makers to derive ratio scale priorities or weights as opposed to arbitrarily assigning them.
- Easy application of data, experience, insight, and intuition in a logical and thorough way.
- Supports decision-makers by enabling them to structure complexity and exercise judgment,
- Allows incorporation of both objective and subjective considerations in the decision process.
- It uses hierarchical way with goals, objectives, sub-objectives and alternatives

The structure of the AHP modelling is translated into a series of questions of the general form such as "How important is objective/criteria A relative to objective/criteria B?". The input to AHP model is the decision maker's answers to a series of questions in terms of pair-wise comparisons. Questions of this type may be used to establish, within AHP, either in ratio scales or in weights for objectives/criteria.

Table 1 provides a simplified example for the calculation of the pair-wise comparison values in one level hierarchy of an AHP model. For each pair of objectives/criteria the decision maker is required to respond to a pair-wise comparison. Responses are gathered in verbal form and subsequently codified on a nine-point intensity scale as shown in Table 1.

The value in between such as 2, 4, 6, 8 are intermediate values that can be used to represent shades of judgement between those five basic assessments. If the judgment is that B is more important than A, then the reciprocal of the relevant index value is assigned, for example if B is considered to be strongly more important (5) than A as a criterion for the decision than A, then the value 1/5 (or 0.2) would be assigned to A relative to B.

Table A1. AHP pair-wise comparison vale

How Important is A relative to B?	Comparison value
Equally important	1
Weakly more important	3
Strongly more important	5
Very strongly more important	7
Absolutely more important	9

In some cases, judgments by the decision maker are assumed to be consistent in making decision about any one pair of criteria and since all criteria will always rank equally when compared to themselves, it is only ever necessary to make 1/2n(n – 1) comparisons to establish the full set of pairwise judgments for n criteria.

Then the results of all pairwise comparisons is stored in an input matrix A = [a ij] that is an n x n matrix. The element a ij is the intensity of importance of criterion ni compared to criterion nj. The following figure shows a typical matrix for establishing the relative importance of three criteria: establishing the relative importance of three criteria:

$$\begin{pmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 7 \\ 1/5 & 1/7 & 1 \end{pmatrix}$$

Figure A1. AHP pair-wise matrix.

In short, according to [8] one should follow four simple steps below in order to apply AHP method for guiding decision making process:

1. Structure the problem into hierarchy.
2. Comparing and obtaining the judgment matrix.
3. Locate weights and consistency of comparisons
4. Aggregation of weights across various levels to obtain the final weights of alternatives..

APPENDIX 1 MODEL RESULTS WITH RELATIVE WEIGHTS WITH RESPECT TO FOUR INTERVENTION STRATEGIES

Table A2. Model results with relative weights with respect to four intervention strategies.

Level 1	Level 2	Level 3	Business Development	Policy and Governance	Research and Development	Technology and Extension	Grand Total
Enhanced Adaptive Capacity (L: .499 G: .499)	Economic Capital (L: .351 G: .1	Adequate income to adopt techniques of climate change adaptation/mitigation intervention (L: .430 G: .075)	0.017	0.016	0.028	0.016	0.077
		Equipment to adopt some of the techniques of climate change adaptation/mitigation intervention (L: .131 G: .023)	0.004	0.007	0.009	0.005	0.025
		Infrastructure to adopt techniques of climate change adaptation/mitigation intervention (L: .058 G: .010)	0.004	0.003	0.001	0.003	0.011
		Other financial resources e.g. credit and savings to adopt techniques of climate change adaptation/mitigation intervention (L: .180 G: .032)	0.003	0.010	0.010	0.012	0.035
		Publically funded infrastructure (telecommunications, roads, power etc) (L: .164 G: .029)	0.007	0.011	0.007	0.002	0.027
		Technologies to adopt techniques of climate change adaptation/mitigation intervention (L: .038 G: .007)	0.000	0.002	0.001	0.002	0.005
	Economic Capital (L: .351 G: .175) Total		0.035	0.049	0.056	0.040	0.180
	Environmental (L: .124 G: .062	Good climatic system (L: .053 G: .003)	0.001	0.000	0.001	0.001	0.003
		Good quality native vegetation & biodiversity (L: .321 G: .020)	0.007	0.007	0.005	0.004	0.023
		Good soil resources (L: .090 G: .006)	0.002	0.001	0.001	0.000	0.004
		Healthy natural pest resistance (L: .157 G: .010)	0.003	0.004	0.003	0.002	0.012
		Natural salinity mitigation and other environmental services (L: .162 G: .010)	0.004	0.003	0.004	0.001	0.012
		Natural shelter for stock and production landscapes (L: .119 G: .007)	0.003	0.002	0.002	0.001	0.008
		Natural water sources (springs, streams, lakes, rainfall) (L: .060 G: .004)	0.000	0.001	0.001	0.001	0.003
		Soil biodiversity (L: .038 G: .002)	0.000	0.000	0.001	0.000	0.001
	Environmental (L: .124 G: .062) Total		0.020	0.018	0.018	0.010	0.066
	Social Capital (L: .525 G: .262)	Close social bonds with relatives and community that encourage cooperative actions for adaptation (L: .090 G: .024)	0.002	0.002	0.003	0.009	0.016
		Family support to adapt to new business environment (L: .071 G: .019)	0.000	0.005	0.004	0.007	0.016
		Formal education to understand the issues and requirements for climate change adaptation (L: .130 G: .034)	0.013	0.007	0.005	0.002	0.027
		Good health (including mental health) to address the risks of climate change and required adaptation (L: .093 G: .024)	0.008	0.009	0.006	0.004	0.027
		Local community cultural cohesion (L: .059 G: .016)	0.002	0.002	0.000	0.006	0.010
		Membership of associations/ organisations with interests in climate change risks, adaptation and mitigation (L: .034 G: .009)	0.000	0.001	0.003	0.003	0.007
		Online/Social Web access (e.g. Internet, facebook and twitter) providing links to ideas, information and resources to address climate change issues (L: .234 G: .061)	0.018	0.023	0.020	0.010	0.071
		Personal ability to adapt business to climate change (L: .050 G: .013)	0.002	0.005	0.003	0.002	0.012
		Political culture to support adaptation needs (L: .035 G: .009)	0.003	0.003	0.002	0.001	0.009
		Skills to adapt business to climate change (L: .085 G: .022)	0.007	0.006	0.008	0.007	0.028
		Social links/ networks that provide ideas, information and resources to address climate change impact (L: .042 G: .011)	0.004	0.001	0.004	0.001	0.010
		Training/knowledge to adapt business to climate change (L: .078 G: .020)	0.002	0.004	0.007	0.008	0.021
	Social Capital (L: .525 G: .262) Total		0.061	0.068	0.065	0.060	0.254
Enhanced Adaptive Capacity (L: .499 G: .499) Total			0.116	0.135	0.139	0.110	0.500
Minimise Risk (L: .501 G: .501)	Enhanced Bio-Security (L: .180 G: .090)	Control pests and diseases (L: .038 G: .003)	0.000	0.000	0.001	0.001	0.002
		Protect Biodiversity (L: .962 G: .087)	0.001	0.005	0.012	0.033	0.051
	Enhanced Bio-Security (L: .180 G: .090) Total		0.001	0.005	0.013	0.034	0.053
	Food Business Resilience (L: .	Control adverse impact from declining current product variety (L: .037 G: .012)	0.003	0.002	0.003	0.005	0.013
		Improve pasture productivity (L: .126 G: .041)	0.015	0.011	0.013	0.011	0.050
		Maintain Gross Margin Relative to CPI (L: .096 G: .031)	0.012	0.011	0.010	0.010	0.043
		Maintain reproductive rate (L: .130 G: .042)	0.016	0.013	0.014	0.014	0.057
		Protect health of industry labour force (financial & mental) (L: .147 G: .048)	0.018	0.010	0.013	0.006	0.047
		Protection from lower market prices relative to CPI (L: .079 G: .026)	0.007	0.006	0.008	0.010	0.031
		Reduce cost of production relative to Consumer Price Index (CPI) (L: .185 G: .060)	0.022	0.016	0.015	0.007	0.060
		Reduce Industry sustainability risk (L: .164 G: .053)	0.009	0.010	0.014	0.020	0.053
		Reduce undersupply of horticulture produce (L: .038 G: .012)	0.002	0.005	0.004	0.004	0.015
	Food Business Resilience (L: .648 G: .325) Total		0.104	0.084	0.094	0.087	0.369
	Minimise CC Impact (L: .172 G:	Control adverse impact of seasonal change (e.g. growth and production of crops) (L: .034 G: .003)	0.001	0.001	0.001	0.000	0.003
		Measures to reduce more bush fires (L: .161 G: .014)	0.002	0.001	0.003	0.005	0.011
		Solutions to change in seasonal rainfall pattern (decrease in summer/winter Rainfall) (L: .258 G: .022)	0.005	0.005	0.006	0.008	0.024
		Solutions to increased Evaporation/Decrease in surface cover (L: .109 G: .009)	0.000	0.001	0.002	0.004	0.007
		Solutions to increased natural calamity (rainfall changes/water shortage/more drought/increased storm intensity/local flooding) (L: .213 G: .018)	0.002	0.005	0.004	0.007	0.018
		Solutions to increasing risk of Salinity (L: .130 G: .011)	0.002	0.003	0.003	0.004	0.012
		Solutions to temperature increase (warm climate/more days over 350c) (L: .095 G: .008)	0.001	0.001	0.002	0.003	0.007
	Minimise CC Impact (L: .172 G: .086) Total		0.013	0.017	0.021	0.031	0.082
Minimise Risk (L: .501 G: .501) Total			0.118	0.106	0.128	0.152	0.504
Grand Total			0.234	0.241	0.267	0.262	1.004

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