Climate Change, Community and Environment

Draft Interim Final Project Report

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The Environment Institute
University of Adelaide

The Premier's Science and Research Fund

Climate Change, Community and Environment

Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes.

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EXECUTIVE SUMMARY

1.1 INTRODUCTION

This report presents the development and outcomes to-date of the Premier's Science and Research Fund Project 'Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes'.

This meets the requirements of the project including reporting on:

- Expenditure of grant monies;
- Performance against activities, deliverables and Key Performance Indicators;
- Industry links and collaborations made during the project;
- Outputs and statistics; and
- Future activities.

This final report provides a comprehensive overview of the project including its background, aims, methodology, key findings and outputs and outcomes to date. This will provide an appropriate reference for the project and be important as a Climate Change (CC) library resource.

The report was compiled using a range of sources:

- Milestone reports from the project;
- Scientific papers written as a result of the project;
- Milestone reports and final reports written for contributing sub projects; and
- Detailed input from project contributors including a comprehensive workshop process with the management team reviewing and synthesizing project outcomes and the results of the research process.

The project seeks to understand the potential impacts of CC within a region and to identify planning options that can assist adaptation. A robust methodology has been used to examine future CC scenarios within two SA NRM areas, Eyre Peninsula (EP) and South Australian Murray Darling Basin (SA MDB) and assesses possible changes in a range of natural resource and social contexts.

The project's key methodology was based around a landscape futures analysis framework. This included determining the specific regional responses to climate change scenarios and determining possible implications for changes in the distribution of land use as the region adapts to the changed conditions.

The project objective was to build the capacity of a multi-disciplinary research and influencing team. It sought to extend CC science through the development of appropriate models and assessments of CC effects across key components in regional natural resource management (NRM) areas. These components include primary production, carbon capture and bio-fuels, ecosystem function, water resources, and economic and social development.

The project was delivered with significant engagement with regional NRM staff along with capacity building opportunities for research staff. In this process considerable research and communication outputs have been generated that can form the base for further refinement and extended application of the methodologies.

This report provides the overview of how the project achievements can inform the planning and implementation of climate ready plans in South Australian NRM regions.

1.2 Meeting the PSRF Funding Obligations.

The project achieved the PSRF funding obligations as summarised below:

- **Governance and Administration -** the research team was supported by advisory and management groups throughout the project.
- **Report of Regional Data Compiled-** comprehensive data was collated for both NRM regions.
- **Report on Climate Change Scenarios-** four CC scenarios were developed and explored in the two NRM regions and applied to sub projects.
- **Adaptive Capacity Analysis Complete-** This was achieved with application of a vulnerability framework and assessment of adaptive capacity in biodiversity response and was implicit in production and carbon sequestration analyses.
- **Technical Report on Model Assumptions, Configuration Testing-** a comprehensive technical report describing the models used and testing made has been compiled.
- **Report Trials and Impact Results-** This was achieved with compilation of the Technical Report and comprehensive sub-project reports.

Industry links and collaborations were formed. In the EP NRM region the major industry groups associated with agriculture have been involved with lesser interactions with local government and other primary production including fisheries and aquaculture. In the SA MDB NRM region the major interaction has been with local governments and with irrigators in one section of the River Murray. Contact with the rain dependant agricultural groups has mainly been through the NRM Board activities.

The project formed demonstrable links to industry and stakeholders including liaison and testing of CC outcomes with primary producer groups (horticulture, wheat producers); formation in SA MDB of a multi-stakeholder consultation group; supported formation of CC sector agreement and cross-stakeholder committee; engagement with a range of stakeholders in development of CC initiatives including tourism, wine and other horticultural groups, regional development, local council and regional NRM Boards.

The key outputs and statistics for the project were:

- Research papers (x19) and conference presentations (x4);
- Written Reports (x22) and brochures/articles (x5);
- Websites (x2) including podcasts (x2);
- Climate Change models developed (x 6);
- Decision Support Tools (x5);

- Industry, Stakeholders and Community Groups involved (x6);
- Data sets collected and compiled (x 110); and
- Meetings/Workshops/Conferences Held/Participants (x 50).

1.3 Regional Level Outcomes

The key regional outcomes are outlined below.

South Australian Murray-Darling Basin

The Landscape Futures Analysis that had been developed previously (Bryan et al. 2011) was used as a basis for bringing information together to provide further analysis and advice on CC adaptation strategies to the eleven local governments in the region. Through an extensive literature review and engagement process, an issue based approach was taken to identify strategies to increase community resilience and address future vulnerability.

Stakeholder engagement identified the need for the approach to involve collective action, an urgent need to adapt quickly, particularly to retain the viability of the primary production base and be supported by appropriate leadership and strategic planning.

The project promoted the concept of community resilience and looked at future opportunities for CC adaptation including water trading, irrigation efficiency, developing a low carbon economy, changes in irrigation configuration and change in land use to include bio-fuels agriculture, biomass agriculture, forests for ecosystems and ecosystem services.

The region is projected to become warmer and drier with much less run-off. Given the uncertainties involved, a scenario based approach to CC projections is recommended.

The effects of projected CC scenarios were scoped including those on agriculture, biophysical change and impact on emergent industries of the region. Agricultural production is likely to decline due to lower water availability, yields and reduced animal productivity. Higher temperatures may affect crop production due to reduced frosts and higher temperature affecting fruit characteristics. There is likely to be a shift in land-use and agricultural practice to adapt. Alternative land-uses such as bio-fuels and biomass may become more viable. Other allied industries such as tourism and mining are likely to be affected but adaptations to mitigate negative effects are possible.

The project resulted in a set of possible strategies for adapting to climate change including:

- Primary Production- Foster private sector changes in farming systems by supporting leadership in CC, providing appropriate landholder information, strengthening communication and networking strategies and promoting a development vision for future food production.
- Renewable Energy- Encourage renewable energy programs into primary production programs by developing strategic directions for wind, solar and bio-energy, improving community engagement and undertaking a Regional Energy Cooperative Feasibility Study and undertaking field trials.

- Tourism- Planning for tourism enterprises in a more variable climate, particularly drought and integrating tourism with NRM and biodiversity conservation programs.
- Local Government- Improve capacity to develop appropriate planning guidelines for land-use change including carbon sequestration, improve skills and capacity, progress the concept of planning for “green” towns.
- Leadership and communication- Develop a formal climate change adaptation alliance to foster appropriate vision, investment and funding programs. Develop a CC adaptation action plan and appropriate communications strategies.

Also in the SA MDB a focused study developed a tool to assist landholders to adapt to CC in a horticultural context. Significant engagement was undertaken with landholders prior to and during the development of the tool which led to a good understanding of CC and acceptance of CC scenarios. The tool also scaled down CC projections to an enterprise or farm level. It produces options for the landholder to consider in medium and longer term planning. Trials of the Interactive Landuse Strategic Assessment (ILSA) Tool found the following:

- Landholders can trial different scenarios, to better understand future outcomes and bottlenecks to productivity and profitability;
- CC projections indicate significant droughts with low water allocations are possible and will impact on future viability depending on crop types and water entitlements;
- Water trading does decrease the effect of low water allocations on landholders but it is likely that those with lower water entitlements will be more severely affected;
- Further work is required to promote the tool as a practical, widely used application that has potential use for future innovation and business development planning.

Eyre Peninsula

In line with the project objectives the major focus for the work on Eyre Peninsula was the gathering and collation of data to describe the resources and their condition and to then develop a Landscape Futures Analysis for the region.

The Landscape Futures Analysis was implemented at a regional scale with a focus on the development of a number of CC research modules to support vulnerability assessment and CC adaptation strategies including:

- Modelling levels of wheat production and economic viability of wheat under CC scenarios;
- Modelling levels of biomass and carbon sequestration and economic viability under CC scenarios;
- Modelling impacts of CC on biodiversity, specifically plant species viability and distribution;
- Understanding social capacity in the region, and level of resilience and potential to uptake CC initiatives.

Stakeholder engagement in the region identified that building and fostering social capacity was a key requirement of the project.

The region is projected to become warmer and drier with rainfall reliability as a key factor. Reductions in reliability will be most significant in spring at a 2070 time horizon. This has implications for cropping, particularly in areas that rely on spring rainfall to finish crop yields.
The impacts of projected CC scenarios were modelled with the following key results found.

- Wheat productivity is projected to decline most significantly in the northern areas of the region.
- In some southern areas wheat productivity is predicted to actually increase.

The potential for carbon capture and biosequestration was modelled under future CC scenarios, with rates of carbon capture being around 3 t/ha. In relation to resilience to CC, environmental plantations showed the most resilience with less decrease in rates of carbon capture as climate conditions became more severe.

In relation to native plant species, distribution models show that CC is likely to cause significant decreases in the extent of many species distributions.

CC adaptation strategies recommended for the region include increased diversification of wheat farming enterprises with increased levels of livestock production, and incorporation of plantations for carbon capture and bio-sequestration. The viability of carbon capture and bio-sequestration will depend on specific site conditions, price of carbon, capacity to access government incentives and incorporation into a whole of farm plan considering associated benefits of revegetating landscapes.

A number of priority conservation areas were identified in the region to optimise species viability into the future. The areas were concentrated in the southern latitudes and higher altitudes (western priority areas). Such areas as also going to be prime areas for wheat production under CC and increasing tension over appropriate land-use should be anticipated.

A social network hierarchy associated with NRM information and influence was developed for the EP region. Not unexpectedly, the influencing is disproportionately vested in a few individuals and organisations. This forms the basis for understanding how to build leadership and community capacity. Social network modelling also showed that the region has a high level of social capacity but is reliant on a number of primary nodes to hold the social network together. Accidental or deliberate removal of these nodes is highly likely to have significant effects on the potential to promote outcomes and pursue stakeholder goals.

1.4 Overall Outcomes

The research group was highly successful in engaging the community and stakeholders through the project design and approach.

Methods of engagement included meetings, workshops and electronic communication. Key outcomes of this included setting agreed ways forward to build a positive vision of future regional development; raise awareness of CC impacts and potential adaptation strategies across key influential groups including local government, primary producers, regional development organisations; build increasing confidence in CC researchers and increased understanding of CC projections and potential impacts; improve links to CC opportunities such as Clean Energy Futures Plan.

The project was undertaken with an evaluative approach to assist improvement in future programs. Key learnings include the need to scale down CC projections to a meaningful level; the need to consider both risks and opportunities of CC to optimise outcomes; and CC strategies will involve significant institutional adjustment particularly local and state government if they are to support required outcomes. Having a strategic management and research base is vital for on-going CC adaptation; CC adaptation potentially integrates across issues creating more sustainable NRM futures.

The project has helped shape a range of CC adaptation strategies across primary production, biodiversity, tourism, regional development, state and local government.

Key findings were that CC adaptation strategies are required to be developed at both a regional and local scale to be effective; there is scope to adapt current primary production methods particularly in horticulture and dry land farming or to diversify enterprises that are less adaptable to CC.

A major focus of CC adaptation is the development of new and innovative industries such as bio-mass and carbon capture/sequestration. However, the viability of this depends on site specific conditions and socio-economic factors. Institutional arrangements need to more explicitly support CC adaptation measures particularly in relation to planning at local and state level.

The private sector will often lead initiatives but need institutional support. Building community capacity is also vital for CC adaptation including potential implementation of new institutional arrangements such as CC sector agreements. Conservation planning will be required to maintain ecosystem and species viability with requirement to set aside key areas for conservation to facilitate species migration and adaptation.

The project also implemented models for determining optimal landscape options including:

- Constrained Land-use Model- identifies land use across Australia which maximises profitability based on constraints on capacity; this was used to determine the economic viability of carbon sequestration and biomass energy. The model was implemented successfully but requires further development in the coming year.
- Multi-functional Land-Use Model- this optimises land-uses through maximising net social value across food, energy, carbon, water, soil health, biodiversity and economic returns. The Land-Use Evolver tool was developed to optimise a range of indicator values across the landscape based on changing land-use from current use. Trial runs of the tool have clearly shown that land-use optimisation results in specific zones of land-use types across the landscape. This is an important projection and should inform future planning and policy frameworks and illustrates the importance of such a tool.
- Landscape optimisation was also developed at local scale through a horticultural tool where landholders can predict future business viability under a range of CC scenarios and test methods to improve viability through altering water use, crop types and/or crop varieties.

Significance at State, National and International level

The project had high significance at state, national and international level. The project clearly mapped well to the required outcomes of the South Australia Strategy- "Tackling Climate Change (2007)", including providing suitable models for leadership, community involvement, energy alternatives and natural resource adaptation. It also worked closely with the NRM boards in the two regions to contribute towards the delivery of appropriate NRM outcomes.

At a national level the project has high significance because it provides a potential model for developing CC projections, vulnerabilities and adaptation strategies at the level of a NRM region.
The application in two NRM regions provides suitable testing for applying in other regions and is consistent with national approaches for transforming Australia's landscapes. The project also addressed some big picture drivers that are significant nationally, including water resource management, viability of primary production, strategies to strengthen biodiversity, carbon capture and renewable energy and integrated strategies to ensure NRM regions are climate ready. The research has international significance by furthering work on modelling of CC impacts on biodiversity, modelling biologically captured carbon and storage, using participatory models for engaging local government and development of land use change models.

1.5 Looking Forward

Evaluation of outcomes and setting of future directions was an important aspect of project delivery, including delivery through the research, management and advisory teams.

The key learnings for the project are:

- The process of developing the project was as important as the outcomes, it drew in community and stakeholder involvement and helped set directions and increase "ownership";
- The Landscape Futures Analysis framework helps identify vulnerable components and more importantly it provides a process based assessment of possible adaptive responses. The approach is effective across a range of issues and contexts but there is further work to consolidate methods and determine landscape scale trade-offs using different analytical methods ;
- Changes in land-use and management will be a key future focus of adaptation to CC and require significant planning and change to current practices. Analyses informed by tested science as through this project can provide significant support for this. Linking into the Clean Energy Futures Plan and carbon capture programs is important as is empowering NRM and local government planners into the process.
- Incorporating CC research into NRM decision making is complex and will not occur quickly. It requires appropriate capacity building, communication and cooperative arrangements.

Future directions for the project include further developing the research base and capacity to inform regional CC strategies. A particularly important further development is the incorporation of the regional scale implications into more targeted analyses that can be applied at farm scale. It is at this scale that the directions indicated from regional analyses will mostly be implemented. Farm level decision makers will be the ones to give effect to the plans, policies and practices of the NRM Boards and local governments.

CC adaptation is complex and requires significant shifts and changes in behaviour, further strategic planning and fostering leadership and input from all regional stakeholders.

The research team will continue to support CC adaptation plans in the two NRM regions, further develop the tools and models formulated and continue to have high influence over state and national CC adaptation processes.

2 KEY FINDINGS

2.1 PROJECT APPROACH

- The project methodology revolves around accessing and collating the base information that describes the current conditions from land forms, soil types, land use, historic climate, private and public lands, endemic species distributions, populations and infrastructure. With these descriptions it is then possible to model representative agricultural productivity, potential carbon sequestration, distribution of endemic flora and "ground" truth this with existing data. From this base, model projections using climate change scenarios are developed and hence some assessment can be made of the vulnerability of particular components in the bio-physical and socio-economic landscape. With on-ground data and process based model projections it is then possible to consider adaptation strategies that inevitably involve tradeoffs in many of the regional landscape components.

- The project was designed to have high levels of collaboration between researchers, government (State & Local), key stakeholders and the community. This was deemed critical for achieving project outcomes, particularly for identifying and addressing specific barriers to future CC adaptation and facilitating change within existing institutional arrangements which is important for facilitating future implementation programs.

- The project's large scope, across regional landscapes and with consideration of social, economic and environmental values increased its complexity but effected realistic and credible options tailored for the regional landscape of concern. This approach increases capacity to protect natural resource assets into the future and has critical relevance to NRM Board planning processes.

2.2 RESEARCH CAPABILITY

- Increased research capability has been primarily developed through the employment of three post doctorate staff as well as greatly extending the influence of the research and its finding with NRM regional stakeholders.

- Staff and contractors involved in the project have developed a new awareness of the information and tools that can be used in the assessment of CC vulnerability and adaptive capacity. Improved assessment that is process based across wheat production (APSIM model), carbon sequestration and biomass (3PG), biodiversity (species), economic modelling (wheat and biomass and carbon sequestration) and social impacts of climate change has been developed.

- For irrigators in the SA MDB NRM region where water allocation and changing crops are important a new decision support tool (Interactive Land-use Strategic Assessment) has been developed to assist in developing CC adaptation strategies to achieve optimal outcomes.

- The research has involved strong engagement and communication to effectively increase awareness and stakeholder capacity about CC and assist planning and implementation of adaptive responses.

- Future research directions are clear from the work and the research team is now focusing on further development of key research tools and further engagement programs with the specific aim of increasing implementation of the planning and prioritising approach.

- Research capacity has been increased including development of new skills, application of new tools to better understand behaviour of natural systems and likely impact of CC and increased level of collaboration and sharing knowledge. All of these have increased the appreciation of CC science among a wide group of stakeholders.

2.3 Developing Strategies for Climate Change Adaptation

- Adaptation to CC is possible within the ongoing need to adapt to changing markets and social expectations. To adapt though will require significant change to current institutions, existing practices and developing a longer term vision of what a positive future might look like. A key requirement is to support private sector investment in CC adaptation, particularly in the key areas of carbon capture and bio-fuel production in line with the Clean Energy Futures Plan.

- CC adaptation strategies have been identified across a diverse range of issues and contexts. This includes strategies to facilitate adaptation of primary production (wheat and horticulture), tourism, biodiversity adaptation, water management and conservation, and appropriate leadership and governance arrangements. A successful CC adaptation strategy needs to be linked to opportunities such as the Clean Energy Futures program, Carbon Farming Initiative and National Biodiversity program.

- There is a requirement for significant future strategic planning to support the implementation of CC adaptation strategies at local and state levels. Appropriate policy and strategic guidance will greatly improve on ground outcomes.

- Community/local stakeholder involvement in the development of CC adaptation strategies has been high and the buy-in has been good. In the case of the EP this has led to the development of long term institutional arrangements to address CC through the EP Regional Sector Agreement.

- To adapt to CC requires changes to current land-use that optimise what land use is implemented and practiced where. Successful adaptation across a region can build ecological and economic resilience, with modelling developed here effectively demonstrating how to optimise a range of outcomes associated with particular climate change scenarios.

2.4 Demonstrating/Securing Regional Viability

- The Project found that future regional viability is dependent on, or can greatly benefit from exploiting climate change opportunities such as carbon capture, renewable energy and through land-use change. This strengthens the economic base of the community and can provide multiple benefits such as increased biodiversity value.

- Whole of landscape planning is required to ensure that clear adaptation strategies can be implemented to maximise outcomes across the landscape, including the requirement to cease primary production in areas that become marginal and unviable. Further development of CC models and input of appropriate data will provide more insight into when primary production systems will become unviable and require a land-use change. However, opportunities for carbon capture are becoming available now and provide an additional opportunity to consider changes to land-use, some at a local scale and some other at a sub-paddock scale.

3 CONTEXT

3.1 NRM IN SOUTH AUSTRALIA AND THE FUTURE UNDER CLIMATE CHANGE

South Australia faces significant challenges in managing its natural resources to support regional communities. The State is required to address the historical legacy of excessive clearance of native vegetation, introduction of pest plants and animals and loss of biodiversity. Previous land management and water management practices have often been unsustainable and degraded water and land resources.

The hot, dry and highly variable weather conditions also results in limited water availability, restricting the scope of primary production. Soils are also naturally poorly fertile, highly weathered and erodible, again affecting potential agricultural production and increasing the vulnerability of natural and agricultural systems to changed climate conditions. Hence climate change poses a risk to regional communities especially if they are poorly prepared and unable to adapt at a sufficient rate. Climate change is likely to promote warmer and drier conditions across the State and see reduced catchment flows into rivers including the River Murray.

However, adaptation to CC also provides an opportunity to strengthen natural resource and community resilience and optimise regional responses to the many market and social changes that are present and growing. Opportunities exist through employing a scientific approach to natural resource assessment and identifying options that reduce vulnerability and maximise opportunities. Through employing such an approach, CC strategies have the potential to shift NRM outcomes from prevention of further natural resource decline and move to a more positive future. Of critical importance to this is ensuring that CC adaptation strategies are robust and can be practically implemented within a regional governance arrangement.

This project provides a foundation for this by providing a scientific, innovative and collaborative approach for building climate change resilience in two NRM regions in South Australia.

3.2 LANDSCAPE SCIENCE CLUSTER

This project developed through the action of the Landscape Science Cluster. The cluster was formed in 2007 in order to improve the management of natural resources with the aim to:

> 'bring together researchers, government agencies and regional groups to explore new ways of improving and maintaining our environment. The Landscape Science Cluster promotes the development of technologies, processes and relationships to improve the condition of natural resources. The over-arching aim is to develop and promote an advanced research, teaching and outreach capability that can analyse, model, visualize and present current and future options for managing and conserving landscapes'.

Landscape Futures Analysis is a key approach taken by Landscape Science Cluster. Landscape Futures Analysis allows the identification of future land use options to give the best combination of environmental, ecological, economic and social outcomes in the face of climate and market changes.

As part of the Landscape Science Cluster but within the University of Adelaide Environment Institute the Landscape Futures Program aims to develop:

- new methods and models for Landscape Futures Analysis that better informs managers and policy makers of conservation, repair and maintenance options for sustainable land use;
- improved information systems to assess and monitor natural resource condition and provide a basis for projecting likely environmental condition into the future;
- skills and knowledge for planning, implementing and monitoring for improved natural resource management.

A major developmental step in Landscape Futures Analysis was the completion of the Lower Murray Landscape Future Project (LMLF) in the South Australian Murray-Darling Basin and two CMA regions in Victoria. This project developed a baseline data-set to investigate the impact of climate change on natural resources and on the achievement of NRM plan targets. The project found that in order to achieve optimal NRM outcomes, CC adaptation needed to be strategically targeted to key actions with specific locations in the landscape. The LMLF also demonstrated through modelling that CC adaptation can generate positive flow-on effects for regions including economic, social and environmental benefits. In addition, the analysis framework developed a GIS platform using spatially referenced NRM data and provided the basis for applying the methodology across a range of different physical, biotic, economic and social environments.

This current project sought to extend and strengthen the methods and findings of the LMLF project by:

- Strengthening research capability: Increase the size and capacity of the research team in regional and landscape modelling, including the inclusion of two new researcher members to help create a critical mass of climate change research; Build the skills and capacity of the research team in CC adaptation.
- Further develop and implement the CC adaptive framework: Develop new tools and processes for developing CC adaptation, challenge current paradigms, identify new climate change adaptation strategies and test appropriate management options.
- Plan and implement in regional NRM: Integrate the research within regional NRM planning and implementation processes through engaging stakeholders and NRM decision makers in the project from instigation to completion. Widen the impact of the project and account for local experience and views to develop management options in two NRM regions.

3.3 Strategic Linkages

The project is well linked strategically to State and regional level strategies and plans.

The project aligns well with and contributes to State Strategic and State NRM targets
due to its capacity to:

- identify options that protect natural resources including soil, water and biodiversity;
- promote integrated management of natural resources; and

- assist planning and implementation of sustainability objectives and contribute to options for regional viability.

The project has high regional level significance including contributing strongly to NRM targets that are cognizant of climate change adaptation in the SA MDB NRM Plan. It also directly informs the Eyre Peninsula's strategy 'Responding to Climate Change' though promoting appropriate research initiatives that can directly influence NRM planning.

The approach is also highly consistent with five of the eight goals of the South Australian strategy "Tackling Climate Change 2007" and provides a basis for achieving these goals;

- Providing suitable models for Leadership;
- Community Involvement;
- Industry Engagement;
- Energy Alternatives; and
- Natural Resources adaptation across a significant area of South Australia.

3.4 Research Focus- Premier's Science and Research Fund

The project is implemented under the Premier's Science and Research Fund (PSRF) which has the following aims:

- Relate specifically to capabilities and opportunities available in South Australia;
- Build world competitive science and research infrastructure;
- Attract highly skilled scientists and innovators to SA;
- Significantly build SA's science, mathematics and innovation skill base;
- Facilitate the creation and application of world competitive science and research in South Australia; and
- Potentially contribute to sustainable economic, social and environmental outcomes for the State.

This project directly contributes to these aims and has State and National level significance by:

- Providing a leadership and coordination focus for climate change research with local, state and national implications. Such an approach is important for achieving sustainable economic, social and environmental outcomes for the State given the imminent effects associated with climate change;
- Supporting the development of world leading research on climate change methodologies which can be widely applied to NRM regions nationally. This includes mapping climate change vulnerability and developing innovative tools and processes to provide options and their assessment to assist adaptation to climate change, and increase resilience; and
- Provides a unique research approach that involves transferring research outcomes into highly targeted policy and management investments that are well based on the best available information and sound analysis of options.

4 INTRODUCTION

The PSRF funded project 'Climate Change, Community and Environment: Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes project' (CCCE) is the lead coordinating project for developing CC adaptation strategies within the Eyre Peninsula and SA MDB NRM Board.

The project commenced in 2009 for a period of three years with a total budget of $2.7m.

The overall project aims were achieved through the implementation of three sub-projects:

- EP- *Eyre Peninsula Landscape Futures (EPLF)*- Applying Landscape Futures Analysis to the Eyre Peninsula NRM region. The analysis included assessment of the effects of CC scenarios on dryland farming (wheat production), biodiversity and examining future social and economic viability.
- SA MDB - *Climate Change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling region (SBC CCAP)*- Applying the CC adaptation methodology in the SA MDB to examine future options for CC adaptation in local government (councils) associated with infrastructure, planning, horticulture, tourism, carbon capture and bio-fuel production. Led by the SA MDB NRM Board in strong partnership with the 11 councils in the NRM region.
- SA MDB- *Developing Landholder Capacity to adapt to Climate Risks and Variable Resource Availability in the Bookpurnong and Pyap to Kingston On Murray Regions of the Riverland South Australia (MDP LAP)*- Developing tools and building capacity to respond to CC within the irrigation/horticulture communities of the Riverland in South Australia. The major focus was on future business decisions including allocation of water and choice of crop types as part of adaptation planning.

The first project was funded entirely by the PSRF, while the second received additional funding from the Strengthening Basin Communities program and the third project from the Australian Government Department of Agriculture, Fisheries and Forests (DAFF). This reflected the overall project approach of seeking additional resources to increase project scope and capacity and further test project methodologies.

The additional funding increased the overall project budget to $3,167,000.

This three year PSRF project had contributions from seven partners:

- The University of Adelaide;
- CSIRO Climate Adaptation Flagship;
- South Australian Research and Development Institute (SARDI) / Primary Industry and Resources SA (PIRSA);
- Department of Water, Land and Biodiversity Conservation (DWLBC);

- Department for Environment and Heritage (DEH);
- SA Murray-Darling Basin Natural Resources Management Board; and
- Eyre Peninsula Natural Resources Management Board.

Note:
On July 1st 2010 the natural resources section of DWLBC combined with DEH to form the new Department of Environment and Natural Resources (DENR).

The project built on and was strongly linked to current NRM programs within the regions including the Murray Futures and Riverland Futures in the SA MDB and East meet West Biodiversity corridor in the Eyre Peninsula region.

Outputs and insights from this project will assist the two regions to plan for a climate changed future through addressing risk and its implications and identifying options for adaptation (including emerging industries and associated demographic patterns).

The key deliverables for the project are:

1) Development of climate change scenarios for the two regions;
2) Assessment of CC vulnerability and development of CC adaptation strategies; and
3) Optimisation of these strategies across the landscape and mechanisms to implement these strategies.

The final report was compiled from a number of information resources including:

- Milestone reports from the project;
- Scientific papers written as a result of the project;
- Milestone reports and final projects written for contributing projects;
- Workshop with management team reviewing and synthesizing project outcomes and the results of the overall research process; and
- Individual interviews with key players in the project.

4.1 Project Aims

The overall aim of the project was to:

> Use Landscape Futures Analysis to estimate responses of regional agricultural and carbon production, biodiversity and economics to CC scenarios which can then inform regional scale climate change adaptation strategies within the EP and SA MDB NRM regions by 2012.

The project had additional research aims and questions including:

1. What conservation, production and community components are most vulnerable and what actions can be taken to assist adaptation to climate change?

2. How best to maintain and improve the condition of soil, water and biota resources in a region. Retain confidence that incentives and management actions taken will not adversely compromise some other part of the system, especially given likely climatic change?

3. What are the best management investments and where should they be made to get the best improvement in natural resource condition and look after the jobs and services for the regional community?

4. How do we make robust decisions now that will still be applicable and valuable in 30 to 50 years?

4.2 Project Approach

The project focused on the SA Murray-Darling Basin and the Eyre Peninsula NRM region as case study areas for developing research capability and exploring possible climate change outcomes.

A consistent approach was taken in both regions. However, the methodology was adapted in each region to allow for localised differences including different governance structures, socio-economic factors and the existing research base. The SA MDB had already undertaken some CC assessment work through the LMLF Project so was more advanced at project inception.

Through the CCCE project, a common support base was provided for all sub projects through the governance, management and research support arrangements.

The EPLF project particularly benefited and built on previous experience with Landscape Futures Analysis. For example, the methodology developed for assessing adaptation and resilience of biodiverse systems for LMLF was directly applied to the Eyre Peninsula region.

The project stages are itemised below:

4.2.1 Stage 1- Develop Research Team & Governance

Develop the CC multi-disciplinary research team and set up governance and management arrangements for the project (Milestone 1A & B).

4.2.2 Stage 2- Develop Methodology

Investigate and formulate CC methodologies including the application of CC adaptation frameworks and multi-criteria optimisation (Milestone 2B).

4.2.3 Stage 3- Collate & Standardise Regional Information

Collate and standardise the NRM and socio-economic information that characterises the region to have an objective base to use in the modelling of system responses to CC scenarios (Milestone 1C).

4.2.4 Stage 4- Develop Climate Change Scenarios

Develop regional scale CC scenarios identified by downscaling from larger scale General Circulation Model estimates in order to determine regional CC vulnerability and risk (Milestone 2A). Use current climate conditions to verify that model outputs are consistent with observed yields and system responses.

4.2.5 Stage 5- Model Responses to Climate Change

Quantify the responses of production, ecological, economic and social systems to agreed CC scenarios. Quantify how a range of values may change under CC, specific vulnerabilities and risks i.e. model the effects of climate change (Milestone 3A and 3B). This includes:

- Modelling processes for estimating water, carbon and nutrient balances of different crops and vegetation types with changed climate;
- estimating ecological and agricultural system responses;
- estimating economic responses based on primary production responses and flow on, add on from production and conservation; and
- if possible, identifying social system response around the community issues of jobs, services and facilities.

4.2.6 Stage 6- Determine CC Adaptation Strategies

From the analyses, suggest possible adaptation strategies that optimise NRM outcomes under CC conditions. These will use GIS based mapping, modelling, analysis and decision tools. (Milestone 3B).

CC adaptation strategies could include:

- facilitated adaptation of primary production systems including cropping and horticulture;
- facilitated on-going viability of biodiversity communities;
- facilitating carbon storage;
- encouraging renewable energy production including bio-fuels;
- strengthening community capacity to adapt and exploit available opportunities including future investment opportunities;
- allowing future planning and local government activities to support private investment in CC; and
- allowing new collaborations, identify shared goals and clearly defined roles and responsibilities.

Further detail on the data collation, the models and the verification processes used can be found in the technical report ‘Climate Change, Community and Environment: Technical Report (with an emphasis on Eyre Peninsula), hereafter called the “Technical Report”.

There were three general principles applied during the development of CC adaptation strategies namely:

- **Triple Bottom Line**- identify the management investments that get the best improvement in natural resource condition while looking after jobs and services for the regional community;
- **Integration**- Develop new combinations of environment, land use, social and economic factors that give the regions the best capacity to adapt to CC and other changes;
- **Risk and Opportunity awareness**- Target policy to achieve the acceptable regional risk associated with land use options and remain mindful of the opportunities that adaptation to CC may offer.

4.2.7 Stage 7- Achieve a positive outlook on the future of the NRM region

This is an iterative stage and occurs throughout the life of the project.

The purpose was to encourage an outlook for NRM that focuses on moving from overseeing the decline in resource condition to one that is more strategic, targeted, and forward looking to achieve a positive NRM future.

The process was directed to give increased confidence to planning and implementation of regional natural resource management.

5 PROJECT OUTCOMES

This section outlines the project level outcomes including financial information.

5.1 *FINANCIAL ACQUITTAL*

The project has been well managed financially with all monies accounted for. The project is currently under-spent by $209,000. A financial acquittal will be finalised and submitted in mid August.

5.2 *ACHIEVEMENT OF PROJECT MILESTONES*

5.2.1 *MILESTONE 1/KEY PERFORMANCE INDICATORS 31ST MARCH 2010*

A. Project agreement and administrative arrangements in place and operational.

- The Funding Deed was signed on 20 May 2009;
- Letters of commitment were signed by all partners by 9 June 2009;
- A finalised research agreement was signed on 18 January 2010 (including the partners of University of Adelaide, Ministers for DEH, DWLBC, PIRSA/SARDI, CSIRO, SAMDB NRM Board and Eyre Peninsula NRM Board); and
- University of Adelaide established appropriate administrative and reporting arrangements including acquittals.

B. Governance for project developed including management group and advisory group.

- The governance arrangements were established early in the projects life to ensure appropriate direction;
- The advisory group met quarterly and provided higher level strategic direction to the project. This included advice on the scope and direction of the research and how to ensure good connection with stakeholders and to identify growth and influence opportunities for research. This was found to be particularly effective at a regional level, in assisting in identifying connections within EP and flagging communication needs for stakeholder groups.
- The management group was established successfully and had monthly meetings throughout the life of the project to ensure the day to day running of the project. The Group included representatives from the key partners;
- The Research Team met each Monday morning for a briefing in which team members informally reported on latest developments.

Report of regional data compiled and submitted for the two regions.

A range of State and National data was sourced and compiled for the regions including: meteorological, land-use, cadastral, vegetation distribution, soils, geological, demographic and regional economic data.

This data was sourced from a range of providers including Bureau of Meteorology, Australian Soils Resource Information System, Australian Bureau of Agricultural and Resource Economics and Australian Bureau of Statistics as well as State data from Department of Water, Land and Biodiversity Conservation, Department for Environment and Heritage and Primary Industries and Resources South Australia. A list of the regional data compiled can be found in the Technical Report.

5.2.2 MILESTONE 2 /KEY PERFORMANCE INDICATORS 31ST MARCH 2011

A. Submit reports on climate change scenarios and their origin for two regions.

Four climate scenarios were defined. These were a baseline (S0) essentially reflecting historic climate and three climate change scenarios (S1, S2, S3) which represent mild, moderate and severe warming and drying (See Table 1). The baseline climate data was modelled from existing records of rainfall, maximum temperature, minimum temperature and solar radiation.
These are consistent with those used in the LMLF analyses and with those being used by other State Government Departments (Bryan et al., 2010a; Bryan et al., 2007; Bryan et al., 2011; Bryan et al., 2010b; Summers et al., Accepted).

Table 1. Climate scenarios

Scenario	Description	Temperature	Rainfall	CO_2 (Parts per Million)
S0	Baseline	Historical mean	Historical mean	390
S1	Mild warming and drying	1°C warmer	5% dryer	480
S2	Moderate warming and drying	2°C warmer	15% dryer	550
S3	Severe warming and drying	4°C warmer	25% dryer	750

As shown by Table 1, temperature, rainfall and CO_2 were adjusted in the change scenarios. Solar radiation was not adjusted and historic values were used.

For wheat yield modelling, an additional three scenarios were projected to examine the effects of possible future change in seasonal distribution of (Refer Table 2).

Table 2. Additional seasonal projection scenarios for APSIM modelling

Scenario	Temperature (degree C)	Summer Rainfall (%)	Autumn Rainfall (%)	Winter Rainfall (%)	Spring Rainfall (%)	CO_2 (PPM)
S4	+0.80	-3.5	-3.5	-7.5	-7.5	480
S5	+1.75	-7.5	-7.5	-15.0	-15.0	550
S6	+2.25	-7.5	-7.5	-15.0	-30.0	550

Climate Change Projections - SAMDB

The climate change projections developed for the SA MDB included:

- Regionally specific current and projected changed temperatures and rainfall, as well as derived values for, humidity, wind speed and evapotranspiration;
- Locally specific conditions for towns in the Region; and
- estimates of River Murray and eastern Mt Lofty Ranges stream flows.

The data projections can be viewed in Strengthening Basin Communities: Milestone Report 2: Climate Change Scenarios and the Technical Report.

In addition to these generic CC projections, two other CC projection formats were developed to use within models of biodiversity and biomass response. All climate projections were developed from comparable bases to ensure consistency. More details are given in the sections below and in the Technical Report.

Climate Change Projections - Eyre Peninsula

The CC projections for the EP included:

- Overall regional projections; and
- Projections included in formats tailored for particular models. (Refer Table 3).

Table 3. CC projections tailored for specific models.

Model	Adjustments
APSIM	Adjusted **each daily** baseline record for 111 years by the **overall change** in temperature, precipitation and CO_2 changes (i.e. for S1, add 1°C to every daily record for the **111** years, decrease the rainfall records by 5% and set the CO_2 level to 480 parts per million) – assumes daily **variations** for each climate change scenario
3PG- Carbon Sequestration	Created 64 years of mean monthly temperature and rainfall values by adjusting the baseline (S0) values in annual increments from 2006 to reach either the S1, S2 or S3 values by 2070 – assumes gradual change over 64 years for each climate change scenario.
3PG- Biomass	Adjusted the single year of long term mean monthly data by the overall change in temperature, precipitation and CO_2 change (either the S1, S2, or S3 changes). Used the new single year of monthly averages to model biomass under a 6 year rotation – assumes constant values over 6 years
Biodiversity (Species Vulnerability)	Adjusted the single year of long term mean annual data by the overall change in temperature, precipitation and CO_2 change (either the S1, S2, or S3 changes). Used the new single year of annual averages to model biomass for a single year for each climate scenario.

Developing adaptation options – defining adaptive capacity

As part of achieving the aim of the project viz:

> "Use Landscape Futures Analysis to estimate responses of regional agricultural and carbon production, biodiversity and economics to CC scenarios which can then inform regional scale climate change adaptation strategies within the EP and SA MDB NRM regions by 2012."

The project used the vulnerability assessment framework to guide data collection and structure some of the analysis. The vulnerability framework defines CC as a hazard with defined impacts based on exposure and sensitivity (Figure 5.1).

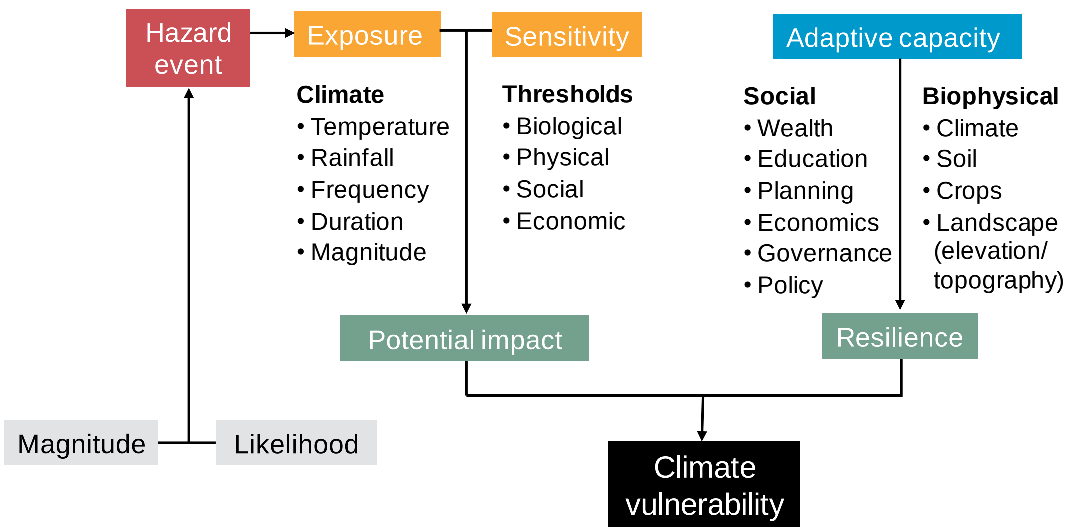

Figure 5.1: Vulnerability framework (adapted from Preston et al 2009, Adger 2006 and Turner 2003)

As indicated in the figure, an assessment of the level of exposure and the sensitivity of a species or sub system to climate change helps to quantify potential effects and assist in ranking their vulnerability. Different species or sub systems are likely to have different adaptive capacities and hence be more or less affected. In this context adaptive capacity is similar in concept to resilience; a characteristic that is exhibited as the ability to "bounce back" to a "usual state" after exposure to a short or even longer term perturbation such as extreme climate events. This conceptual construct can apply to biophysical, social and economic components or sub systems .

In a social context, important components are community engagement, participation, collaboration and partnership.

> *'Adaptive capacity', or a 'system's ability to cope with change', comes through building resilience into people and systems and is found in many shapes and forms. For example, social resilience can relate to concepts of wealth and education; and biophysical resilience can be built into crops and soil through more drought tolerant root stocks or higher soil organic content which improves ability to retain soil moisture.*

Adaptive capacity in this context means the ability of the environment and communities to adapt to the changing climate. This involves adjusting, modifying or changing characteristics in order to moderate potential damage or take advantage of opportunities. This involves changes in behaviour as well as in resources and technology.

The development of an adaptive capacity analysis was developed around the following key literature sources:

- Adger, W. N. 2006. Vulnerability. Global Environmental Change, 16, 268-281.

- Schneider, S. H., Semenov, S., Patwardhan, A., Burton, I., Magadxa, C. H. D., Oppenheimer, M., Pittock, A. B., Rahman, A., Smith, J. B., Suarez, A. and Yamin, F. 2007. Assessing key vulnerabilities and the risk from climate change. In: Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. and Hanson, C. E. (eds.) Climate change 2007: Impacts, adaptation and vulnerabilities. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K.: Cambridge University Press, 779-810.

A number of research papers/milestone reports have also been published on adaptive capacity including:

Research papers:

Crossman, N. D., Bryan, B. A. and Summers, D. M. 2012. Identifying priority areas for reducing species vulnerability to climate change. Diversity and Distributions, 18, 60-72.

Summers, D. M., Bryan, B., Crossman, N. D. and Meyer, W. 2012. Species vulnerability to climate change: Impacts on spatial conservation priorities and species representation. Global Change Biology, 18, 2335-2348.

Bryan, B.A., Crossman, N.D., King, D. and Meyer, W.S. (2011). Landscape futures analysis: assessing the impacts of environmental targets under alternative spatial policy options and future scenarios. Environmental Modelling and Software. 26(1): 83 - 91. Developed from Landscape Future

Papers in preparation:

Meyer, Wayne S., Kellett, B.M. (2011). A prosperous horticultural region changing in response to drought and commodity prices- Limits to irrigated landscape change.

Lyle, Greg (2011). Place and nested scales: A review of potential indicators of climate change adaptation ability in Australian agriculture.

Reports:

Meyer, W., Siebentritt, M., Hayman, P., Alexander, B., Kellett, B., Summers, D., Bryan, B., Connor, J., Spoehr, J., Sharma, V., Sharley, T. and Lyle, G. (2010). Strengthening basin communities program - climate change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling basin, The Environment Institute, The University of Adelaide, Adelaide, South Australia, 68 pages.

Kellett, B., Summers, D., Barnett, K., Siebentritt, M., Meyer, W. and Spoehr, J. (2010). Adaptation and emerging opportunities for the SA Murray-Darling region. Milestone 2 report, The Environment Institute, The University of Adelaide, Adelaide, South Australia, 49 pages.

Summers, D., Siebentritt, M., Sharley, T., Meyer, W., Bryan, B., Connor, J. and Spoehr, J. (2011). Climate change impact assessment report for the SA Murray-Darling region. Milestone 3 report., The Environment Institute, The University of Adelaide, Adelaide, South Australia, 40 pages.

A key concept furthered in the project is that of community resilience, i.e. what are the resources, tools and strategies needed to adapt to potential effects of CC and other market and social changes. While vulnerability is an important concept and the structured framework (Fig. 5.1) can be used to guide assessment and then to assist prioritisation it does not, of itself, lead to development of adaptation options nor any analysis of the trade-offs or opportunities implicit in the options. To develop this next level of analysis requires spatially explicit data collation, process informed modelling and various levels of multi-objective optimisation. This is the framework that is Landscape Futures Analysis.

As part of the Landscape Futures Analysis a suite of modelling tools and processes were used to produce assessment of likely responses to CC and market settings. These included:

- **Biodiversity assessment** in EP and SA MDB to understand plant species vulnerability and adaptive capacity and hence likely distribution responses to CC;
- **Agricultural assessment** in EP, SA MDB to understand wheat production responses. Assessing this response is used as a surrogate for agricultural productivity which is in turn used as an indicator of economic activity in regional communities.
- **Forest growth assessment** in the EP and SA MDB to understand the potential for alternative land uses such as carbon sequestration (particularly in the event of a price on carbon) and alternative energy production through biomass electricity generation;
- **Social/Economic Modelling & Analysis** in EP & SA MDB to understand social and economic adaptive capacity to CC. In the SA MDB this involved a major analysis on non-primary industries such as tourism, as it was acknowledged that non – primary industry sectors will likely form a larger component of the regional economy.

Model integration

Several integration methods have been identified to assist analysis of landscape futures options and these are described below:

- **Target based landscape futures analysis**
  This method incorporates regional natural resource targets and examined different strategies to incorporate those targets into landscape planning. Targets may include a variety of goals such as revegetation, land condition improvement, production levels and water quality. For example, revegetation goals may detail the number of hectares revegetated by a certain year, whereas land condition goals my aim to reduce the number of hectares at risk from erosion or salinity. The method can examine different policy options to achieve these goals, such as with the least cost, most cost efficient or with the highest biodiversity outcome. We can then identify the different cost, benefits and trade-offs involved with achieving these different goals under different policy options.

- **Constrained land use change method**
  This method involves a constrained optimisation of land use over time which aims to identify land uses across Australia which maximise profitability, given constraints on capacity (i.e. bioenergy processing capacity, ability to conduct broad scale reforestation). We used an annual time step model and incorporated change trajectories in market prices (oil, electricity, carbon, water, food, biodiversity etc.) and climate. The method analyses potential land uses including woody perennials for renewable electricity production, cereal crops for biofuels, carbon monocultures, environmental plantings, and the many types of irrigated and dryland agriculture. Impacts of land use change over time were also calculated and trajectories in carbon sequestration, biodiversity, food production, water use, and energy production were assessed.

- **Multi-functional land use method**
  The idea here is to optimise land use with the objective of maximising the net social value produced by landscapes. Net social value includes food, energy, carbon, water, soil health, biodiversity and economic returns. Again, half a dozen alternative land uses are considered. The integrated model optimises land use across the landscape such that all indicators are increased together in a balanced way. The resultant landscape is truly a multi-functional landscape as it produces a range of marketed and non-marketed ecosystem services and includes economic returns to landholders.

5.2.3 Milestone 3 /Key Performance Indicators 31st March 2013

Milestone 3:

A. Technical report prepared on model assumptions, and configuration testing.

The technical report ‘Climate Change, Community and Environment: Technical Report’ includes documentation of model assumptions and configuration testing. A short summary is provided in Table 4.

Table 4 Summary table of model assumptions and configuration testing

Model	Assumptions	Configuration Testing
APSIM Model	Extrapolation of soil data from different localities.	Collated on-ground crop yield and soil data across a variety of scales to validate the crop model used to make yield projections with the different climate change scenarios.
$3PG_2$ biomass and carbon sequestration modelling	Generalisations within plant species parameterisations. Regional soil data contains generalisations and is based on polygons where internal variability is not represented.	Species parameters were calibrated and validated against field measurements. Overall forest growth under the current climate was calibrated and validated against field measurements to ensure suitable yield projections.
Species distribution modelling	The biological survey of South Australia consists of observed presence sites. Synthetic absence data for each species was randomly generated from known survey sites. A generic dispersal kernel was used to simulate species dispersal for all species. Regional soil data contains generalisations and is based on polygons where internal variability is not represented.	To reduce any potential bias from the generation of synthetic absence data, each of the three models was run ten times for each species. For each run a random 70/30 split was used to create calibration and validation datasets from the presence records and a new selection of randomised absence records. A sensitivity analysis was carried out on the kernel to identify a dispersal distance that was assumed to represent species dispersal over several generations. The species distribution modelling under the current climate was validated against known locations.
Wheat Economics Modelling		
Biomass and carbon sequestration economics	A range of assumptions and generalisations around costs of production were used: • carbon sequestration – establishment, maintenance and transaction • biomass – establishment, maintenance, harvest, fertiliser and transport For biomass production it was assumed that integrated processing plants were accessible in the Eyre Peninsula and Lower Murray regions	Cost assumptions were based on a typical production schedule for biomass and carbon sequestration production systems The factory gate price ($/t) of biomass was determined using an economic model for an integrated processing plant. The viability of biomass production and carbon sequestration are very sensitive to price variation. Thus a range of price scenarios were examined to explore the impact of changing commodity markets and policy options
Interactive Land use Strategic Assessment (ILSA) tool	The model assumes that irrigators will undertake actions that maximise the profit of the enterprise. Default values setting are derived from	Model design and setup was developed iteratively in conjunction with a sample group of users to ensure compatibility. Default settings are able to be manipulated

	regional sources which may not always reflect the true values on farm. Assumes that irrigators apply water to the crops of highest value first.	within the process to reflect local irrigator's values. Only affects mixed crop enterprises where the irrigator chooses to model all crops in the mix at once. Can be cross checked or altered through single crop approach.

B. Report trials and impact results from research and implications for regional groups.

A summary of results is provided here (Table 5) but more detailed resulted are presented in the Technical Report.

Table 5 Summary table of report trials and results and implications for regional groups

CC Adaptation Module	Key Results	Implications for Groups
APSIM- Wheat Productivity EP	The impact of CC on wheat production will be highly variable depending on site conditions - particularly rainfall.	Northern areas will be affected to a greater extent due to rainfall declines and future projections suggest these areas will become more marginal.
3PG$_2$ – Biomass and carbon sequestration modelling	Potential biomass production and carbon sequestration from forest growth varies with environmental properties, particularly rainfall. Hardwood production (E. cladocalyx) had the highest levels of carbon sequestration under the baseline scenario. Followed by environmental plantings and then biomass production (oil mallee). Environmental plantings and biomass production performed better under warming and drying scenarios	The low rainfall areas will be more impacted by warming and drying. Future projections indicate that these areas will become more marginal. More southern areas and those of high altitude will be less impacted due to higher rainfalls Hardwood production offers the highest potential rates of carbon sequestration. However, biomass production and environmental plantings may be more resilient to climate change.
Species Vulnerability under Climate Change	The majority of native plant species are likely to contract in range due to CC. Priority areas for conservation are in the southern and more elevated parts of the region.	Trade off between protecting sensitive species and ensuring broad level of representation of other species. Reserves/conservation areas need to be clearly targeted to areas that facilitate species and ecosystem adaptation in this case the more Southern regions.
Wheat Economics		

Modelling		
Biomass and Carbon Sequestration Modelling	Biomass production was not viable at carbon prices under $30/tonne. Hardwood production and environmental plantings were not viable at carbon prices below $20/tonne The viability of biomass, hardwood and environmental plantings increased with increasing carbon price but decreased with increasingly severe warming and drying High rainfall areas performed substantially better than low rainfall areas. In some high rainfall areas economic viability increased with mild warming and drying	The viability of biomass production and carbon sequestration are very spatially variable but also very dependent upon prices received for the commodities. Under some climate change and price scenarios biomass production and environmental plantings are potentially more resilient adaptation options than *Eucalyptus cladocalyx*
Social Impacts of Climate Change	Capacity building is required at a number of levels from property scale up to national level to influence change. The region contains a relatively robust social ecological network with some key stakeholders playing a critical role in maintaining the network.	Requirement to maintain current institutional arrangements to facilitate CC adaptation; Key players of vital importance to retaining network need to be valued and supported.
Interactive Land use Strategic Assessment (ILSA) tool	An increase in the frequency of drought states of nature (dry, very dry and extremely dry) is likely under CC. This significantly reduces allocation and levels of production under poor case scenarios. Water trading and having surplus water volumes significantly improves outcomes.	Testing the resilience of horticulture enterprise under CC scenarios is worth while and can identify future risks to production. CC scenarios can be scaled down to a meaningful level for irrigation enterprises to impact on business decisions.

B. Success of capacity building during 3 years- benefits accrued and lessons learnt.

Benefits Accrued

The project was specifically designed to have a strong focus on building the capacity of community and stakeholders to understand and respond to CC. The research group also recognised the importance of involving the stakeholders and community in the project from the inception in order to improve project directions and help ensure the project would be of maximum utility. The project was specifically designed to facilitate collaboration and build capacity within the regions.

A range of tools were used to promote engagement and involvement including attendance at meetings, workshops, pod-casts and electronic communication. The research, management and advisory groups also ensured the project was integrated within wider processes and gained recognition and acknowledgement.

The key benefits/outcomes of the engagement is documented below:

- Community and stakeholders had input into project directions. For example, in the interaction with local governments in the SA MDB they identified the need to focus on industries such as tourism and fine food and wine production as key development areas as part of regional adaptation;
- Raised the awareness regarding CC projections at a regional scale and likely impacts across a range of groups including state and local government, horticulturalists and dryland farmers.
- Developed new institutional arrangements and approaches for tackling CC into the future, For example, the EP Industry Sector Agreement which involves multi-partnerships;
- Raised awareness, understanding and confidence in research institutions providing locally relevant and understandable interpretations. This has had a positive multiplier effect, with community/stakeholders involved disseminating information to a wider audience and further promoting CC adaptation as for example, local councils developing CC adaptation plans;
- Increased confidence and relationship building between researchers, government and community leading to joint development of CC adaptation strategies;
- Community has increased confidence regarding future viability and how to secure NRM values and community prosperity into the future;
- Build a positive attitude for change;
- Increased research capacity to develop CC projections and adaptation strategies within a multi-disciplinary team which can be applied across NRM regions;
- Connect stakeholders and community to CC related opportunities both at a State and National Level through increased awareness and potential to integrate with Clean Energy Plan;
- Build capacity to be innovative, look at alternative land-uses and apply new tools such as the potential use of bio-fuels and carbon capture strategies; and
- Increase the capacity of local government to think strategically, at a regional scale and to work together to develop region wide leadership programs around adaptation to CC.

Lessons Learnt

A summary of important learnings follows:

- CC projections and effects need to be examined from a range of perspectives as at scales from regional to local to facilitate capacity building;
- For irrigators/landholders it is very important to scale projections to "what it means to me", and to translate effects into measures that are meaningful and relevant. CC model outputs

and inferences need to be scaled to property level to fully engage landholders in taking positive action;

- Engaging with CC and adjusting to consequences means having confidence in the projections. This involves relationship building and developing trust at a personal level to engage and engender confidence and trust in the process;
- CC adaptation must include both examination of risks and opportunities to fully engage people and show what positive benefits can accrue;
- CC discussions need to be linked to future regional prosperity and viability and offer solutions to harness collective action;
- Long term capacity building requires new institutions and arrangements, a good example of an innovative and fundamentally necessary approach is the EP Regional Sector Agreement;
- Models of capacity building need to be adapted to the region of concern and work within existing frameworks;
- Critical to capacity building is having community leaders to promote adoption;
- Local government and State need to be responsive to the needs of the community to adjust to CC and help facilitate the required changes;
- Over-arching strategic management and incorporation of research expertise is highly empowering for building capacity and accelerates project development; and
- Supporting specific CC projects helps to create natural engagement and cooperation through shared common goals and outcomes.

5.2.4 Outputs and Statistics

A range of outputs and statistics were completed for the project as outlined in Table 5.5:

Table 6: Key outputs and statistics generated by the PSRF Project.

Output	Number	Description
Research and Conference Papers	23	Papers published regarding research that were new, innovative in CC research
Climate Change Models Developed	6	Models developed to support identification of CC vulnerability and adaptation
Decision Support Tools	2	Number of decision support tools to support CC adaptation planning
Industry, Stakeholders and Community Groups Involved	36	Key Groups involved in project development across the two NRM Regions
Data Sources Collated	105	Data sources collated to contribute towards project implementation
Meetings/Workshops/Conferences Held	50	Number of engagement events to develop and implement the project
Number of Participants at Meetings	750	Number of participants in the meetings held
Number of Reports Developed	22	Number of reports developed for the project
Number of Web-sites, podcasts	4	Number of websites promoting the project and

		podcasts.
Number of Brochures/articles	5	
Number of new institutional arrangement developed	1	New institutional arrangements developed to foster further CC work- EP Sectoral Agreement
Number of Sub-Projects Funded	2	Number of sub-projects funded as a result of the key project
Area of Land addressed by the Project	10 million hectares	Area of land for Project Scope and Delivery

6 REGIONAL LEVEL OUTCOMES

6.1 SOUTH AUSTRALIAN MURRAY-DARLING BASIN

The SA MDB region was a key focus for the project including implementing Stages 1-7 of the project methodology. In this region, additional work built on the outputs of the LMLF which served to inform the sub project "Climate Change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling region" that involved a major focus on the role of local government in implementation of adaptation plans.

In relation to the CC model modules two new ones were implemented within the SAMDB component :

- 3PG2 – Biomass Modelling; and
- Species Vulnerability under Climate Change.

Within the SA MDB there was the opportunity to work directly with horticulturalists to examine the effects of CC and help identify adaptation options through the project 'Developing Landholder Capacity to adapt to Climate Risks and Variable Resource Availability in the Bookpurnong and Pyap to Kingston On Murray Regions of the Riverland South Australia'. The outcomes of the projects are outlined in more detail below.

6.1.1 COLLATE BASELINE DATA AND REFINE CC ADAPTATION OPTION DEVELOPMENT METHODOLOGY

Baseline data for the project was captured initially in the LMLF Project and updated for this project. Key baseline data collected included soil types, current land-use, water use, and climatic data.

The project was implemented through the following approach:

- Review of current literature to help determine future vulnerabilities to CC and future opportunities (Refer Milestone Report 1).
- Undertake community and stakeholder consultation to refine and direct the approach to identifying opportunities and adaptation options(Refer Milestone Report 2);
- Focus on the improvement of community resilience through a positive approach to community development (Refer Milestone Report 2).
- Identify CC adaptation options that can increase resilience by focusing on opportunities (Milestone Report 4).

CC Adaptation Option Development

The project used the outputs of the CC scenarios developed during the LMLF to identify likely changes in land use as the region adapted through time. This then provides a reasonably objective basis for identifying those areas and land uses that are likely to be most affected and hence may be deemed most vulnerable.

With this analysis in hand it was then possible to undertake a detailed stakeholder engagement and consultation process in combination with a detailed review of current regional studies (Refer M2 Outcomes of Stakeholder Engagement).

The outcomes of the stakeholder engagement helped to shape the direction of a CC adaptation framework in the region, including the need for:

- **Whole of region adaptation**- The adaption needs to be whole of region to achieve integration and appropriate planning and implementation. This includes collective action and a whole of community and industry approach. This need can be readily illustrated from the outputs of the model projections which show the connections and inter-dependencies of for example, vegetation and land management on productivity, soil erosion, economic activity and in turn, community viability.
- **Urgency and priority of adaptation-** There is an urgent need to identify economically viable adaptation options and a high priority is to adapt the primary production base (irrigation and dry land farming) as this drives the regional economy;
- **Leadership & Planning-** Adaptation requires a comprehensive climate change adaptation plan and a whole of region response that fosters informed leadership across all levels of government and community.

The stakeholder engagement process found that the level of awareness of CC was quite high from media and anecdotal observations. However there is a significant challenge to maintain on-going awareness, to build credibility of the science information and to help understand the implications of uncertainty associated with any future projections.

Opportunities

In addition to a risk based approach, the project also established up-front emerging opportunities for adapting to CC, both from a local government view-point and from the perspective of primary production (Section 4 Milestone One Report).

Identifying opportunities built on the concept of community resilience:

> *In light of the significant degree of uncertainty associated with climate change, the application of a community resilience approach to adaptation is likely to be particularly useful in that it "accepts that change is inevitable and unpredictable. Rather than focusing on the potential points of weakness, [it] identifies the resources and adaptive capacities that a community can utilise to overcome any problems that may result from change" (Maguire and Cartwright 2008, p3).*

Key opportunities highlighted included water trading, improved irrigation efficiency including changes in irrigated area configuration, development of a low carbon economy, and change in land-use to include biofuels agriculture, biomass agriculture, forests for ecosystems and ecosystem services. Essentially many of these potential opportunities increase the diversity of activities in the region and in turn, these are likely to increase resilience by providing a buffer to climate and market induced "shocks" in the future.

6.1.2 Develop Climate Change Scenarios

Climate Change Projections

The project identified three important principles in relation to CC projections. They need to:

- Be authoritative – in Australia this generally means using CSIRO and the Bureau of Meteorology as original sources of CC projections;
- Acknowledge the uncertainty – different projections at various spatial scales have different levels of uncertainty;
- Action orientated – the purpose of using projections of future climates is to act now at appropriate levels and hence avoid crisis situations in the future.

The climate change projections developed for the SA MDB included:

- Regional projections for 2030 and2070 including temperature, rainfall, evapotranspiration, humidity, solar radiation and wind speed;
- Projections of climate for towns in the region and
- Implications of changes to rainfall, runoff and streamline flow from project climate change in the River Murray and eastern Mount Lofty stream flows (Milestone 2 Report, Milestone 1a Report).

Key Findings

The SA MDB NRM region, like the rest of Southern Australia is expected to be warmer (high confidence) and drier (lower confidence). When the output of the global climate models are ranked from coolest to warmest projections for the region for 2030 show a warming of between 0.5 to 1.3 °C with the mid range model showing 0.8 °C. At 2030 the range is due to different models and is not sensitive to the emission scenarios (Refer Appendix B for SA MDB Climate Change Projections).

By 2070 there is a significant influence of emission scenarios (whether greenhouse gases are greatly increased or stabilised). Under medium emission scenarios the projected warming is 1.8°C with a range or 1.3 to 2.8°C. Under high emission scenarios the warming is projected to be 2.3°C with a range of 1.8 to 3.5°C. The most likely future is a drier future, but there is considerable uncertainty between models and considerable debate within the scientific community on the appropriate level of confidence to place on projected drying compared to the projected warming.

Outputs from the climate change models for the region indicate that by 2030 there is likely to be a 20% reduction in stream flow, a 5% increase in evaporation and up to a 4% increase in the 99th percentile rainfall intensity. Although these can be used as a best estimate for planning, it is important that the caveats associated with the estimates are understood and that the uncertainties around the estimates are appreciated. We recommend a scenario approach where a range of future climates are used for planning.

In addition to summarising the results for the region as a whole we examined climate change projections for temperature, rainfall and evaporation for 17 towns in the region. Two global climate models were used. Miroc-H which is a model that shows moderate warming and drying for the region and CSIRO Mk3.5 which shows a greater degree of warming and drying. Both models were used under the SRES (special report for emission scenarios) of A1F1 and a setting of moderate global warming. This analysis showed although there is a difference between locations (greater warming inland than on the coast) that the difference between these two models is much greater than the adjustments for locations.

Not only is the region projected to be warmer and drier, it is also projected to have less runoff. As a general guide, the decline in runoff is about 2 to 3 times that of rainfall, hence a decline in rainfall of 10% leads to a decline in runoff of 20 to 30%.

6.1.3 Quantify Response to Climate Change Scenarios

The project then assessed the impacts of climate change on the councils, communities, industries and services that exist within the region. This included examining the:

- major dry land and irrigated production systems to identify the impact of climate change on agriculture,
- biophysical impacts that affect agricultural productivity as well as the potential economic viability and changes in the area under production, and
- likely impact of emergent industries such as alternative energies and water trading (Milestone Report 3).

Key Findings

Impact on agriculture

- Warmer and drier conditions will reduce yield of crops and quality of fodder in dry land farming areas.
- Increased temperatures and heat stress may reduce animal productivity.
- Increases in CO_2 will increase plant dry matter accumulation rates, but also result in reduced fodder and grain quality.
- A warmer and drier climate in major catchments for the Murray will result in less water entering storages and ultimately lower allocations to irrigators.
- Higher maximum temperatures can negatively influence fruit set, taste, colour and the rate of ripening for fruit crops. Conversely, higher minimum temperatures can reduce the number of days that frost is experienced and hotter and drier conditions could reduce the spread of some diseases.
- Warming and drying (and reduced water allocations for irrigation) will reduce productivity from current agricultural practice. The size of this potential decrease can be significantly reduced and overcome with better adapted practices and varieties.
- Climate change may result in a change in the area of land under different production systems. For dry land farming, this could mean less cropping and increased grazing.
- The area of irrigated crops is likely to reduce as water is traded from lower to higher value production systems. The likely decrease in water allocation for irrigation will also reduce the

area irrigated but total productivity from irrigated activities need not decline and could potentially increase with greater productivity from a smaller total area.
- Alternate land uses in the SA MDB are unlikely to threaten food security for the region, South Australia or Australia, but the region may see a shift in current agricultural practices.

Emergent industries

- Bio-fuel and biomass agriculture can provide significant economic benefits. However, their economic viability is driven largely by whether there is a price on carbon emissions and how high this price is.
- While planting trees for carbon could generate some income and other environmental benefits it is likely to be much less profitable than bio-fuels and biomass.
- The impact of climate change on ecosystem services such as amenity values for tourism should not be underestimated as they can have a real impact on local economies beyond the bounds of traditional agriculture.
- Water trading has induced water savings on one hand but increased activation of existing licences on the other and reduced return flows. Based on experience during the recent drought, water trading stands to be an important tool for adapting to variable water supplies in the future.

Impact on tourism

- Tourism generates significant revenue in the Murray-Darling Basin with the Murray River itself a major attraction. False negative perceptions around the recent 'Millennium drought' contributed to a decline in tourism.
- A recent review highlighted strategies to improve the resilience of the region in the face of negative publicity generated by drought and flood.

Impacts of sea level rise

- Global sea levels have risen approximately 200 mm since 1870 and climate change is expected to increase global average sea levels by 180 to 590 mm by 2100.
- Impacts of sea level rise include inundation by sea water, increased coastal erosion, soil salinity and salt water intrusion of aquifers.

Impact on mining

- Mining is heavily dependent on the availability of water and as such will likely be negatively impacted by a warming and drying climate.

6.1.4 Determine Adaptive Strategies Across Region.

Adaptive strategies were developed across the major areas of primary production, renewable energy, tourism, local government and leadership. These were based on a consideration of both addressing risks and opportunities, key issues raised in consultation and activities that would increase resilience. A key consideration was ensuring that the economic base of the regional economy would not decline through impacts on primary production and therefore threaten further capacity to adapt.

A key outcome was to develop an agreed set of outcomes/recommendations for enabling CC strategies. These were typically strategic in nature and providing the basis for practical implementation.

Primary production – As the major economic driver for the region, adaptation of farming systems is essential for the continued prosperity of the region as a whole. Some farming systems will need to consider how to adapt to warming and drying conditions over periods of decades; others will contemplate more rapid changes in the face of opportunities to generate revenue from carbon farming. The private sector will lead future changes in farming systems and the aim of these recommendations is to support and facilitate this change rather than lead it.

It is recommended that the region:

- Invest in rural leaders through establishing a ***Primary Producer Leadership Grant for Climate Change Adaptation***, to better equip the next generation of farmers with the skills needed to adapt their farming businesses to future climate and economic conditions;
- Communicating carbon farming opportunities to landholders through development of a ***Land holder Information and action kit***, which will outline risk and opportunities of new carbon farming activities
- Inform the people who advise farmers through development of a ***Primary Producer Support Network Communications Strategy***, which will focus on communicating messages about climate change adaptation to the trusted advisers and communities of practice that inform decisions farmers make about management of their businesses
- Create a vision for continued and adapting food production through development of a ***Food Plan for the South Australian Murray-Darling Basin***, which will assess suitability of current and alternate crops to current and future climatic conditions overlayed with an assessment of future demand from domestic and international markets. This would also contribute to the development the Federal Government's National Food Plan, which is currently being prepared.

Renewable energy – The SA MDB offers potential for the establishment of major energy projects like wind and solar, biofuel and biomass incorporated into traditional farming systems as well as smaller scale distributed energy. Renewable energy can offer news jobs and contribute to the local economy rather than paying to import over $100 million of electricity from other regions. To further scope the potential energy future of the region a Local Energy Security Study was conducted as part of this sub project. The SA MDB region energy security was assessed as follows:

Dimension	Rating
Affordability	Low-Moderate
Adequacy	Moderate
Reliability	Low-Moderate

Drawing on the recommendations of the Local Energy Security Study and other work conducted for this Plan, it is recommended that the region:

- Ensure infrastructure matches growth aspirations by undertaking an **Electricity Reliability Enhancement Project** and **reviewing Natural Gas availabilit**y in the SA MDB.
- Promote local energy supply, particularly renewables, for the benefit of the local economy through developing a **Bioenergy Roadmap** and further scoping **Mid Scale Wind and Solar Opportunities**;

- Deliver greater influence over the region's energy future by conducting a **Regional Energy Cooperative Feasibility Study** and analysing the potential for P**ublic Institution Demand Aggregation**.
- Engage in a coordinated and strategic way with the community regarding renewable energy developments through preparing and implementing a ***Community Engagement Strategy for renewable energy in the SA MDB,*** which would provide a common understanding amongst the community of how consultation will be conducted with respect to major renewable projects and provide a way to facilitate new and diversified investment in the region consistent with community standards and values.
- Support development of two large scale renewables demonstration projects called the ***Murray Mallee Bio-fuel Trial*** and ***Establishing a wood biomass industry in the SA MDB***. These trials have been favoured because of the large potential for both activities to influence future land use change in the SA MDB but provide a new way for producing energy that engages with the primary production sector.

Tourism – Tourism is touted as holding major potential to help the region diversify its economy, which will become increasingly important if climate change reduces revenues from primary production. Yet the recent drought suggests that the region's tourism sector is vulnerable to perceptions about whether the region's major tourism drawcards – nature based tourism and food and wine – are worth visiting during extreme climatic conditions.

It is recommended that the region:

- Support development of a ***Blueprint for Tourism in a Variable Climate*** to develop forward thinking on how to build resilience in the region's tourism industry so that it is better able to cope with periods of drought. This includes how to counter negative publicity, much of which is based on perceptions rather than reality, associated with low river levels. Learning how to cope with periods of drought will enable tourism operators and the region to consider how best to prepare for and manage future climate change.
- Develop a ***Nature Based Tourism Action Plan*** to determine how to best leverage off of future investment in natural assets across the SA MDB through programs like The Living Murray and the Federal Government's new Biodiversity Fund. This would include specific analysis of how to progress regional authenticity developments combining food, wine and the environment.

The response of Local Government – Through stakeholder engagement, Local Government has been seen as a potential enabler of climate change adaptation, through facilitating community wide projects that can access low carbon communities funding, through to an inhibitor of change because of the challenges faced by proponents in understanding planning guidelines.

It is recommended that the region:

- Invest in clearer communication of how planning guidelines will be applied to new energy projects or changes in land use through developing a ***Planning for Climate Change Information Kit***. This will address requests by stakeholders that planners inform applicants as much as regulate their activities.

- Undertake a ***Capacity and Skills Assessment for Local Government Planning*** to understand the potential capacity and skill constraints presented by new applications for land use change (e.g. carbon farming, renewable energy) to Local Government planners and identify ways that these could be addressed.
- Develop ***a Decision Support Tool for Land Use Change for Carbon Sequestration*** to (a) provide guidance to landholders considering land use change to sequester carbon and (b) increase the knowledge of Council planners with respect the benefits and risks associated with commercial forestry.
- Further progress developing low carbon communities through a ***Green Towns Concept Plan*** which would build on the KESAB tidy towns model and seek to position the region to access funding through the Federal Government's Low Carbon Communities, with a focus on energy security for towns, energy efficiency for low income households and water security.

Collaboration, coordination and leadership – The SA MDB will face increasing pressure in the future to adapt to climate change. It will also be presented with an increasing number of economic opportunities as there is a national and international shift toward low carbon economies. New projects will be required in response to both drivers that require skilled people with relevant, innovative ideas and an ability to weigh up business risk, to work together. Strong, continued collaboration, coordination and leadership across the region will create a climate for investment.

It is recommended that the region:

- Build on the existing consortium of Councils and the SA MDB NRM Board involved with this sub project and develop a formal climate change adaptation alliance for the purpose of:
    - presenting a coordinated vision of climate change adaptation for the SA MDB that encourages investment in the region;
    - reducing potential duplication of effort as various regional entities determine what role they should play in facilitating climate change adaptation in coming years;
    - acquiring funding that will support diversification of the region's economy.

Knowledge about the potential implications and impacts of climate change on systems is essential to the development of well informed responses to climate change in the SA MDB. There is a considerable storehouse of knowledge on adaptation already in the region. This provides a foundation for the development of a more systematic approach to generating new insights into climate change and how we might manage it. As we seek to adapt it is vital that we learn from experience by carefully evaluating what we do, to both improve outcomes in the future and demonstrate the value of our efforts. Fostering the development of adaptive communities that have access to the latest knowledge and embrace innovation will be crucial in the years ahead.

It is recommended that the region:

- Build on the existing consortium of Councils and the SA MDB NRM Board involved with this sub project and develop an ***Adaptive Communities Innovation and Communications Plan*** in collaboration with researchers. This could include:
    - Preparation of a climate change adaption action, monitoring and evaluation plan;
    - Preparation of an adaptive communities research and development priorities strategy;

- Establishment of an Adaptive Communities web portal for knowledge sharing, skill development and networking.
- Development of an Adaptive Communities capacity building program.

6.1.5 *Determine Adaptive Strategies for Horticulture within the Loxton Region*

Background

A sub project led by the CSIRO was conducted in the Loxton region to help determine future horticultural adaptation strategies. It was entitled 'Developing Landholder Capacity to adapt to Climate Risks and Variable Resource Availability in the Bookpurnong and Pyap to Kingston-On-Murray Regions of the Riverland South Australia (MDP LAP)'.

The project was designed to improve future resilience of horticultural communities through the provision of a software information tool to assist making business decisions under future CC scenarios. This assists irrigators to better understand and predict production outcomes under a range of realistic CC scenarios.
This is particularly relevant given the likelihood that future droughts will be even more severe than the recent millennium drought and hence there are significant risks to future horticultural production. Irrigators need guidance on the effects of future availability of water and likely production outcomes with a range of climate scenarios.

The tool is called Land Use Strategic Assessment tool and is described in further detail below:

Integrated Land use Strategic Assessment (ILSA) tool

The tool focuses on addressing the financial risks of future production under changing climatic and water resource availability conditions, in a real life context taking into account current water entitlement and management arrangements. Itexplores adaptation options and the consequences in a range of water availability, climate conditions, crop mixes and commodity prices.

The tool addresses issues such as decisions about:

- whether to continue irrigating given uncertain future water availability,
- whether to remove certain blocks(crop areas) from production,
- whether to update with new varieties, or to abandon the block
- expected returns to future irrigation on average across possible future water availability and market price years, and
- the downside economic risks of possible future droughts

The tool also effectively translates CC science into a form that is suitable for communicating to irrigators and links scientific projections and outcomes to irrigators strategic business planning.

The tool is developed at the enterprise scale and combines scientific and individual production circumstance information in an easy to use and practical format. It presents historical and future climate in decadal sequences up to 110 year time-frames this enables a range of CC scenarios to be modelled to test outcomes and horticultural futures.

The tool provides the landholder with information on expected:

- costs,
- returns,
- water use,
- opportunities to sell water or need to buy water to meet a gap between available allocations and planned application rates.

ILSA can become a key management aid for determining future horticulture decisions as it allows the testing of the effects of changing crop types and varieties and levels of water application on outcomes.

Results/Outcomes

This sub project provided a sound opportunity to engage landholders in thinking and initiating planning for CC adaptation strategies. Many landholders involved had a high initial scepticism about CC and required significant interaction to consider how they might be able to use information that included CC projections.

A key finding was that landholders will only take account of CC and act on it if the CC information comes from trusted and known sources. Also, most CC scenarios have limited relevance unless translated into a format that is directly relevant and applicable to landholders.

The ILSA tool has been designed to be directly applicable to landholders through customisation where landholders input their specific horticultural and water use information. Tailoring the information and analysis for the individuals circumstances is an important aspect of the work and greatly increases the chances that the information tool will remain relevant and be used into the future.

Early feedback suggests the tool will be highly valuable for landholders, with landholders greatly valuing having access to more detailed analysis of possible future options.

> *The appealing part is that this "what if" exploration can be done with no risk, and provided there is sufficient trust in the validity of the inputs and plausibility of the outputs there is a good chance of having better informed landholders.*

The tool has been run using a 'sample farm' to test outcomes under a number of climate change scenarios. Farm data from a local stone fruit grower was used to test the model under multiple climate decades, water prices and commodity prices.

The main findings have been that:

- Under normal climatic conditions based on historical sequences drought states of nature (dry, very dry and extremely dry) are relatively rare;
- Taking into account future CC projections the drought states of nature become much more frequent and impact more significantly on business viability and profitability;
- The major impacts include reduced water availability, higher water prices and increased production costs;
- The capacity to trade in water significantly reduces impacts, for example without water trade the millennium drought looks a lot worse for the sample irrigator with considerable declines in net returns and in some varieties and states of nature an economic loss.
- Adaptation is impacted by crop mix, price of commodities and water and the costs of irrigation activities.

Future Directions

The tool has proven highly useful but requires translation into a practical application. This requires on-going awareness raising programs to promote the availability of the tool as well as directed workshops using the tool as a focus for option development and adaptation discussions.
The workshops would also provide valuable data regarding irrigation crops, water use and potential to remain profitable under a range of climate change scenarios. This will greatly help in planning future research and potentially policy programs.
Further development of the tool can potentially be undertaken within a wider business model support model currently being employed by Primary Industries and Regions South Australia and groups such as the Riverland Taskforce.
The tool can potentially support future investment opportunities and encourage landholders to look into the long term and weigh up potential risks to future viability.

6.2 Eyre Peninsula

The EP region was the second region involved in the project. The project methodology gathered the regional biophysical and demographic data, applied modelling to develop outputs associated with CC scenarios and through that identified areas and activities subject to change and adaptation options that could be considered.
The EP sub project was called '*Eyre Peninsula Landscape Futures*' used CC scenarios to look at a range of land-uses, biodiversity and social and economic factors.
A series of system models/modules were applied or developed to gain an understanding of the spatial distribution and the size of possible responses to CC. These were:

- **APSIM- Productivity of wheat** - Wheat production is a major economic driver for the region and reduction in potential yields will have a significant effect on rural livelihoods. The impact of CC on wheat productivity was simulated using the APSIM model. The model was implemented using local weather, soils and agronomic practice, the outputs were validated from measured yields and then it was applied with CC scenarios to estimate in yield. See the Technical Report for details;

- **Wheat Economics Modelling**- This used the wheat productivity modelling of yields to develop economic models of the viability of future wheat production under CC. Costs associated with wheat production were drawn from annually published cost estimates;
- **3PG2 – Biomass and Carbon Sequestration Modelling**- The 3PG2 model, designed to describe forest growth was adapted to apply spatially and to represent potential plantings of forest species, oil mallee or a biodiverse mix of species. The outputs were verified with locally relevant data. The future opportunity for the production of biomass and reafforestation for carbon sequestration was estimated. This provides potential benefits such as reduced greenhouse gas emissions and economic returns for farmers (Bryan et al., 2010a; Bryan et al., 2010b).
- **Biomass and Carbon Sequestration Economics Modelling**- Economic models of the future viability of biomass and carbon sequestration were developed and applied based on estimates of carbon accumulation and required input costs.
- **Biodiversity Modelling- Species Vulnerability under Climate Change**- Information from botanical surveys was used to identify the recorded distribution of 285 species in the region. This information was then used to characterise the habitat characteristics for the species. With CC scenarios, new distributions were estimated that identified species that may shrink, expand and/or shift their geographic range; Many species may have changing distributions under climate change. Understanding how they are likely to change may help prevent the loss of species and biodiversity through targeted planning and conservation. There may also be opportunities for biodiversity linked to alternative land uses such if biomass and carbon sequestration.
- **The influential factors for climate change adaptation and decision making** - Analysis of the CC and rural decision making literature identified a multi-scaled conceptual model to understand the factors influencing rural regions to adapt to CC. One significant factor examined in depth was the current influential people and the degree of social networking existing within the EP.

The project received strong support from the EP NRM Board staff and board members who were represented on the PSRF management and advisory groups. Other stakeholders in the region also participated and shaped project directions including SARDI, PIRSA, DENR, Rural Solutions and primary producers. This improved project outcomes by ensuring that the project had relevance and was able to influence NRM planning processes in the region and also assisted in the introduction of new institutional arrangements to support CC adaptation.

6.2.1 Collate Baseline & Refine CC Adaptation Methodology

Baseline data for the project was collated from a range of sources and details are provided in the Technical Report. The sub project was implemented with the following approach:

- Identify the relevant natural resource issues and community requirements for adapting to CC including consideration of relevant NRM targets;
- Formulate and agree on future climate scenarios (one baseline from historic climate data and three potential climate change;

- Use a series of models to assess the effect of CC on the biophysical, ecological, social and economic aspects of the EP region;
- Integrate the findings in analyses that explore potential landscape future options and their regional impact; and
- Ensure that project outputs are used to inform community and NRM plans, with the choice of preferred options to be made by the community and NRM Board.

Further detail on the methodology and approaches taken can be found in the Technical Report.

6.2.2 Application of Climate Change Scenarios

The climate change projections applied to the EP included:

- Scenarios taken form IPCC projections for Australia with declines in rainfall and increases in temperature and carbon dioxide;
- EP region specific climate change projections taken from BoM and CSIRO which incorporated more precise seasonal reduction in rainfall; and
- Climate Change projections for specific modules of the project including wheat productivity and profitability, 3PG-Carbon Sequestration, 3PG Biomass and biodiversity. For each of the datasets defining the baseline scenario for the various modules, data for the climate change scenarios [mild (S1), moderate (S2), and severe (S3) warming/drying] were created by modifying the baseline temperature, rainfall and CO2 records by the relevant amounts. Solar radiation was kept constant for the change scenarios.

Key Findings

Seasonal climate change projections identified by BoM and CSIRO for the Eyre Peninsula in 2030 and 2070 show an overall increase in temperature and decrease in rainfall. By 2030, the 50th percentile (best estimate) under medium emissions is for annual temperatures to increase by between 0.8°C and 1.75°C by 2070. The best estimate for annual rainfall under medium emissions is a reduction of 3.5% by 2030 and a reduction of 15% by 2070. There is more confidence in the projections of temperature than rainfall.

The sub-project had a particular emphasis on future rainfall reliability under CC as its seasonal timing as well as the total amount is a key determinant of crop growth and yield.

CC projections for seasonal rainfall reduction for 2030 were 3.5% in Autumn, 7.5% in Winter and 7.5% in Spring). This projected decrease occurs across the EP. Alternatively CC projections for seasonal rainfall reduction in 2070 were as much as 7.5% in autumn and 15% in winter. Spring showed the most significant reductions in rainfall reliability, although this was distributed unevenly across the EP region: For example:

- Penong is a low rainfall region that currently has a 70% probability of receiving rainfall of greater than 30mm. Using CC projections indicates a reduction to 40% probability of falls of 3mm or more.
- Streaky Bay is a medium rainfall area that which has a 75% probability of receiving rainfall greater than 40mm. This probability is projected to fall to 50%;
- Cummins is a high rainfall area that shows a similar 25% decline from 75% to 50% in the probability of receiving 50mm or greater.

These predictions effect current crop management and future adaptation options. In low rainfall areas, cropping will become more marginal and future land use options are needed that can cope with significant reductions in the mount and distribution of rainfall, particularly in spring. Some areas with higher rainfall have less reliance on spring finishes and will be able to cope with lower spring rainfalls. However, secondary influences like soil types will play a greater role in their future management of CC.

6.2.3 Quantify Response to Climate Change Scenarios

The project assessed the impact of climate change on a range of bio-physical, social and economic values as shown below:

Productivity of wheat cropping under climate change

Crop modelling was used to identify the impacts of CC on wheat production on the Eyre Peninsula. Wheat productivity on a sub regional scale was aggregated into their corresponding rainfall zones described as low, medium and high. Potential wheat yields were simulated under the baseline (S0) and the six future climate scenarios (S1 to S6).

Results found that CC will affect crop productivity differently across the sub-regions of Eyre Peninsula. These effects will depend on rainfall and temperature interactions and to a lesser extent the soil types on which the crops are grown.

Applying the S1 and S4 scenarios gives an indication of what the potential climate could be in the next ten years or if significant CO_2 mitigation efforts were undertaken soon. Results show increases in wheat yield due to the increase in temperature and CO_2 level and limited reduction in rainfall across all rainfall zones.

Applying the S3-S4 CC projections (a possible climate for 2030), show a reduction in average yields in the majority of localities that make up the low rainfall zone. Changes in soil texture, a graduation from coarser to finer textures, show an increase in yields for the coarser textured soil in the medium and high rainfall zones. Spatial variation in the impacts of these CC projections exists across all rainfall zones.

Applying the S6 CC projection shows large yield reductions in the low rainfall area, apparent on finer textured soils. In medium rainfall zones, slight increases in yield on coarser textured soils but yield reductions (10-30%) across finer soil types. In higher rainfall areas, similar simulated yield trends are

apparent with greater increases (0-20%) on average on coarser and 0-20% yield reduction on finer soil types.
The management of different textured soils through opportunistic cropping or selection of soil types for land –uses change will play an important part in CC management in areas across the EP.

Productivity of wheat

Crop modelling shows that there are a variety of yield consequences with the interaction of climate change scenarios and soil types within the current climate zones.

For the milder climate change scenarios (S3-S5), simulated yield results highlight that only a small reduction in production will be evident in the low rainfall zone. While this seems small (around 200kg/ha) in absolute terms, the reduction is quite significant because of the regions current yield capacity (current average production for a farm is around 1-1.2 t/ha). Textural differences between soil types in this zone have only a minor influence with rainfall the limiting factor. Extreme or longer term projections show that simulated wheat yields will reduce considerably. Given this may represent a climate for 2030 there may be some urgency to change in this region either through the adoption of different agronomic practices or adoption of different land uses.

Milder CC projections for the medium rainfall zone show similar reductions in average yields but these reductions do not have the same relative impact due to these regions generating higher yields. For extreme or longer term CC projections the distribution of soil types will play a more dominant factor especially for soils with deep finer textured soils. Economic analysis of cropping enterprise will come into play in this region to determine farm business and community viability. A patchwork of cropping and other land uses such as carbon sequestration may be possible in this region with the loss of income from cropping offset by payments for carbon sequestration.

Milder CC or short term projections for the high rainfall zone show increases in simulated wheat yields across the region with negligible reductions across soil types. Longer term or more extreme CC projections show yield increase with coarser textured soils and decrease on finer textured soils. Although different yield trends exist, increases in yield on coarser textured soils show only small relative increases because they come from a smaller yield base. These simulated yield increases do not offset the reduction on the finer textured soils. While this CC projection causes large yield reductions, the productivity of the soils still remains substantially high. Agronomic changes and crop management might provide the best CC adaptation strategy in this zone since the cropping may be still more profitable than other alternative land-uses. Alternative land-uses may also be constrained since the high rainfall zone of the EP is a significant water catchment area.

Running economic analysis on this simulated datasets re-enforce these conclusions that low rainfall areas in the short term or under in mild CC projections are highly vulnerable and in the longer term or extreme CC scenario are unviable. Medium rainfall zones in the longer term are vulnerable. In the immediate future yields across the EP will increase marginally.

Broad mapping of the EP soil types has given us the ability to extrapolate the impacts of CC on wheat yield which has allows for the spatial comparison of economic trade-offs with other spatially distributed datasets.

The spatial distribution of climate, soils and their interactions with the CC projections has been shown through crop modelling to have different impacts on wheat yields in different areas. A range of strategies will be needed and will have to be implemented across different timelines and in different rainfall areas to keep the EP agricultural community financially viable.

Wheat Economic Modelling

Wheat Economic modelling was undertaken to examine the economic viability of wheat production under future CC projections for low, medium and high rainfall areas of EP.

Costs for wheat production were derived from Rural Solutions gross margins handbook and ABARE surveys.

The model showed that northern areas of EP will be the first to become unviable for wheat production in the first instance due to declines in rainfall and rainfall reliability.

Biomass Production and Carbon Sequestration

$3PG_2$ was used to predict forest productivity (biomass yield) for homogenous plantations of 2 *Eucalyptus* species (*E. cladocalyx, and E. kochii)* and a multi-species environmental plantation, based on climate data modelled for each of the four climate scenarios (S0, S1, S2, S3).

E. cladocalyx is among the most common species used in commercial plantations in southern Australia, with the potential to store large amounts of carbon through reafforestation over the long-term (Almeida et al., 2007; Polglase et al., 2008). *E. kochii* is a drought-resistant mallee species that has the potential to be useful in the production of bioenergy from biomass and eucalyptus oil when coppiced on short rotation under dry conditions (Bryan et al., 2010a; Wildy et al., 2004).

$3PG_2$ models forest growth patterns based on the absorption of photosynthetically active radiation (PAR) and constrained by environmental variables including temperature, vapour pressure deficit (VPD), frost, available soil water (ASW), stand age and site nutritional status. The selected outputs from $3PG_2$ were the total biomass of forest trees per hectare (tonnes dry matter/ha), allocated between foliage, root and stem.

Each of these individual species (*E. cladocalys* and *E. Kochii*) are suited to different growing conditions. Under the spatially heterogeneous environmental variables across the EP NRM region each species will be better suited to different areas.

The level of biomass and carbon sequestration for each species from 2006-2070 is shown in the following figures and tables:

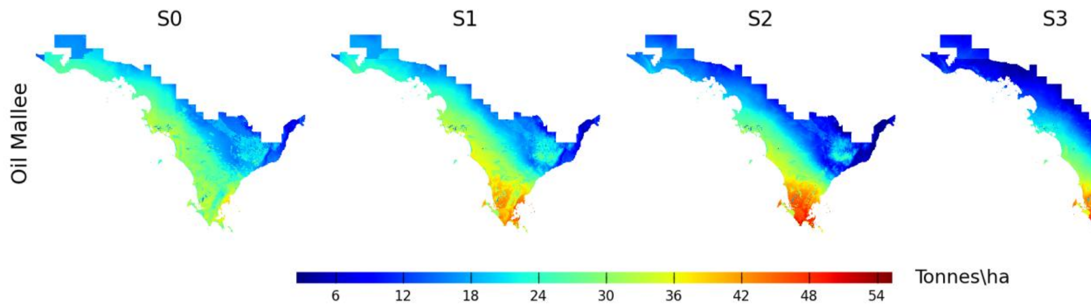

Figure 6.1 Productivity of Oil Mallee in the Eyre Peninsula after 6 years (t/ha)

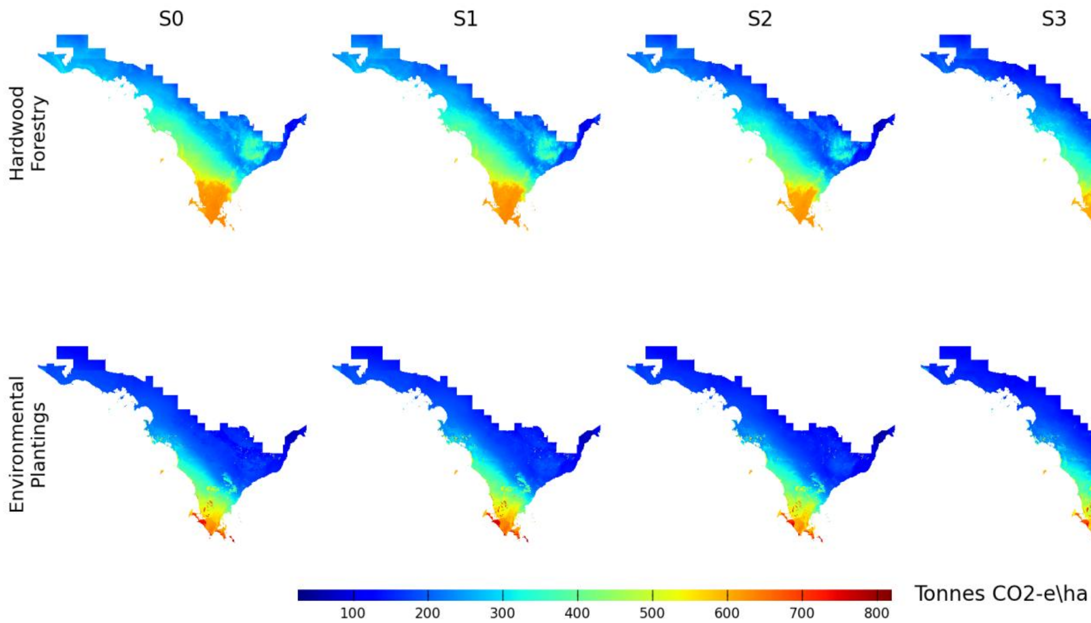

Figure 6.3 Estimated CO2 sequestration potential of Hardwood Plantations and Environmental Plantings in the Eyre Peninsula after 64 years (t/ha)

The results for hardwood plantations show that:

- Total carbon sequestration for the modelled hardwood plantations (Eucalyptus *cladocalyx* around 326 tonnes per hectare at a rate of approximately 5 CO_2^{-e}/ha/year under the baseline scenario;
- Carbon sequestration rates under the baseline climate varied substantially across the study area ranging from 1.4 tonnes CO_2^{-e}/ha/year in the drier areas up to around 10 tonnes CO_2^{-e}/ha/year in higher rainfall regions;
- Average annual sequestration rates reduced by approximately 4.8% under the mild, 15.3% under the moderate and 26% under the severe climate scenario over the 64 year simulation; and
- More productive high rainfall areas experienced small reductions (e.g. up to 2.4% under S3) compared to the low rainfall areas (e.g. up to 71% under S3).

The results from modelling the environmental plantings show lower carbon sequestration levels:

- Total carbon sequestration for modelled environmental plantations was around 227 tonnes/ha rate of approximately 3.5 tonnes CO_2^{-e}/ha/year over the 64 year simulation under the baseline scenario;
- Sequestration rates under the baseline scenario varied spatially, ranging from 0.9 tonnes CO_2^{-e}/ha/year in the arid regions up to around 12.5 tonnes CO_2^{-e}/ha/year in the higher rainfall regions;
- Average annual carbon sequestration rates of environmental plantings decreased by approximately 2.3% under the mild, 3.5% under the moderate and 9.4% under severe climate change scenarios'
- Overall, environmental plantings were more resilient to climate change scenarios than hardwood plantations;
- Some of the more productive areas experienced an increase in carbon sequestration rates with increasing warming and drying; and
- Increases of up to up to 2.4% under the severe warming and drying scenario were modelled.

In low productivity areas sequestration rates decreased by up to 54.3% under severe climate change in the low productive areas.

The results for biomass production show that:

- Under the baseline scenario, modelled total dry weight of biomass production averaged 22.6 tonnes per hectare with an annual growth rate of 3.8 tonnes per year over the first 6 years;
- Spatial variability ranged from less than a tonne per year (0.7 tonnes/ha/year) in lower rainfall areas to 6.7 tonnes per year in more productive, higher rainfall areas;
- Average growth rates for oil mallee increased under the moderate climate scenario by 4.7%, but decreased by 10.8% under the moderate and 34.5% under severe scenarios; and
- Decreases of up to 41% were modelled in low rainfall areas under the severe climate change scenario. In contrast, growth rates increased in high rainfall areas, with increases of 18.6%, 29.6% and 37.8% observed for mild, moderate and severe climate scenarios respectively.

Plant Species Vulnerability under Climate Change

The vulnerability of 285 native plant species was modelled across the fragmented agricultural landscape of Eyre Peninsula NRM region under three climate change scenarios (S1, S2 and S3) (see Section 3.1) This assessment incorporated the three components of vulnerability (exposure, sensitivity and adaptive capacity) and was adapted from a methodology developed for the Lower Murray (Crossman et al., 2012; Summers et al.,2012).

Species distribution modelling was used to project species potential distribution under different climates (S0, S1, S2 and S3) and provide a measure for species exposure to climate change. The species distribution modelling was carried out using an ensemble of three individual niche-based models logistic regression, generalised additive model and a maximum entropy model. The individual niche-based models use known species locations from the Biological Survey of South Australia and five independent predictor variables (Soil clay content, Soil pH, Temperature, Rainfall, Solar radiation).
The sensitivity of species to each climate change scenario was calculated based on the relative change in distribution between the current climate and the change scenario and quantified species

dispersal potential from known locations to provide a measure of adaptive capacity. Each of these elements – exposure, sensitivity and adaptive capacity – were combined using landscape prioritisation software Zonation (Moilanen and Kujala, 2008b).

The accuracy of the species distributions predictions for the current climate (S0) were validated using area under the curve (AUC) analysis (AUC = 0.832, S.D. ± 0.0089).

Most plant species modelled were found to have reduced distributions under each of the climate change scenarios; 150 species (52.3%), 160 (55.7%) and 162 (56.9%) under the mild, moderate and severe climate scenarios respectively.

The species sensitivity was calculated as the difference between the current climate and each of climate scenarios divided by the climate scenario. Species more adversely affected by drying and warming have higher weights while those less affected have lower weights.

The sensitivity weights ranged between 0.0044 and 12.14 for the mild climate scenario, 0.078 and 216.8 for the moderate climate scenario and 0.077 and 1056.0 for the severe climate scenario. A single generic kernel was used to calculate the dispersal kernel for each of the species and represent species adaptive capacity. The generic kernel, a negative exponential function, was chosen to represent species dispersal over several generations. This provides a dispersal potential layer with higher potential dispersal close to known species locations and reduced potential further away.

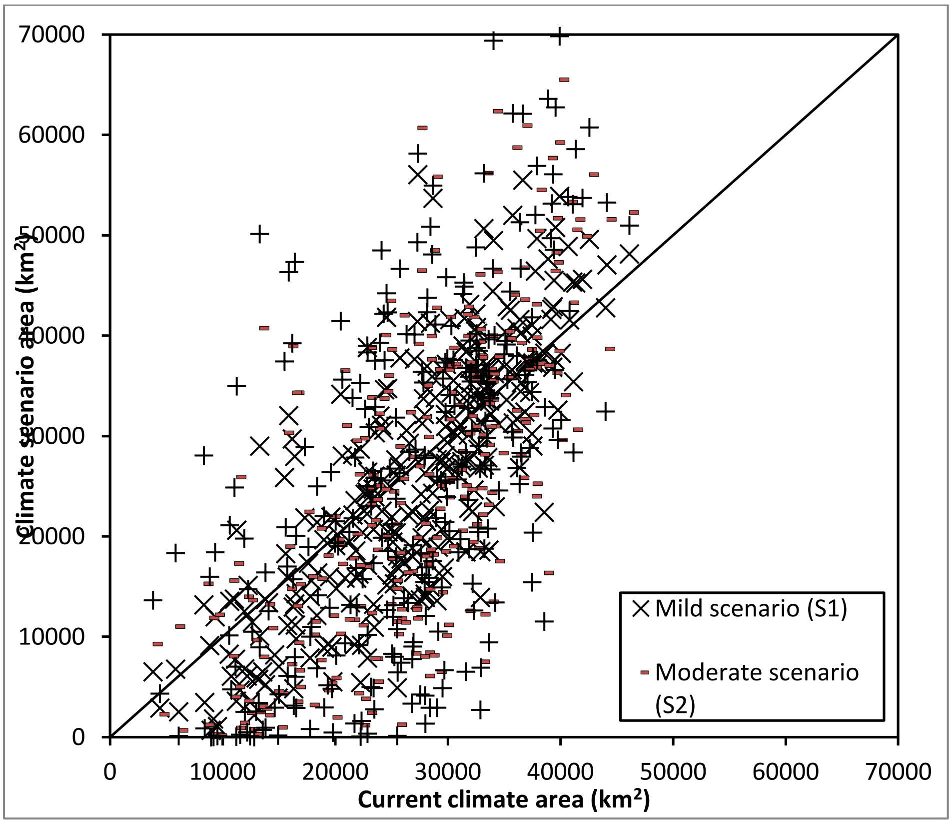

Figure 6.4 Shows the current and predicted areas for each species under the three climate change scenarios. The species with marks below the one to one line have reduced distribution under climate change.

All of these components were combined into the full vulnerability framework using the landscape prioritisation software Zonation (Moilanen 2008). The exposure (species distribution modelling) and adaptive capacity were combined to produce a single combined spatial layer that was used as the input in the landscape prioritisation. The species sensitivity weights were used to weight each individual species in the prioritisation. The output from the Zonation software is a hierarchical classification of the landscape prioritising areas that are more important for vulnerable species.

6.2.4 Determine Adaptive Strategies Across Region.

Wheat Production

The modelling results suggest that wheat farming particularly in the northern areas of EP is likely to become more marginal with significant declines in yield and economic productivity.
An appropriate adaptive management response is for farmers to diversify their farming enterprises to include enterprises of a lower risk profile including live-stock production, carbon capture, biomass production, bio-energy and bio-fuels. Cropping is likely to become more opportunistic in nature.

More detail on viability of some of these initiatives is seen in the Biomass Production and Carbon Sequestration section.

Carbon Sequestration and Biomass Production

The viability of incorporating carbon sequestration plantings and biomass production into agricultural productions systems is dependent upon spatial variability as well as market forces such as commodity price. However, determining the future viability of these practices as an adaptation strategy requires consideration of the trade-offs in changing land-use. These trade-offs include higher water and soil nutrient demands, and a reduction in the amount of arable land available for food, fuel and fibre production. Changing to alternative land-uses also includes high establishment costs, initial loss of revenue and increased levels of risk associated with land use change.

It is therefore important to model the economics of carbon sequestration and biomass production to understand their applicability across the region as an adaptive strategy. For each of these production systems a range of costs were identified. For carbon sequestration these were; establishment, maintenance and transaction costs. For biomass production there are additional costs including harvest, fertiliser and transport to processing plants.

Five carbon prices were assessed as part of the economic modelling of carbon sequestration (\$10/tonne/ CO_2^{-e}, \$20/tonne/ CO_2^{-e}, \$30/tonne/ CO_2^{-e}, \$40/tonne/ CO_2^{-e} and \$50/tonne/ CO_2^{-e}. Three of these prices were examined as part of the biomass economic modelling. Biomass prices were calculated relative to projected carbon and electricity prices (see Table 7). The costs associated with each land use were incorporated into the economic viability assessment.

Table 7 Relationship between carbon price, electricity price and farm gate biomass price

Carbon Price	\$30/tonne CO_2^{-e}	\$40/tonne CO_2^{-e}	\$50/tonne CO_2^{-e}
Relative Electricity Price	\$68/MWh	\$88/MWh	\$103/MWh
Relative Biomass Price	\$19.18/tonne	\$100.18/tonne	\$167.68/tonne

The economic modelling identified that the area of land viable under carbon sequestration was highly dependent on carbon price and climate. Hardwood plantations were viable across a larger part of the study area than environmental plantations for each of the climate change scenarios, however, environmental plantations generally displayed a higher resilience to climate change. No areas within the Eyre Peninsula region were viable under a carbon price of \$10/tonne/CO_2^{-e} for either land use. Biomass viability across the study area increased significantly with a carbon price increase from \$30/tonne/CO_2^{-e} to \$40/tonne/CO_2^{-e}. For all climate scenarios, over 90% of the study area was viable under a carbon price of \$50/tonne/CO_2^{-e}.

Hardwood and environmental plantations have multiple benefits to the enterprise including increased shading and stock shelter, reduced wind erosion, increased aesthetics and social value, reductions in temperate and reduced loss of humidity. Environmental plantations also include habitat and biodiversity benefits. These benefits provide additional incentives to invest in such options aside from purely economic gain. It also increases the potential opportunities to apply for resources to achieve multiple benefits, for example, the Commonwealth government biodiversity fund which incorporates carbon capture plantings into meeting state and national biodiversity priorities.

Due to the high establishment costs, government policies are required to enable cost sharing and provide incentives for landholders in order to make carbon sequestration and biomass production an attractive investment within the Eyre Peninsula.

Species Vulnerability under Climate Change

Climate change will likely have significant impacts on species distributions with many experiencing shrinking, expanding and/or shifting geographic ranges (e.g. Santos et al., 2009; Schneider et al., 2007; Vos et al., 2008). Many species will become more vulnerable if natural migration is hindered by landscapes altered by humans (Manning et al., 2009). Hence, targeted conservation is required to facilitate adaptation and migration, especially for the most sensitive native species.

The vulnerability framework of exposure, sensitivity and adaptive capacity (see section 1.1.3) can inform spatial priorities and help target conservation actions to facilitate these actions. Figure 6.5 demonstrates the landscape prioritisation carried out using the full vulnerability framework and also the different combinations of the components.

Using all three components of vulnerability (exposure, sensitivity and adaptive capacity) priority areas were concentrated in more southern latitudes and higher altitudes (Figure 6.5a-c). These areas are typically cooler and wetter are likely to become rarer under climate change. In the mild warming and drying scenario there some localised priority areas in the far west however, these areas are less of a priority under the moderate and severe climate change scenarios. These localised priority areas in the far west would typically have higher rainfall than the inland, central districts. Overall the prioritisation of these areas that can be seen as cooler and wetter is consistent with the findings of other studies from around the world (e.g. Carvalho *et al.*, 2010; Engler *et al.*, 2011; Garzón *et al.*, 2008; Thuiller *et al.*, 2005).

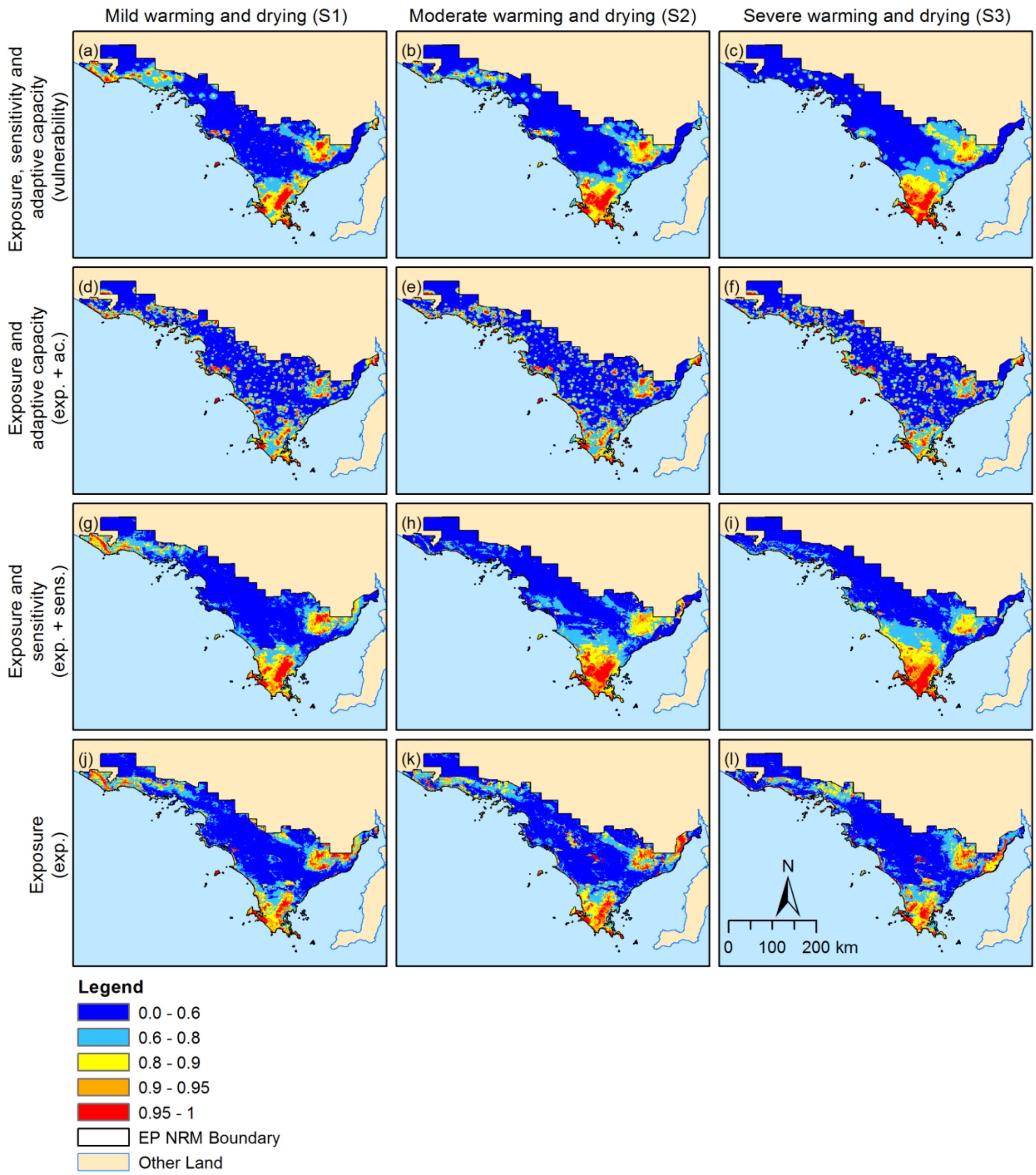

Figure 6.5: Spatial conservation priorities identified using exposure, sensitivity and adaptive capacity (vulnerability) (a-c); exposure and adaptive capacity (d-f); exposure and sensitivity (g-i) and exposure alone (j-l).

Landscape prioritisations carried out with the other elements of the vulnerability framework return the same overall pattern as the full vulnerability analysis with an emphasis on lower latitudes and higher altitudes.

However, there is still significant variation in the areas prioritised and this is reflected in the low to moderate correlation between the prioritisations carried out with the different components of vulnerability. These differences are also evident in the localised prioritisations, particularly using exposure and adaptive capacity (Figure 6.5d-f) and to a lesser degree exposure (Figure 6.5i-j). Importantly, there are also differences in the species representations with the various levels of analysis. Using the full vulnerability framework prioritised the most sensitive species in the landscape and this is less the case of the other components of the framework.

While we advocate consideration of exposure, sensitivity and adaptive capacity for targeting spatial areas for conservation actions aimed at reducing species vulnerability to climate change (see also Crossman *et al.*, 2012, Summers *et al.*, 2012). Our results demonstrate that this strategy comes at some costs with a trade-off between sensitive species and the representation of other species. These trade-offs highlight the importance of complementarity-based spatial prioritisation and represent a significant advance over previous studies (e.g. Crossman et al., 2012). These trade-offs are also the central theme in the various arguments around conservation triage (e.g. Bottrill et al., 2008; Wilson et al., 2011) including whether or not to undertake cost-effective allocation of conservation funds or whether to focus investment on priority species.

The results of this study have practical implications for conservation agencies. Different arrangements of spatial conservation priority resulting from the inclusion of different components of vulnerability and the trade-offs in species representation have significant implications for conservation investment. Expensive conservation actions such as land acquisition, pest species eradication, ecological restoration, and fencing and livestock removal need to be spatially targeted to achieve efficient outcomes (Wilson *et al.*, 2010). These results highlight the need for agencies to have clear objectives when targeting areas for nature conservation under climate change.

Strengthening Social Capital and Resilience to Climate Change

Research was undertaken in the EP to understand the functioning social networks and their relative capacity to contribute towards appropriate NRM programs as would be required in CC adaptation. This helps set the scene for determining appropriate CC adaptation strategies in the region.

Social Network Framework

A social network framework has been defined here using a nester layered approach, with the following layers:

> *layers of individual, household, farm, farmer typology, Community level, Community typology, Bio-region, Governance- regional and state and national.*

The modelling found that no one factor is most important in determine social and community resilience and examining in a nesting scale helps to identify indicators for CC adaptation for the region and help target policies to influential factors at each level of the hierarchy.

This helps identify the potential bottlenecks to CC adaptation across the different scales.

This hierarchy helps to understand the drivers in decision making at a landscape level, characterising influences at particular scales for decision making.

The social network framework helps understand how the EP region can adapt to CC through having informed leaders and methods to build community capacity.

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Social Ecological Network Modelling

A social ecological network was modelled to illustrate the EP as a network of players working together and interacting to generate outcomes. This acknowledges the importance of the social network in facilitating change, uptake of new initiatives and achievement of required NRM goals.

The study focused on efforts to implement biodiversity conservation programs looking at the combined effects of a range of stakeholders.

This data, once analyzed, provided a list of stakeholders along three main axes:

- whether the stakeholder implements or promotes EP biodiversity conservation programs
- whether the stakeholder affects, or is affected by, EP biodiversity conservation programs
- how influential the stakeholder is perceived to be in pursuing his/her goals

This list effectively identified the main nodes of the network, as well as setting its boundaries.

Following the initial face-to-face interviews, an online questionnaire was developed to study the large-scale structural qualities of this complex social network. The aim was to reach anyone who had, in the last 3 years, been involved in any project or program, directly or indirectly, related to biodiversity conservation on the EP.

In order to determine strategies of adaptation the resilience of the social-ecological network was assessed, to identify areas of potential robustness, vulnerability and high learning and adaptive capacity.

The results showed a high level of social capacity which can be valuable for achieving positive NRM outcomes as evidence by a large number of connections between nodes (Figure 6.2). However the strength of links vary.

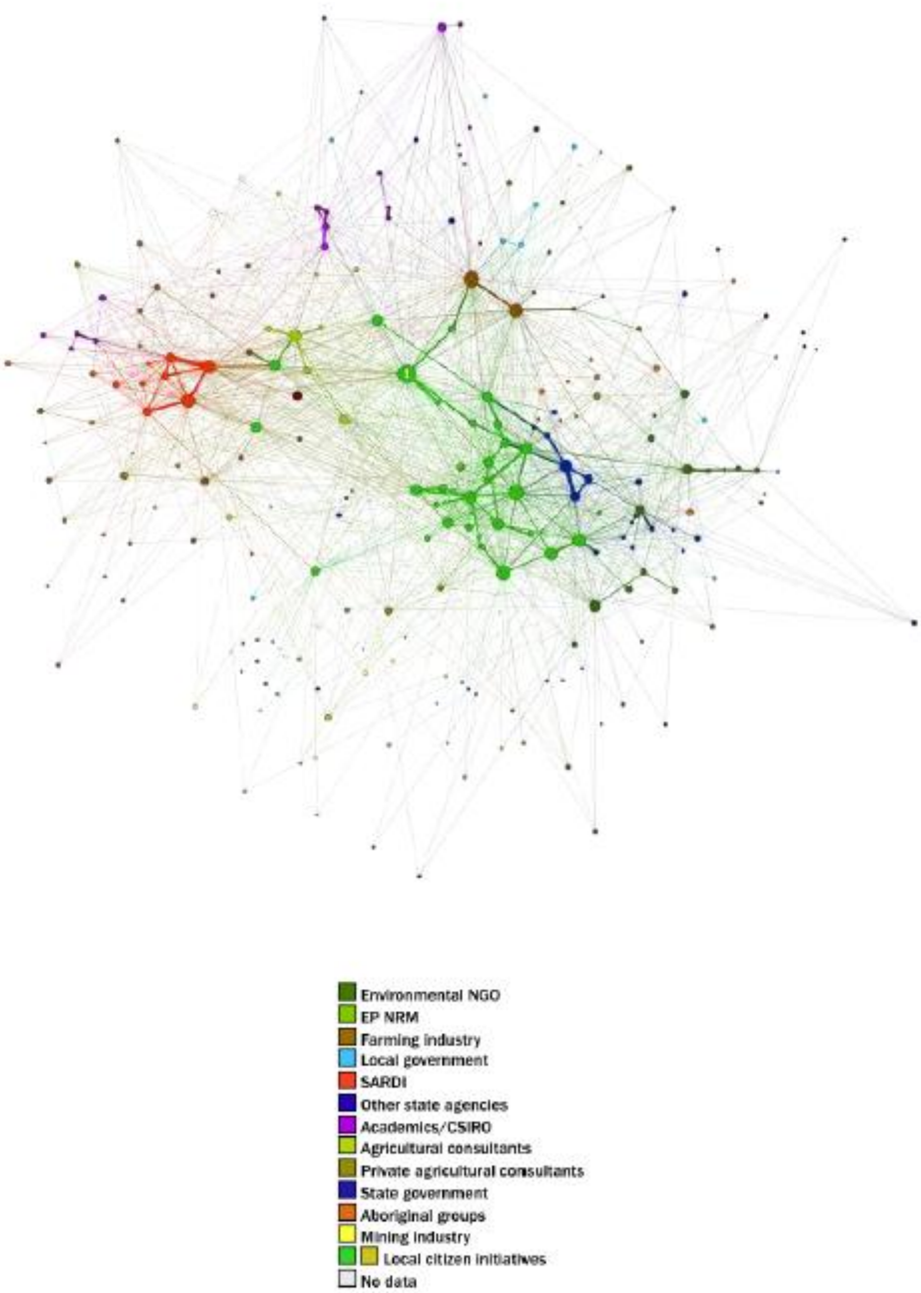

Figure 6.2 Presentation of the network of information and knowledge sharing among actors for the EP.

Nodes represent actors (Stakeholders), their colours represent the category or group they belong to, and the edges (whose thickness is relative to the frequency of interactions) represent information or knowledge sharing or lack thereof. Finally the size of nodes indicates their Eigenvalues, that is the level to which they each contribute to the general connectivity of the network (Technical Report).

However, it is clear that there are stronger ties between nodes belonging to similar groups which potentially indicates specialisation and development of new ideas within specific groups which can potentially assist adaptation strategies.

It is also clearly evident that a small number of nodes are responsible for keeping the whole network connectivity and if those nodes were to disappear, the social capital would most likely be diminished. Furthermore, one node (noted "1" in the graph) is really significant (highest eigenvalue) and removal of this node would be most significant particularly as it connects several important sub-groups (EP NRM, SARDI, members of farming industry). Academic and research (CSIRO) nodes are more peripheral to the network but connect several important groups.

These results will inform stakeholders on the strength and ability of this structure to continue looking after the valuable biodiversity assets of EP in a changing environment. They will contribute to a better understanding of biodiversity conservation on the EP.

It also indicates the importance of maintaining the network in its current form to assist in the formulation and dissemination of CC adaptation strategies.

7 OVERALL OUTCOMES

7.1 *INDUSTRY, COMMUNITY & STAKEHOLDER ENGAGEMENT*

The project has been highly successful in engaging industry, community and stakeholders within the regions. This was achieved through meetings, workshops, detailed consultation, one-on-one engagement and attendance at relevant representative groups and workshops.

The project targeted a range of industry groups including:

- Wheat growing groups through engagement with Minnipa Research Centre, Agricultural Advisory Board and through participation in Field Days and inclusion of staff from Rural Solutions;
- Engaging with the EP CC Regional Sector Agreement Committee that has representatives from community and industry groups in the EP;
- Engaging with Local Action Planning and horticultural groups in the Loxton to Bookpurnong region through the SA MDB sub-project to determine appropriate strategies for horticultural adaptation;
- In the SA MDB a Consultation Reference Panel was formed to provide input and direction to the sub project and included representation from horticultural groups, dry land farmers, graziers, irrigation trusts, wine industry, dairy farmers and tourism interests;
- Involvement and input into the project by Regional Development Australia, Murraylands and Riverland who have strong linkages and relationships with industry groups.

A range of community and stakeholder groups were engaged and involved in the project including:

- Regional NRM Boards- They helped lead and direct the project and were represented on the management and advisory groups of the project;
- State Government- They provided significant project direction and support through membership on management and advisory groups and direct project participation;
- Local Government- In the SA MDB, 11 local governments were project partners exploring strategies to understand the implication of CC and how they might adapt; this has resulted in increased awareness of CC effects being considered in any council plans.
- Local Action Planning Groups- Provided major input through membership on SA MDB Consultation Reference Panel and involved in direct project implementation in Bookpurnong region;
- Aboriginal Groups- Aboriginal groups were represented by involvement of a aboriginal project officer from the SA MDB board on the Consultation Reference Panel;

The aim of the engagement was to raise awareness of and capacity in understanding what adaptation to CC might be necessary in their jurisdictions. The outcomes of the involvement of these groups is summarised in Section 5.2.3.

A significant development in the EP region that is consistent with important findings from this project was the formation of the EP CC Regional Sector Agreement as described below:

7.1.1 EP CC Regional Sector Agreement

The EP CC Regional Sector Agreement is the first in Australia to develop a joint commitment to respond to CC by focusing on strategies of adaptation and identifying economic opportunities.
The sector agreement is an agreement between the following agencies:

- SA Minister for Sustainability & Climate Change;
- Eyre Peninsula Natural Resources Management Board;
- Eyre Peninsula Local Government Association; and
- Regional Development Australia (Whyalla & Eyre Peninsula)

A major aim of the sector agreement is to develop a five year action plan which will

- Be based on evidence and scientific research;
- Identify common interests and recognise that key communities may need specific responses;
- Complement existing policies and programs.

The sector agreement will also involve major collaboration with research institutions such as CSIRO, SARDI, DFW, PIRSA, DENR, University of Adelaide, Uni SA and Flinders University.

7.2 Climate Change Adaptation Strategies

A range of CC adaptation strategies have been identified in this project across both the EP and SA MDB regions. Some important generalisations can be made regarding adaptation strategies:

- A research base is fundamental for contributing to CC adaptation and future planning. Modelling provides valuable insight into strategies suitable for specific locations and how to optimise a range of landscape values and socio-economic factors across the landscape.

- Scaling CC projections to a local level is fundamental for developing on-the ground CC adaptation strategies. For example, the ILSA tool scales down CC projections to a horticultural enterprise level.

- There is scope to adapt current methods of primary production, including wheat sheep systems though careful and informed diversification. In the case of irrigated horticulture adaptation and diversification may be possible by changing crop types, varieties and improving water use management and using contemporary business planning;

- CC projections indicate that in some cases, current forms of primary production will become unviable depending on the location and type of enterprise, e.g. wheat production in the northern areas of EP is likely to become more marginal as yields are decreased below already low yields by less rainfall.

- A major mode of CC adaptation is the emergence of new industries and initiatives such as bio-fuel, biomass production and tree planting for carbon capture/sequestration that link, for example, into the Australian Government's Clean Energy Plan. Economic modelling and forecasting helps indicate the locations and conditions through which this become viable.

- Successful CC adaptation requires whole of region planning with clarity around roles and responsibilities. Local government has an important role in facilitating change while on-going research is needed to continue to develop and help evaluate new systems.

- Specific industry sectors such as tourism and food production need specific adaptation plans. This may require some lateral thinking, e.g. tourism needs to link more closely into biodiversity conservation sites. Adaptation requires further building of community capacity and fostering leadership in the community including new institutional arrangements such as the EP Sector Agreement. It is important to maintain the current social fabric and social network of players that help ensure NRM strategies can go forward. Support organisations are vital to this ongoing need.

- Adapting ecosystems and species to CC will require careful conservation planning based on modelling of the relative impacts on species and communities and their capacity to adapt. Key locations on the landscape need to be set aside for conservation to facilitate species migration and adaptation and retain critical mass of ecosystem representation.

7.3 Determining Optimal Landscape Scale Outcomes

The project identified three methods of developing integrated landscape futures and optimising outcomes across the landscape.

The use of these tools is described below:

7.3.1 Constrained Land Use Change Model

This model involves a constrained optimisation of land use over time which aims to identify land uses across Australia which maximise profitability, given constraints on capacity (i.e. bioenergy processing capacity, ability to conduct broad scale reforestation).

The constrained land-use model was used to determine the economic viability of carbon sequestration and biomass energy. This identifies land uses across Australia which maximise profitability, given constraints on capacity (i.e. bioenergy processing capacity, ability to conduct broad scale reforestation, etc.).

An annual step time model was used that incorporated change trajectories in market prices (oil, electricity, carbon, water, food, biodiversity etc.) and climate. The model analyses potential land uses including woody perennials for renewable electricity production, cereal crops for biofuels, carbon monocultures, environmental plantings, and the many types of irrigated and dry land agriculture. Impacts of land use change over time can be calculated and trajectories in carbon sequestration, biodiversity, food production, water use, and energy production were assessed.

The methodology and approach has been built up by this project but will be extended further in the coming financial year through the NCCARF funded project. This will allow the user to explore different futures and incorporate policies like a biodiversity payment, bioenergy industry capacity building and reforestation capacity building.

7.3.2 Multi-Functional Land-use Model- Land Use Evolver

This model optimises the land use by maximising net social value. Net social value includes food, energy, carbon, water, soil health, biodiversity, economic returns. This approach, called the Land-Use Evolver Tool (LUET) allows the user to optimise a range of indicator values across the landscape based on changing land-use from current use and accounting for the interactive effects of changing land-use. Alternatively, the user can optimise a specific indicator type and see the trade-offs that occur, i.e. effects on other indicators.
Some trials have occurred of the Land-Use Evolver in the SA MDB and shown some interesting results:

- The model when run to optimise the key indicators showed clear zonations of where specific land-uses should be implemented to achieve maximum outcomes (See Figure 7.1). This provides clear planning frameworks for developing policies and incentives for promoting land-use change in ways that will be most effective and optimal.
- The tool is an effective way to engage planners and land-owners at a multitude of scales to show how to achieve multiple landscape objectives and how to achieve multi-functional landscapes. This provides an important learning and communication tool for understanding tradeoffs and benefits.

The model offers a new approach and a suitable tool for optimising landscape outcomes but requires further development and testing and application in a range of contexts.

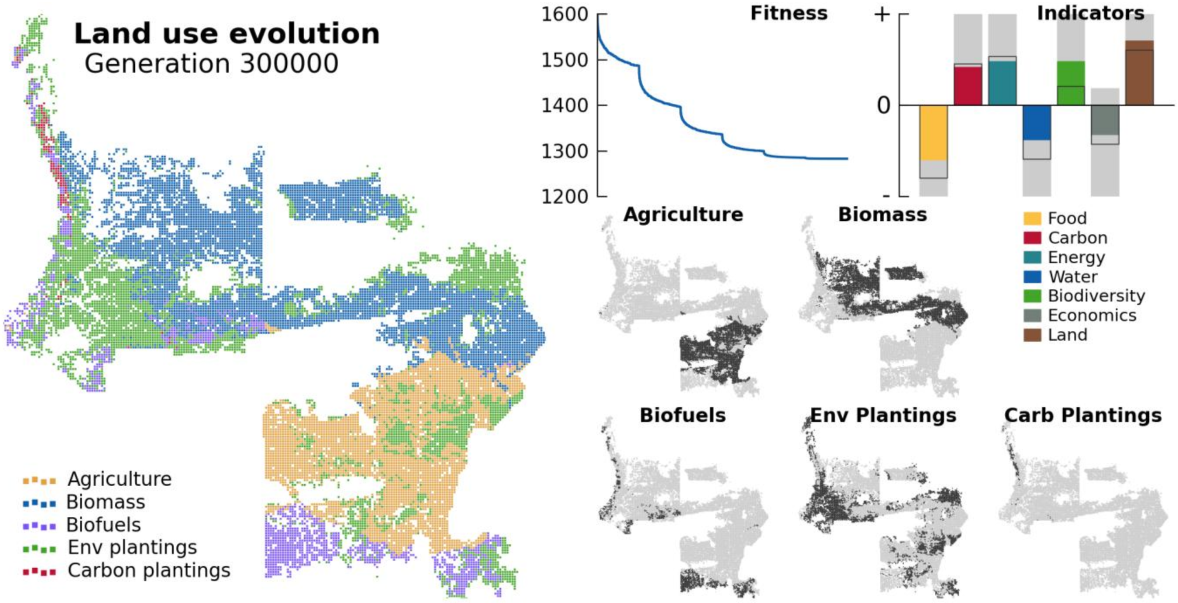

Figure 7.1: **Trial model of Land-Use Evolver in the Lower Murray region with the SA MDB (upper left).**

7.3.3 Integrated Land use Strategic Assessment (ILSA) Tool

A further land use optimising tool has been developed which focuses on optimising outcomes for horticulture producers in the Riverland region. The tool enables horticulturalists to enter in key information about their property such as costs, returns, water use and opportunities to sell water and forecasts horticulture returns for specific crop types and varieties. The tool is predictive and can assist the landholder determine strategies to optimise future business through altering water use, changing crop types and or varieties.

The tool has proven useful as an extension tool and illustrates the importance of having tools at a property scale to help support future CC initiatives.

State Of Nature	Years/10	Alloc (%)	Applied (ML/ha)	Yield (t/ha)	Crop ($/t)	Irrig ($/ha)	Op Costs ($/ha)	Fixed ($/ha)	Price ($/ML)	Used (ML)	Bought (ML)	Profit ($Total)
Wet	7	100.00	9.5	40.0	$ 300	$ 3620	$ 5284	$ 586	$ 17.30	95	27	$ 24627
Normal	0	0.00	0.0	0.0	$ 0	$ 0	$ 0	$ 0	$ 60.00	0	0	$ 0
Dry	1	70.00	9.5	40.0	$ 300	$ 3620	$ 5284	$ 586	$ 100.06	95	48	$ 20344
Very Dry	1	40.00	9.5	40.0	$ 300	$ 3620	$ 5284	$ 586	$ 245.74	95	68	$ 8422
Extremely Dry	1	20.00	9.5	40.0	$ 300	$ 3620	$ 5284	$ 586	$ 501.24	95	81	$ -15718
Ten year average	10	83.00	9.5	40.0	$ 300	$ 3620	$ 5284	$ 586	$ 96.81	95	0	$ 18544

Figure 7.2 Trial outputs of ISLA showing whole of farm and crops grown (King et al. 2012).

7.4 Significance at State, National, International Level

The project has a high level of significance at state, national and international levels.

7.4.1 State Level

The project contributed significantly to the achievement of the South Australia Strategy- "Tackling Climate Change 2007" including:

- **Providing suitable models for Leadership**- The project has encouraged participation and leadership from a range of stakeholders and groups in CC strategy particularly regional NRM

Boards and also local government. The Advisory and Management Group also have provided a strong leadership focus for CC strategies within the two NRM regions. The project has also acknowledged and supported the need for community networks and recognised leaders and fostered their involvement in developing leadership models.

- **Community Involvement**- The project included a limited amount of community involvement, particularly primary producers of both EP and SA MDB NRM regions and also representatives from organisations linked into the community. Through up-skilling the community participants it is likely that they will also promote CC adaptation within their region and further promote the work. This is particularly so with the NRM Boards that have strong community links and also the EP sector agreement which brings together the key decision making organisations in the region.

- **Energy Alternatives;** The project explored and scoped the opportunities for alternative energy sources including the potential for bio-energy and bio-fuel production and the potential for regions to become regionally energy independent. This included exploring the economic feasibility of such enterprises.

- **Natural Resources adaptation across a significant area of South Australia-** The entire methodology was designed to determine appropriate forms of natural resource adaptation through assessing vulnerability, resilience and adaptation strategies across soils, water and biodiversity at a regional scale.

The project was significant at a State level because it developed for the first time, regional scale CC projections, from which integrated CC adaptation options can be developed and discussed. In this respect it is more advanced that current State government programs that are mainly focussed on vulnerability assessment and are less well developed in proposing options for management actions.

7.4.2 National Level

The methodology developed here to identify options for climate ready planning and actions is transferrable to other NRM regions within Australia. This capability seems consistent with the Australian Governments requirement for NRM regions to develop and implement Climate Ready NRM Plans.

The application of Landscape Futures Analysis in the two regions of this project provides guidance through sharing experience and expertise to other NRM regions. Both the project approach and the technical analysis have been shown to be effective in identifying adaptation options.

The project made new ground in relation to participatory CC approaches and how to ensure research is incorporated into institutions and current processes. It provides a sound research base and methodology of landscape analysis that will be required for future NRM planning particularly for the consideration of multiple use landscapes.

The project addresses the big picture drivers that are significant at a national scale. For example:

- Water resource management and understanding implications of reduced water availability;
- Impact of CC on the viability of future primary production and how to best adapt;
- Strategies to strengthen the natural resource base to conserve nationally significant flora and fauna;
- Regional scale initiatives to contribute to national commitments in relation to carbon capture and renewable energy.
- Integrated strategies to ensure NRM regions can become Climate Change ready based on best landscape science;

7.4.3 International Level

The research undertaken was internationally significant and will result in publishing results in international journals that include:

- Modelling of CC impacts on biodiversity and assessment of adaptive capacity, sensitivity and vulnerability to determine tradeoffs in conservation planning;
- Modelling of carbon capture and storage via plant systems;
- Participatory models for engaging local government and other stakeholders into CC research and strategy development;
- Development of high end land-use change models integrating a range of socio-economic and environmental factors to determine CC adaptation strategies;

8 LOOKING FORWARD

The evaluation of outcomes and setting of future directions was an important aspect of project delivery that was considered by the research, management and advisory groups. The learnings gained and future directions identified are outlined below:

8.1 LEARNINGS GAINED FROM THIS PROJECT

- It is important right at the start to determine what the regional community needs to help shape its future directions.

- The process of deriving adaptation options is as important as the outcomes achieved. The process was successful in involving stakeholders and community and developing sound working relationships and collaborations which will help in future work. This contributed to a strong sense that the future can be positive and improvements in resource condition and peoples' well being are possible.

- Identifying the base data that describes the regional resources and their condition followed by assessment of likely changes in response to CC takes time and is a complex process. The project has delivered significant outputs in the form of options for long term management that adequately address CC and provide focus for regional adaptation processes.

- Changes in land-use will occur because of market forces and reduced viability of existing practice. Facilitating and guiding these land use changes requires planning that is well informed and has clear direction. This planning includes aspects such as transport and energy infrastructure, appropriate zoning and capacity to assess development applications in light of the Australian Governments Clean Energy Future Plan.

- Local government has a key role to play and requires support to address complex matters and potentially large investments. Councils that are in marginal areas may need assistance, as they have very limited resources but are likely to be more affected by the need to adapt.

Significant land-use change brings its own challenges and there is a high level of interest in the consequences of change i as it affects infrastructure, planning, provision of services and transport.

- An important influence on land use will be the Clean Energy Future Plan as it will lever funds and resources and provide a possible new market opportunity. While the economics of this plan have very limited viability at present, the signal it provides will be important in influencing landholder attitudes to vegetation and restoration. Rapidly developing markets for renewable energy sources highlights that developing a local energy security strategy should be a regional priority.

- The project has established some key ingredients for incorporating CC research into NRM decision making. This includes (1) providing support, training and means to build relationships; (2) identify common needs, develop collaborations and employ economies of scale; (3) use a variety of communication tools and formats; (4) coordinate research as far as possible and disseminate activities; (5) access past and current research and knowledge activities; (6) facilitate the research and its influence within a participatory framework.

8.2 Future Directions.

- The experience gained from this project has convinced us more than ever that the development of CC adaptation plans at a regional scale using Landscape Futures Analysis to identify options is an important step for informed decisions.

- The work and expertise developed here has the potential to inform the DENR integrated vulnerability assessment and CC adaptation plans which are being delivered within each NRM region of South Australia. This project already provides much of the key material for these projects in the two NRM regions studied and the research staff from this program are providing valuable direction to the project.

- A key focus of future CC work by the research consortium is to increase the impact and reach of the CC research. This includes incorporating the research into evidence based policy and planning. This involves getting greater buy-in from NRM planners and stakeholders to incorporate CC research and science into their planning strategies.

- This acknowledges that the capacity to implement CC strategies is limited by lack of awareness of alternative methods and by limited technical capacity to use new methods in planning. A NCCARF funded project is being implemented in 2012-2013 to identify how these limitations can be mitigated. Workshops have been held to achieve a common vision of planning CC futures and discussions held with current NRM regional planners to evaluate their current approach and methods to incorporate climate change. Early work suggests that the context setting and hence approaches taken will be quite different in the SA MDB and EP regions. This will provide an opportunity to test different approaches and methodologies. The ultimate aim is to describe a template process across Australia for ensuring NRM regions are climate ready and can plan effectively.

- Further work is required on methodologies of integrating and optimising CC adaptation strategies across the landscape. This includes tools at both the regional and property scale with both contributing equally to adaptation strategies. The two tools developed through this project, require further development and testing practical application. In the case of the EP there is also the scope to develop a property based tool to determine/predict wheat futures as opposed to other forms of primary production.

- The research consortium plans to continue its promotion and exposure across a variety of forums. Strong engagement with State government agencies is continuing as are discussions with relevant Commonwealth agencies such as the Department of Sustainability, Environment, Population and Communities. A particular point of discussion is about development of CC ready plans and carbon capture within NRM regional plans.

- The CC modules developed through this project are known to be technically valid. However there is need for further development and acquisition of field measurements to calibrate and validate the models.

- There is an on-going and important role for governments at all levels to facilitate, rather than dictate, adaptive change through enabling legislation and information provision. A logical and tested framework that identifies potential adaptive changes can be used as a way of defining roles and responsibilities and hence guide facilitation. Landscape Futures Analysis can greatly assist in providing such a framework.

- Further work is required at the enterprise level to develop predictive tools to guide future management and land-use activities. This can contribute to Climate Energy Plans and Carbon Capture Strategies.

8.3 Supporting Future CC Research and Regional Implementation.

Some key recommendations can be made for ensuring the delivery of the future project directions:

- Continued financial support for the CC Research Team
  Ongoing financial support is required for the CC Research Team with the potential for a Cooperative Research Centre Model. The financial support will attract internationally significant research and help attract funds for future CC research projects; It will also support significant CC leadership and change management within key institutions and the private sector; It will also ensure that knowledge is retained and disseminated to key players.
- Support for development of regional CC adaptation plans
  Regions can begin the journey of scoping CC adaptation whilst CC projection and vulnerability continue to be refined.
- Funding to support and promote innovative CC implementation with NRM regions
  Help build capacity, promote and test the development of adaptation solutions.

9 CONCLUSIONS

This project has extended our understanding of the change processes and forces that are changing our landscapes now and increasingly into the future. The learning over the three years has challenged researchers, stakeholders and community people involved in thinking about CC and how we might adapt.

Regional capacity to address and adapt to CC has significantly increased during the course of this project. The project has been able to simplify some of the complexity associated with CC projections and develop a robust research methodology to develop options for adapting at a regional scale. It has greatly extended the work of the Landscape Science program and capitalised on the ground breaking work of the LMLF project.

The PSRF project has supported the development of regional scale assessment of likely changes and helped identify possible CC adaptation. The sub-projects developed have well complemented the primary research base to improve the capacity to develop regional level outcomes and engage the community and stakeholders. The project has led CC research and implementation in the NRM regions but it is acknowledged that developing CC adaptation strategies takes time and concerted planning.

The process itself has been as important as the outcomes to improve confidence in CC research and development of agreed shared outcomes with high levels of engagement and cross collaboration.

The projects key emphasis on addressing risks and harnessing opportunities was important for developing future viable options and testing these in a real world context. Identifying short term opportunities such as linking to national strategies including the Clean Energy Futures Plan will be important for harnessing momentum and resources to build change. Strategic and landscape based planning is vital for supporting this process.

The legacy of the project will continue through building on the methodology of Landscape Futures Analysis and the insights that it enables. There with be a focus on building CC adaptation into planning strategies and further refining CC models, CC projections and CC adaptation particularly in relation to optimising CC strategies across the landscape.

10 REFERENCES

10.1 *PUBLISHED PAPERS*

Brennan, D. (2006). Water policy reform in Australia: lessons from the Victorian seasonal water market. The Australian Journal of Agricultural and Resource Economics, 50, 403–423.

Bryan, B.A. (2010). Robust, cost-effective investment decisions for managing natural capital and ecosystem services. Biological Conservation 143, pp.1737-1750. doi:10.1016/j.biocon.2010.04.022.

Bryan, B.A., Crossman, N.D., King, D. and Meyer, W.S. (2011). Landscape futures analysis: assessing the impacts of environmental targets under alternative spatial policy options and scenarios. Environmental Modelling and Software 26(1), 83-91.

Bryan, B.A., Grandgirard, A., and Ward, J.R. (2010). Quantifying and exploring strategic regional priorities for managing natural capital and ecosystem services given multiple stakeholder perspectives. Ecosystems 13, pp. 539–555. doi: 10.1007/s10021-010-9339-0.

Bryan, B.A., King, D., Wang, E. (2010). Biofuels agriculture: landscape-scale trade-offs between fuel, economics, carbon, energy, food, and fiber. Global Change Biology – Bioenergy 2(6), pp. 330-345. doi: 10.1111/j.1757-1707.2010.01056.x.

Bryan, B.A., King, D., and Wang, E. (2010). Potential of biomass production for achieving widespread natural resource management under climate change. Land Use Policy 27(3), pp.713-725. doi: 10.1016/j.landusepol.2009.09.012

Bryan, B.A. King, D., and Ward, J. (2011). Modelling and mapping agricultural opportunity costs to guide landscape planning for natural resource management. Ecological Indicators 11(1), pp. 199 – 208. doi:10.1016/j.ecolind.2009.02.005

Bryan, B.A., Raymond, C.M., Crossman, N.D. and Hatton MacDonald, D. (2010). Targeting management of ecosystem services based on community values: where, what and how? Landscape and Urban Planning 97(2), pp. 111-122. doi: 10.1016/j.landurbplan.2010.05.002

Bryan, B.A., Raymond, C.M., Crossman, N.D., and King, D. (2011). Comparing spatially explicit ecological and social values for natural areas to identify effective conservation strategies. Conservation Biology 25(1), pp.172-181. doi: 10.1111/j.1523-1739.2010.01560.x

Crossman, N.D., Bryan, B.A. and Cooke, D.A. (2011). An invasive plant and climate change threat index for weed risk management: Integrating habitat distribution pattern and dispersal process. Ecological Indicators 11(1), pp. 183 – 198. doi:10.1016/j.ecolind.2008.10.011.

Crossman, N.D., Bryan, B.A., Summers, D.M. (2011). Carbon payments and low-cost conservation. Conservation Biology 25(4), 835-845.

Crossman, N.D., Bryan, B.A., and Summers, D.M. (2012). Identifying priority areas for reducing species vulnerability to climate change. Diversity and Distributions 18(1), 60-72.

Gonzales, R. and Parrott, L. (2012). Network theory in the assessment of the sustainability of social-ecological systems. Geography Compass, Network theory for social-ecological system analysis 6(2), 76-88.

Higgins, A.J., Bryan, B.A., Overton, I.C., Holland, K., Lester, R.E., King, D., Nolan, M. and Connor, J.D. (2011). Integrated modelling of cost-effective siting and operation of flow-control infrastructure for river ecosystem conservation. Water Resources Research 47, W05519. doi:10.1029/2010WR009919.

Kandulu, J.M., Bryan, B.A., King, D., and Connor, J.D. (2012). Mitigating economic risk from climate variability in rain-fed agriculture through enterprise mix diversification. Ecological Economics 75, pp. 105-112. doi:10.1016/j.ecolecon.2012.04.025

Pettit, C., Raymond, C.M., Bryan, B.A., and Lewis, H. (2011). Strengths and weaknesses of visualisation for communicating landscape planning. Landscape and Urban Planning 100(3), pp. 231-241. doi:10.1016/j.landurbplan.2011.01.001

Summers, D.M., Bryan, B.A., Crossman, N.D. and Meyer, W.S. (2012). Species vulnerability to climate change: Impacts on spatial conservation priorities and species representation. Global Change Biology 18(7), 2335-2348.

Yang, W., Bryan, B.A., Hatton MacDonald, D., Ward, J.R., Wells, G., Crossman, N.D., Connor, J.D. (2010). A conservation industry for sustaining natural capital and ecosystem services in agricultural landscapes. Ecological Economics 69, pp. 680-689. doi:10.1016/j.ecolecon.2009.11.028

Zerger, A; Lefroy, T; Bryan, B.A. (2011). Science to improve regional environmental investment decisions. Environmental Modelling and Software 26(1), p.1.

10.2 *Accepted Papers*

Briere, M. and Meyer, Wayne S. (in review). Contrasting farms are carbon accumulating. Agricultural Science, AIAST (accepted subject to revision August 2011).

Parrott, L., Chion, Gonzales, R., C., Latombe, G. (in review). Agents, individuals and networks: Modeling methods to inform natural resource management in regional landscapes. Ecology & Society (accepted June 2012)

Parrott, L. and Meyer, W.S. (in review). Future landscapes: managing within complexity. Frontiers in Ecology and the Environment (accepted May 2012).

Paterson, S.E. and Bryan, B.A. (in review). Food-carbon trade-offs between agriculture and reforestation and the efficiency of market-based policies. Ecology & Society (submitted Feb 2012).

10.3 *Submitted Papers*

Bryan, B.A., Higgins, A., Overton, I.C., Holland, K., Lester, R.E., King, D., Nolan, M., Hatton MacDonald, D., Connor, J.D. (in review). Rebalancing ecological health and socio-economic values of river ecosystems: information integration for the operational management of environmental flows. Ecological Applications (submitted May 2012).

Bryan, B.A. and Crossman, N.D. (in review). Interacting financial incentives display synergies, tensions, and dependencies in the supply of multiple ecosystem services. Conservation Letters, (submitted January 2012).

10.4 *Papers in Preparation*

Bryan, Brett A., Crossman, Neville D. Interacting markets, land use change potential, and the supply of ecosystem services. Proceedings of the National Academy of Sciences.

Lyle, G. Place and nested scales: A review of potential influencing factors affecting decision making for climate change adaptation in Australian agriculture.

Lyle.G, and Davenport, D. Evaluating the ability to simulate regional wheat yields in Australian agricultural landscapes: A case study of the Eyre Peninsula.

Lyle.G, and Davenport, D. Integrating spatial soil information, crop simulation modelling and expert opinion to assess the spatial impact of climate change on wheat production in the Eyre Peninsula agricultural region.

Lyle.G, and Davenport, D. Applying simulation modelling to understand the climate change impacts on wheat yield within the Eyre Peninsula agricultural region.

Meyer, W.S. and Kellett, B.M. A prosperous horticultural region changing in response to drought and commodity prices: limits to irrigated landscape change (draft completed, journal submission pending).

10.5 Reports

Connor, J., Doble, R., Elmahdi, A., Walker, G., Stenson, M., Jolly, I., Ferris, M., Morrison, J., Kirby M., Kaczan, D., King, D., Pickett, T., Overton, I., Pettit, C. (2007). Lower Murray Landscape Futures River Corridor Component. Final Report. Volume 5 - Futures Modelling Methods and Data. Policy and Economic Research Unit, CSIRO Land and Water. Available at http://www.landscapefutures.com.au/publications.html Client Report

Connor, J.D., Banerjee, O., Kandulu, J., Bark, R.H. and King, D. (2011). Socioeconomic implications of the Guide to the proposed Basin Plan – methods and results overview. Goyder Institute for Water Research Technical Report Series No. 11/3, Adelaide.

Crossman, N.D. Summers, D.M. and Bryan, B. (2010). Opportunities and threats for South Australian agricultural landscapes from reforestation under a carbon market. CSIRO client report.

CSIRO (2008). Water availability in the Murray-Darling Basin. A report from CSIRO to the Australian Government. Canberra, CSIRO.

EBC et al. (2011). EBC, RMCG, Marsden Jacob Associates, EconSearch, G. McLeod, T. Cummins, G. Roth and D. Cornish, Community impacts of the Guide to the proposed Murray-Darling Basin Plan. Volume 1: Executive Summary. Report to the Murray-Darling Basin Authority, May.

Hayman Peter, Thomas Dane, Alexander Bronya, and Nidumolu Uday (2011). Climate Change Scenarios Information. Milestone 2 Report. A report prepared by prepared by SARDI Climate Applications for The Environment Institute, The University of Adelaide, as part of the Strengthening basin communities program – Planning Component Consultancy SBC033A.1/2, 48 pages.

Kellett, Bart M. (2010). Options for farmers to adapt to change in the Riverland of South Australia. Executive Summary Report. University of Adelaide, Environment Institute, Landscape Futures Program, 11 pages.

Kellett , Bart M. and Banerjee, Onil (2010) Reconfiguration scenarios and data needs. Executive Summary Report. University of Adelaide, Environment Institute, Landscape Futures Program, 11 pages.

Kellett, B., Summers, D., Barnett, K., Siebentritt, M., Meyer, W., Spoehr, J. (2011). Adaptation and emerging opportunities for the SA Murray-Darling region. Milestone 2 Report. A report prepared by SARDI Climate Applications for The Environment Institute, The University of Adelaide, as part of the Strengthening basin communities program – Planning Component Consultancy SBC033A.1/2, 54 pages.

Lucy, Schapel (2010) Climate Change, Communities and Environment (SA Murray-Darling Basin) Planning for Outcomes – short term and long term. Report from Rural Solutions, 24 pages.

Lucy, Schapel (2010). Climate Change, Communities and Environment Research Project (Eyre Peninsula NRM Region): Plan for Outcomes and Key Actions. Draft report from Rural Solutions SA, 26 pages.

Lyle, Greg (2010). Eyre Peninsula Spatial Datasets. The University of Adelaide, Environment Institute, Landscape Futures Program, 33 pages.

Lyle, G. (March 2011). Eyre Peninsula Climate Regionalisation. The University of Adelaide, Environment Institute, Landscape Futures Program, 34 pages.

Meyer, W., Siebentritt, M., Hayman, P., Alexander, B., Kellett, B., Summers, D., Bryan, B., Connor, J., Spoehr, J., Sharma, V., Sharley, T. and Lyle, G. (2010). Climate change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling basin. Literature Review. Milestone 1 Report. A report prepared by The Environment Institute, The University of Adelaide, as part of the Strengthening basin communities program – Planning Component Consultancy SBC033A.1/2, 68 pages.

Siebentritt, M.A. and Sharley, T. (2011). Outcomes of Stakeholder Engagement. Milestone 2 Report. A report prepared by SARDI Climate Applications for The Environment Institute, The University of

Adelaide, as part of the Strengthening basin communities program – Planning Component Consultancy SBC033A.1/2, 59 pages.

Siebentritt, M., Meyer, W. And Spoehr, J. (2011). Adaptation and Emerging Opportunities plan for the SA Murray-Darling region. Milestone 4 Report. A report prepared by The Environment Institute, The University of Adelaide, as part of the Strengthening basin communities program – Planning Component Consultancy SBC033A.1/2, 70 pages.

Summers, David and Lyle, Greg. (2010). South Australian Murray Darling Basin NRM Region Datasets. University of Adelaide, Environment Institute, Landscape Futures Program, 16 pages.

Summers, D., Siebentritt, M., Sharley, T., Meyer, W., Bryan, B., Connor, J. and Spoehr, J. 2011. Climate change impact assessment report for the SA marray-darling region. Milestone 3 report, A report prepared by The Environment Institute, The University of Adelaide, as part of the Strengthening basin communities program – Planning Component Consultancy SBC033A.1/2, 57 pages.

Meyer, Wayne S. (2010). Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes. Year 1 Report. The University of Adelaide, Environment Institute, Landscape Futures Program, 7 pages.

Meyer, Wayne S. (2011). Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes. Year 2 Report. The University of Adelaide, Environment Institute, Landscape Futures Program, 10 pages.

Meyer, Wayne S.(2012). Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes. The Premiers Science Research Fund Final Report. The Environment Institute, The University of Adelaide, ? pages.

Wayne Meyer, Brett Bryan, David Summers, Greg Lyle, Neville Crossman, Travis Moon, Rodolphe Gonzales, Dorothy Turner, Peter Hayman, Megan Lewis (2010). Climate Change, Community and Environment: Technical Report (with an emphasis on Eyre Peninsula), ? pages.

10.6 Conference Presentations

Lyle, G. (2012). NRM – land use and sustainable agricultural production. Paper and oral presentation as an invited speaker for the SPAA Precision Agriculture Australia Expo 15th February 2012. Port Lincoln, Eyre Peninsula, SA.

Hayman, P.T. and McCarthy, M.G. (2010). Irrigation and drought in a southern Australian climate that is arid, variable and changing. International Drought Symposium. Water Science and Policy Centre, University of California, Riverside. May 2010.

Meyer, W., Bryan, B., Fisher, A., Crossman, N. & Lewis, M. (2009). Applying landscape science to natural resource management. SSSI Conference, Place & Purpose Symposium, Adelaide, Sept/Oct 2009.

Summers, D., Bryan, B., Crossman, N. D. and Meyer, W. 2012. Conservation planning and vulnerable species. In: Climate Adaptation in Action 2012: Sharing Knowledge to Adapt, 26-28 June 2012 2012. Melbourne, Australia. National Climate Change Adaptation Research Facility.

10.7 Brochures and Articles

Kellett, Bart M. and Meyer, Wayne S. (2010) Lower Murray Landscape Futures Project (www.landscapefutures.com.au) KEY MESSAGES. University of Adelaide, Environment Institute, Landscape Futures Program, 2 pages.

Meyer, Wayne S. (2009). Climate Change, Communities and Environment: Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes. PREMIER'S SCIENCE AND RESEARCH FUND 2009, 1 page.

Meyer, Wayne S. and Bryan, Brett (2011). Productive and healthy landscapes for a changing environment. Submitted to SA NRM Newsletter.

Wahlquist, A. (2011). Agricultural landscapes for a changing environment. ECOS, Issue 141, 4 July 2011.

Wahlquist, A. (2011) Science helps SA farm communities adapt to change. ECOS Issue 161, 4 July 2011.

10.8 Website and Podcasts

Environment Institute: Landscape Futures Program – website
http://www.adelaide.edu.au/environment/lfp/

Project Launch (2009) – available on podcast
http://www.adelaide.edu.au/environment/lfp/news/2009/psrf-launch.html

Place and Purpose Symposium (2009) – key papers available on podcast

http://www.adelaide.edu.au/environment/lfp/news/2009/pandp/run.html

Eyre Peninsula Inaugural meeting (2009) – presentations available online at

http://landscapescience.org/index.php?id=38

SA MDB Inaugural meeting (2009) – presentations available online at

http://landscapescience.org/index.php?id=39

10.9 Cited Literature

Bureau of Meteorology (BoM) (2006) SILO Climate Datasets. Available online (Accessed 2011) < http://www.bom.gov.au/silo/ >

Connor JD, Banerjee O, Kandulu J, Bark RH and King D (2011) Socioeconomic implications of the Guide to the proposed Basin Plan – methods and results overview. Goyder Institute for Water Research Technical Report Series No. 11/3, Adelaide.

CSIRO (2008). Water availability in the Murray-Darling Basin. A report from CSIRO to the Australian Government. Canberra, CSIRO.

Carvalho, S. B., Brito, J. C., Crespo, E. J. and Possingham, H. P. 2010. From climate change predictions to actions – conserving vulnerable animal groups in hotspots at a regional scale. Global Change Biology, 16, 3257-3270.

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C., Game, E. T., Grantham, H., Kark, S., Linke, S., McDonald-Madden, E., Pressey, R. L., Walker, S., Wilson, K. A. and Possingham, H. P. 2008. Is conservation triage just smart decision making? Trends in Ecology & Evolution, 23, 649-654.

Engler, R., Randin, C. F., Thuiller, W., Dullinger, S., Zimmermann, N. E., Araújo, M. B., Pearman, P. B., Le Lay, G., Piedallu, C., Albert, C. H., Choler, P., Coldea, G., De Lamo, X., Dirnböck, T., Gégout, J.-C., Gómez-García, D., Grytnes, J.-A., Heegaard, E., HøIstad, F., Nogués-Bravo, D., Normand, S., Puşcaş, M., Sebastià, M.-T., Stanisci, A., Theurillat, J.-P., Trivedi, M. R., Vittoz, P. and Guisan, A. 2011. 21st century climate change threatens mountain flora unequally across Europe. Global Change Biology, 17, 2330–2341.

Garzón, M. B., de Dios, R. S. and Ollero, H. S. 2008. Effects of climate change on the distribution of Iberian tree species. Applied Vegetation Science, 11, 169-178.

Moilanen, A. 2008 Zonation: Conservation planning software, V 2.0. Metapopulation Research Group, University of Helsinki. Helsinki, Finland.

Thuiller, W., Lavorel, S., Araújo, M. B., Sykes, M. T. and Prentice, I. C. 2005. Climate change threats to plant diversity in Europe. Proceedings of the National Academy of Sciences of the United States of America, 102, 8245-8250.

Wilson, K. A., Meijaard, E., Drummond, S., Grantham, H. S., Boitani, L., Catullo, G., Christie, L., Dennis, R., Dutton, I., Falcucci, A., Maiorano, L., Possingham, H. P., Rondinini, C., Turner, W. R., Venter, O. and Watts, M. 2010. Conserving biodiversity in production landscapes. Ecological Applications, 20, 1721-1732.

Wilson, H. B., Joseph, L. N., Moore, A. L. and Possingham, H. P. 2011. When should we save the most endangered species? Ecology Letters, 14, 886-890.

11 APPENDIX A-CLIMATE CHANGE MODELLING MODULES

Table 8:Modelling modules and key objectives

Module	Key Objectives of Module
Climate Change Scenarios	
Climate Change Modelling	Model climate change for both the Eyre Peninsula NRM region and the Lower Murray region (consisting oftSouth Australian Murray Darling Basing NRM region and the Mallee and Wimmera CMA regions in Victoria). Define a baseline climate scenario (S0) and 3 suitable climate change scenarios (S1, S2, S3) and associated estimates of rainfall, precipitation and atmospheric CO_2 from regional climate models.Model spatial climate surfaces for each scenario using SILO Patched Point Data or ECOCLIM data for both the EP and Lower Murray regions.
Biophysical Modules	
APSIM - Wheat Productivity Modelling	Classify EP into sub-regions based on historic climate data for input to the APSIM Model. Classify EP into sub-regions based on soil characteristics for input to APSIM. Define the parameters for wheat cropping under traditional farm management on EP. Use APSIM to model wheat yield on EP under the baseline and future climate scenarios to inform agricultural economics.
$3PG_2$ – Biomass and Carbon Sequestration Modelling	Model the biomass productivity of 3 homogenous plantations of Eucalyptus species and a multi-species environmental plantation for input into the biomass economic modelling. Do this under the baseline and each of the future scenarios for both the EP and Lower Murray regions. Calculate the carbon productivity (based on biomass) associated with 3 homogenous plantations of Eucalyptus species and a multi-species environmental plantation. Do this for the baseline and future climate scenarios for both EP and Lower Murray regions.
Biodiversity Modelling	Quantify the vulnerability of native plant species to climate change based on exposure, sensitivity and adaptive capacity, for use in the landscape futures analysis. (584 native plant species in the Lower Murray region and 285 native plant species in the Eyre Peninsula NRM region) • Quantify exposure as species' geographic range under climate change using species distribution models. • Calculate sensitivity as a function of the impact of climate change on species' geographic ranges. • Quantify adaptive capacity as species' ability to migrate to new geographic ranges under climate change scenarios, using a dispersal kernel. Using *Zonation*, assess the impact of individual components of vulnerability (exposure, sensitivity and adaptive capacity) on spatial conservation priorities and levels of species representation in priority areas under each climate change scenario. Use the full vulnerability framework as a basis for identifying spatial conservation priorities under climate change.

Benefit and Cost (Economic) Modules	
Wheat Economics Modelling	Quantify the economic returns and costs of wheat production in the EP NRM region. Model the spatial distribution of economic returns from wheat production on EP under the 4 climate scenarios, plus a number of extra scenarios to account for seasonal variations.
Biomass and Carbon Sequestration Economics Modelling	Quantify the economic returns and costs of biomass production for both the EP and Lower Murray regions. Model the spatial distribution of economic returns from biomass production under the baseline and future climate scenarios for 3 homogenous plantations of Eucalyptus species and a multi-species environmental plantation. Quantify the economic returns and costs of carbon sequestration. Model the spatial distribution of economic returns from carbon sequestration (carbon trading) under the baseline and future climate scenarios for 3 homogenous plantations of Eucalyptus species and a multi-species environmental plantation. Quantify the economic returns and costs of biofuel production. Model the spatial distribution of economic returns from biofuel production under the baseline and future climate scenarios for 3 homogenous plantations of Eucalyptus species and a multi-species environmental plantation.
Social Modules	
Social Modelling	Review the literature from Australia and internationally on social indicators that have been used to characterise regional social vulnerability to natural hazards such as drought. Perform surveys of the social relationships within Eyre Peninsula, and perform network modelling using these results to determine who influences who in the decision making process at various levels.

12 APPENDIX B: CLIMATE CHANGE PROJECTIONS FOR SA MDB REGION AS A WHOLE

The following two tables summarise the climate change projections for the SA MDB region for 2030 and 2070.

Table 10. Climate projections for the SA Murray Darling Basin region.

Projections for 2030 are given relative to the period 1980-1999. Individual years will show variation from this average. The 50th percentile (50p; the mid-point of the spread of model results) provides a best estimate result. The 10th and 90th percentiles (10p and 90p; lowest 10% and highest 10% of the spread of model results) provide a range of uncertainty. Emissions scenarios are from the IPCC Special Report on Emission Scenarios where Low emissions is the B1 scenario, Medium is A1B and high is A1FI. Projections from CSIRO and BoM 2007.

Variable	Season	Low emissions			Medium emissions			High emissions		
		10p	50p	90p	10p	50p	90p	10p	50p	90p
Temperature Degrees C	Annual	0.5	**0.8**	0.8	0.5	**0.8**	1.3	0.5	**0.8**	1.3
	Summer	0.5	**0.8**	0.8	0.5	**0.8**	1.3	0.5	**0.8**	1.3
	Autumn	0.8	**0.8**	0.8	0.8	**0.8**	1.3	0.8	**0.8**	1.3
	Winter	0.5	**0.5**	0.8	0.5	**0.8**	1.3	0.5	**0.8**	1.3
	Spring	0.5	**0.8**	1.3	0.5	**0.8**	1.3	0.5	**0.8**	1.3
Rainfall %	Annual	-7.5	**-3.5**	0.0	-15	**-3.5**	3.5	-15	**-3.5**	3.5
	Summer	-15.	**0.0**	7.5	-15	**-2.0**	10.0	-15	**-2.0**	10.0
	Autumn	-7.5	**0.0**	7.5	-10	**0.0**	7.5	-10.	**0.0**	7.5
	Winter	-15	**-3.5**	0.0	-15	**-7.5**	0.0	- 15	**-7.5**	0.0
	Spring	-15	**-7.5**	2.0	-15	**-7.5**	2.0	-15	**-7.5**	2.0
Potential Evapo-Transpiration %	Annual	0.0	**0.0**	3.0	0.0	**3.0**	6.0	0.0	**3.0**	6.0
	Summer	0.0	**0.0**	3.0	0.0	**0.0**	6.0	0.0	**0.0**	6.0
	Autumn	0.0	**3.0**	6.0	0.0	**3.0**	6.0	0.0	**3.0**	6.0
	Winter	0.0	**6.0**	10.0	0.0	**6.0**	10.0	0.0	**6.0**	10.0
	Spring	0.0	**0.0**	3.0	0.0	**0.0**	3.0	0.0	**0.0**	3.0
Relative Humidity %	Annual	-1.5	**-0.8**	0.0	-1.5	**-0.8**	0.0	-1.5	**-0.8**	0.0
	Summer	-1.5	**0.0**	0.0	-1.5	**-0.8**	0.0	-1.5	**0.0**	0.0
	Autumn	-1.5	**0.0**	0.0	-1.5	**0.0**	0.5	-1.5	**0.0**	0.5
	Winter	-2.0	**-0.5**	0.0	-2.5	**-0.8**	0.0	-2.5	**-0.8**	0.0
	Spring	-1.5	**-0.8**	0.0	-2.5	**-1.5**	0.0	-1.5	**-1.0**	0.0
Downward Solar Radiation %	Annual	0.0	**0.0**	1.5	0.0	**0.0**	1.5	0.0	**0.0**	1.5
	Summer	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0
	Autumn	0.0	**0.0**	0.0	0.0	**0.0**	1.5	0.0	**0.0**	1.5
	Winter	0.0	**1.5**	3.5	0.0	**1.5**	3.5	0.0	**1.5**	3.5
	Spring	0.0	**0.0**	1.5	0.0	**0.0**	1.5	0.0	**0.0**	1.5
Wind Speed %	Annual	-3.5	**0.0**	3.5	-3.5	**0.0**	3.5	-3.5	**0.0**	3.5
	Summer	0.0	**0.0**	7.5	0.0	**3.5**	7.5	0.0	**3.5**	7.5
	Autumn	-5.0	**0.0**	3.5	-7.5	**0.0**	3.5	-7.5	**0.0**	3.5
	Winter	-12	**0.0**	3.5	-12	**0.0**	3.5	-12	**0.0**	3.5
	Spring	-5.0	**0.0**	3.5	-7.5	**0.0**	3.5	-7.5	**0.0**	3.5

Table 11 Climate projections for the SA Murray Darling Basin region.

Projections for 2070 are given relative to the period 1980-1999. Individual years will show variation from this average. The 50th percentile (50p; the mid-point of the spread of model results) provides a best estimate result. The 10th and 90th percentiles (10p and 90p; lowest 10% and highest 10% of the spread of model results) provide a range of uncertainty. Emissions scenarios are from the IPCC Special Report on Emission Scenarios where Low emissions is the B1 scenario, Medium is A1B and high is A1FI. Projections from CSIRO and BoM 2007.As for Table 1 but time period of 2070. Note that by 2070 there is a wider range in all parameters at any emission level and there is a significant difference between emissions.

Variable	Season	Low			Medium			High		
		10p	50p	90p	10p	50p	90p	10p	50p	90p
Temperature Degrees C	Annual	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.8	**2.3**	3.5
	Summer	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.3	**2.3**	3.5
	Autumn	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.3	**2.3**	3.5
	Winter	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.3	**2.3**	3.5
	Spring	0.8	**1.3**	2.3	1.3	**1.8**	2.8	1.8	**2.8**	3.5
Rainfall %	Annual	-15	**-7.5**	3.5	-30	**-10**	5.0	-30	**-15**	7.5
	Summer	-30	**-3.5**	15	-30	**-3.5**	30	-30	**-7.5**	30
	Autumn	-15	**-3.5**	15	-30	**-3.5**	20	-30	**-3.5**	25
	Winter	-30	**-7.5**	3.5	-30	**-15**	3.5	-30	**-15**	5
	Spring	-30	**-15**	3.5	-30	**-15**	3.5	-60	**-30**	5
Potential Evapo-Transpiration %	Annual	0.0	**3.0**	6.0	0.0	**6.0**	10.0	0.0	**6.0**	14.0
	Summer	0.0	**3.0**	6.0	0.0	**6.0**	10.0	0.0	**6.0**	14.0
	Autumn	2.0	**6.0**	10.0	3.0	**6.0**	14.0	4.0	**10.0**	18.0
	Winter	2.0	**10.0**	18.0	3.0	**12.0**	18.0	4.0	**16.0**	18.0
	Spring	-2.0	**2.0**	6.0	-2.0	**3.0**	10.0	-3.0	**4.0**	10.0
Relative Humidity %	Annual	-2.5	**-1.5**	0.0	-3.5	**-1.5**	0.0	-4.5	**-2.5**	0.0
	Summer	-2.5	**-0.8**	0.0	-2.5	**-1.5**	0.8	-4.5	**-1.5**	0.8
	Autumn	-2.5	**-0.8**	0.8	-3.5	**-1.5**	1.5	-4.5	**-1.5**	1.5
	Winter	-4.0	**-1.0**	0.8	-4.5	**-1.5**	1.5	-4.5	**-1.5**	1.5
	Spring	-3.5	**-1.5**	0.0	-4.5	**-2.5**	-0.5	-4.5	**-3.5**	-0.8
Downward Solar Radiation %	Annual	0.0	**0.0**	2.5	0.0	**1.0**	2.5	0.0	**1.5**	2.5
	Summer	0.0	**0.0**	1.5	-1.0	**0.0**	2.5	-1.5	**0.0**	3.5
	Autumn	-1.5	**0.0**	1.5	-2.0	**0.0**	3.5	-3.5	**0.0**	3.5
	Winter	-1.0	**3.5**	7.5	-1.5	**3.5**	10.0	-2.0	**3.5**	15.0
	Spring	0.0	**1.0**	3.5	0.0	**1.5**	3.5	0.0	**2.0**	5.0
Wind Speed %	Annual	-7.5	**0.0**	7.5	-7.5	**0.0**	7.5	- 12	**0.0**	12.5
	Summer	-3.5	**3.5**	10.0	-3.5	**7.5**	12.5	-5.0	**7.5**	17.5
	Autumn	-10	**0.0**	7.5	-12	**-2.0**	10	-17	**-2.0**	12.5
	Winter	-12	**-2.0**	7.5	-17	**-3.5**	7.5	-17	**-5.0**	12.5
	Spring	-10	**0.0**	7.5	-15	**0.0**	12.5	-17	**0.0**	17.5

13 Appendix C: Climate Change Projections for EP Region as a Whole

Variable	Season	Low			Medium			High		
		10th	50th	90th	10th	50th	90th	10th	50th	90th
Temperature ˚C	Annual	0.45	0.8	0.8	0.5	0.8	1.3	0.45	0.8	1.25
	Summer	0.45	0.8	0.8	0.5	0.8	1.3	0.45	0.8	1.25
	Autumn	0.8	0.8	0.8	0.8	0.8	1.3	0.8	0.8	1.25
	Winter	0.45	0.45	0.8	0.5	0.8	1.3	0.45	0.8	1.25
	Spring	0.45	0.8	1.25	0.5	0.8	1.3	0.45	0.8	1.25
Rainfall %	Annual	-7.5	-3.5	0	-15	-3.5	0	-15	-3.5	0
	Summer	-15	-3.5	7.5	-15	-3.5	7.5	-15	-3.5	7.5
	Autumn	-7.5	-3.5	7.5	-15	-3.5	7.5	-15	-3.5	7.5
	Winter	-15	-7.5	0	-15	-7.5	0	-15	-7.5	0
	Spring	-15	-7.5	0	-15	-7.5	0	-15	-7.5	0
Potential Evapotranspiration (PET) %	Annual	0	0	3.0	0	3.0	3.0	0	3.0	3.0
	Summer	0	0	3.0	0	0	3.0	0	0	3.0
	Autumn	0	3.0	6.0	0	3.0	6.0	0	3.0	6.0
	Winter	0	3.0	6.0	0	6.0	10.0	0	6.0	10.0
	Spring	0	0	3.0	0	0.0	3.0	0	0	3.0
Relative Humidity %	Annual	-0.75	0	0	-1.5	0	0	-1.5	0	0
	Summer	-0.75	0	0	-0.75	0	0	-0.75	0	0
	Autumn	-0.75	0	0	-1.5	0	0.75	-1.5	0	0.75
	Winter	-1.5	0	0	-1.5	0	0	-1.5	0	0
	Spring	-1.5	-0.75	0	-1.5	-0.75	0	-1.5	-0.75	0
Solar Radiation %	Annual	0	0	0	0	0	1.5	0	0	1.5
	Summer	0	0	0	0	0	0	0	0	0
	Autumn	0	0	0	0	0	1.5	0	0	1.5
	Winter	0	1.5	3.5	0	1.5	3.5	0	1.5	3.5
	Spring	0	0	1.5	0	0	1.5	0	0	1.5
Wind Speed %	Annual	-3.5	0	3.5	-3.5	0	3.5	-3.5	0	3.5
	Summer	0	0	7.5	0.0	3.5	7.5	0	3.5	7.5
	Autumn	-3.5	0	3.5	-7.5	0	3.5	-7.5	0	3.5
	Winter	-7.5	-3.5	0	-7.5	-3.5	3.5	-7.5	-3.5	3.5
	Spring	-7.5	0	3.5	-7.5	0	3.5	-7.5	0	3.5

Variable	Season	Low			Medium			High		
		10th	50th	90th	10th	50th	90th	10th	50th	90th
Temperature ˚C	Annual	0.8	1.25	1.75	1.25	1.75	2.75	1.75	2.25	3.5
	Summer	0.8	1.25	1.75	1.25	1.75	2.75	1.25	2.25	3.5
	Autumn	0.8	1.25	1.75	1.25	1.75	2.75	1.25	2.25	3.5
	Winter	0.8	1.25	1.75	1.25	1.75	2.75	1.25	2.25	3.5
	Spring	0.8	1.25	2.25	1.25	1.75	2.75	1.75	2.75	3.5
Rainfall %	Annual	-15	-7.5	0	-30	-15	0	-30	-15	2
	Summer	-30	-3.5	15	-30	-7.5	15	-30	-7.5	30
	Autumn	-15	-3.5	15	-30	-7.5	15	-30	-7.5	30
	Winter	-30	-15	0	-30	-15	0	-30	-15	0
	Spring	-30	-15	0	-30	-15	0	-50	-30	0
Potential Evapotranspiration (PET) %	Annual	0	3.0	6.0	0	6.0	10.0	3.0	6.0	14.0
	Summer	0	3.0	6.0	0	6.0	10.0	0	6.0	14.0
	Autumn	3.0	6.0	10.0	3.0	6.0	14.0	6.0	10.0	18.0
	Winter	3.0	6.0	14.0	6.0	10.0	18.0	6.0	14.0	18.0
	Spring	0	0	6.0	-3.0	3.0	6.0	-3.0	3.0	10.0
Relative Humidity %	Annual	-1.5	-0.75	0	-2.5	-0.75	0	-3.5	-1.5	0
	Summer	-1.5	0	0	-1.5	-0.75	0.75	-2.5	-0.75	0.75
	Autumn	-1.5	0	0.75	-2.5	0	1.5	-3.5	-0.75	1.5
	Winter	-2.5	-0.75	0.75	-3.5	-0.75	1.5	-4.5	-1.5	1.5
	Spring	-2.5	-1.5	0	-3.5	-1.5	0	-4.5	-2.5	0
Solar Radiation %	Annual	0	0	1.5	0	1.5	3.5	0	1.5	3.5
	Summer	0	0	1.5	-1.5	0	1.5	-1.5	0	3.5
	Autumn	-1.5	0	1.5	-1.5	0	3.5	-3.5	0	3.5
	Winter	0	3.5	7.5	0	3.5	7.5	0	3.5	15
	Spring	0	0	3.5	0	1.5	3.5	0	1.5	3.5
Wind Speed %	Annual	-7.5	0	3.5	-7.5	0	7.5	-12.5	0	7.5
	Summer	-3.5	3.5	12.5	-3.5	3.5	17.5	-7.5	7.5	17.5
	Autumn	-7.5	0	7.5	-12.5	0	12.5	-17.5	0	12.5
	Winter	-12.5	-3.5	3.5	-17.5	-7.5	7.5	-17.5	-7.5	7.5
	Spring	-12.5	0	7.5	-17.5	-3.5	7.5	-17.5	-3.5	12.5