The Environment Institute
University of Adelaide

Strengthening Basin Communities Program
Planning component Consultancy SBC033A.1/2

Climate Change Impact Assessment Report for the SA Murray-Darling region

November 2011

Milestone 3 Report

Table of Contents

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Executive Summary

The South Australian Murray-Darling Basin is one of the state's most productive regional areas, sustaining major irrigation and dryland farming areas as well as tourism and manufacturing. However, recent years have brought the lowest water availability on record which has significantly affected businesses and communities reliant on the Murray. This has combined with low rainfall years in surrounding dryland farming areas and caused major impacts on the wellbeing of people in the region and on the environment and economy.

These conditions may be a pre-cursor of what is to come. Climate change forecasts suggest that the region will trend toward hotter and drier conditions on average over the next 20-60 years and inflows to the state from the River Murray will be reduced. Recognition of the impact of low rainfall and hotter temperatures over the past decade on the SA MDB means that the time is right to consider how to adapt to the forecast impacts of climate change.

This consideration should not be delayed by the assumption that climate change is declining as drought pressure eases such as in the coming season. It will be important therefore to develop user friendly information that differentiates between climate change scenarios and short term drought.

Eleven Councils within the SA Murray-Darling Basin Natural Resources Management Region established two consortia and attracted Federal Funding Strengthening Basin Communities (SBC) Program – Planning Component to deliver a series of plans to assess the impact anticipated climate change will have on communities, their local water dependant industries, urban water resources management, development plan policy and other strategic planning documents for local government. These plans will identify opportunities to adapt to the anticipated climate, and in particular, living with less water. The "Impact Assessment, Adaptation and Emerging Opportunities" Project is the overarching parent project for both consortia.

The Environment Institute at the University of Adelaide and its team was appointed to undertake the overarching project and has four deliverables:

- Climate change scenarios - Make recommendations on the scenario(s) and associated projected climatic conditions to be applied to the parent and broader projects.
- Climate Change Impact Assessment Report - The report will assess the impact of recently experienced (i.e. the extended drought) and predicted climate conditions on each Council, their communities, community assets and services.
- Adaptation and Emerging Opportunities Plan - Opportunities will be identified for each partner Council and their community to address the predicted impacts of climate change.
- Horticultural/Rural Lands Review – This will identify and describe the horticultural/rural land affected by the current drought that may be affected by forecast climate change impacts and then develop potential model statutory planning policy.

This report is a requirement of Milestone 3 of the parent project and presents an assessment of the potential impact of climate change on the councils in the SA MDB region.

The key messages arising from this report are as follows:

Impact on agriculture

- Warmer and drier conditions will reduce yield of crops and quality of fodder in dryland farming regions across the SA MDB.
- 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 dryland 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

- Biofuel 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 biofuels 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 18-59 cm 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.

1 Introduction

1.1 The project

The *Climate Change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling region* (CCAP) project is the umbrella project in a suite of 21 projects as part of the Strengthening Basin Communities (SBC) program funded by the Australian Government. The funding was provided to eleven councils[1] within the South Australian Murray-Darling Basin (MDB) Natural Resources Management Region to undertake this work:

Findings from the project will assist the region to plan for a climate changed future through addressing risk and its implications and identifying options for adaptation (including emerging industries and associated socio demographic patterns).

The key deliverables for the project are:

1) Climate Change Scenarios;
2) Climate Change Impact Assessment Report;
3) Adaptation and Emerging Opportunities Plan; and
4) Horticultural/Rural Lands Review.

1.2 This report

In this report we assess the impacts of climate change on the councils, communities, industries and services that exist within the South Australian MDB Natural Resources Management Region. To do this we examine the:

- major dryland 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.
- likely impact of emergent industries such as alternative energies and water trading.

This report should be read in conjunction with the other reports submitted for the *Strengthening Basin Communities Program Planning component Consultancy SBC033A.1/2*.

[1] Berri Barmera Council, Regional Council of Goyder, District Council of Karoonda East Murray, District Council of Loxton Waikerie, Renmark Paringa Council, Southern Mallee District Council, Alexandrina Council, The Coorong District Council, Mid Murray Council, District Council of Mount Barker, Rural City of Murray Bridge

2 Impact on agriculture

Agriculture in the SA MDB region has a total gross value of over $1.2 billion (ABS 2007) from a diverse range of dryland and irrigated farming systems. Current climate change projections indicate an increase in temperatures and a decrease in rainfall over the SA MDB and a higher frequency of extreme weather events (Suppiah *et al.* 2006, Suppiah *et al.* 2007). These conditions will have significant effects on current dryland and irrigated production systems.

Climate change projections for the SA MDB

Hayman et al. (2011) have prepared information on climate change scenarios for the SA MDB as part of the broader *Strengthening Basin Communities Program Planning Component Consultancy SBC033A.1/2*. Some of the key messages arising from this work include:

- The study region, in common with the rest of Southern Australia is expected to be warmer (high confidence) and drier (lower confidence). By 2030 the region shows a warming of between 0.5 to 1.3 °C with the mid range model showing 0.8 °C increase. At 2030 the range in warming is due to different climate change models and is not sensitive to different emission scenarios.
- Under medium emission scenarios by 2070 the projected warming is 1.8 °C with a range of 1.3 to 2.8 °C.
- The most likely future is a drier one, 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.
- Runoff is projected to decline in response to warmer and dryer conditions. 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%.

Snap shot - Agricultural productivity

Based on Australian Bureau of Statistics data, agriculture in the SA MDB has a total annual average value of over $1.2 billion.

- Dryland agriculture $900 million.
- Irrigated agriculture $280 million.

Reduced **rainfall** will result in less stream flow and lower allocations for irrigators.[2]

Lower **rainfall** will reduce crop and fodder growth - reducing grain and meat yields.

Higher **temperature** may encourage growth in some crops in cooler areas.

Increased **temperature** will generally speed up phenological development, reduce fruit set in some crops and increase blemish problems.

Increased **CO_2** will encourage growth in some crops but may reduce produce quality.

Increased **CO_2** will improve water use efficiency.

[2] Future allocations may also be impacted by water reform processes such as buyback of entitlements.

Some broad generalisations can be made about the impact of climate change on agriculture based purely on plant physiology. For example, plant productivity is directly related to water availability and as such will increase or decrease with changes in rainfall and the availability of water for irrigation. The largest effect of higher mean temperature is that it will speed up the life cycle of most plants, particularly annual crops like cereals and most pasture species. This generally means that plants have less time to accumulate dry matter although this effect is partly offset by better growth because atmospheric CO_2 concentrations are higher. Higher temperatures will likely benefit some perennial crops in cooler areas through increased temperatures and reduced frost while others may suffer from insufficient chilling for fruit set. In warmer regions for example, annual crops may suffer from increased heat stress and changes in water balance (Howden *et al.* 2010). Increased levels of CO_2 will also have an impact as higher concentrations will increase plant dry matter accumulation and increase water use efficiency (Howden *et al.* 2010, Stokes *et al.* 2010). However, it is also believed that the higher CO_2 levels also reduce the quality of produce because the increased rates of development lower the protein content of grain and fodder. It is unlikely that the benefits from higher concentrations of CO_2 are sufficient to offset expected negative consequences such as those discussed above (Howden *et al.* 2010, Stokes *et al.* 2010).

As a consequence of these factors each industry will face unique challenges and opportunities. For example, dryland cropping and grazing will be affected by shortened growing season duration, reduced yield potential, increased stress on livestock and reduced abundance and quality of their feed. Similarly, irrigated cropping will be affected as decreased rainfall over the entire basin means less river flow and likely lower water allocations. Insufficient cold will reduce seed set for some fruit crops (Hennessy and Clayton-Greene 1995) and higher temperatures will affect fruit quality for other crops. The reduced risk of frost will be advantageous for some crops but these benefits can be quickly overshadowed by the prospect of lower rainfall amounts.

In the absence of mitigating measures, the combination of these factors has the potential to increase the vulnerability of farming systems and farming communities. Below we give detailed examples of the impacts on the major farming systems in the SA MDB and discuss how the economical viability of these systems might be affected.

Community perspectives on climate change impacts on agriculture.

A Stakeholder Engagement process has been run as part of the broader Strengthening Basin Communities Program Planning Component Consultancy SBC033A.1/2 project. This involved interviews and meetings with members of a Consultation Reference Panel. The findings of this process most relevant to the impacts of climate change on agriculture included the following:

- There is a consistent view that irrigation and dryland farming will be the industries impacted the most by warmer and drier conditions under future climate change. This will have flow on impacts to the SA MDB community and Councils.

- There is a sense of urgency to prepare for climate change and a sense of uncertainty in how to go about it. There is a strong indication that the current primary production mix across the region can adapt to a low emissions future, but not to a medium emissions future. Inability to adapt could be created by delayed action that makes the cost of adaptation unaffordable when the circumstances arise.

- There is no guarantee that irrigators that stop farming will remain in the district. The capacity of irrigators to adapt not only involves changes in agronomic practices and crop selection, but will depend on financial, and wealth and financial incentives. Dryland farmers are less likely to leave the district indicating that long term adaptation to droughts and uncertainty have increased resilience to climate change, and given them greater capacity to adapt further.

2.1 Dryland agriculture

Key messages

- Without adaptation, warmer and drier conditions will reduce yield of crops and quality of fodder in dryland farming regions acrosss the SA MDB.
- Without alternate aninmal husbandry, increased temperatures and heat stress may reduce animal producvitiy.
- Increases in CO_2 will increase plant dry matter accumulation rates, but also result in reduced fodder and grain quality.
- Less rainfall could reduce salinity risks on one hand but increased rainfall intensity and wind during summer could increase the risk of soil erosion.

Dryland agriculture is the dominant land use (by area) in the SA MDB. Dryland cropping, consisting largely of cereals, legumes and oilseeds covers an area of approximately 1 million ha and has a gross production value of around $900 million (ABS 2007). Cropping in the SA MDB is highly sensitive to climate with historical variations in rainfall causing substantial fluctuations in yield and grain quality (Howden *et al.* 2010). Alternatively, sheep and cattle farming dominate the broadacre grazing industry in the SA MDB with a gross value of $230 million in primary products alone (ABS 2007). Grazing systems in the SA MDB range from semi-arid in the north of the region to near temperate in the south. With projections of drier conditions and increased frequency of extreme weather events it is likely that semi-arid cropping and grazing areas may become more financially risky. This increased risk may translate into lower viability especially for those areas and enterprises that are already marginal. The demise of marginally viable enterprises is often precipitated by an unusual sequence of events, for example, a sequence of very dry years or poor yields and very low market prices. The projections of warmer, drier climate conditions are also likely to have an increased incidence of unfavourable climate sequences. If this is so then areas that are currently marginal are likely to become increasingly unviable.

What rainfall are we likely to experience in the future?

By **2030**, under a medium emissions outlook, using the midpoint of model projections, the average annual rainfall will be 3.5% less than the current annual average, with no change in autumn but 7.5% less rainfall in winter and spring.

By **2070**, under a medium emissions outlook, using the midpoint of model projections, the average annual rainfall will be 10% less than the current annual average, with 3.5% less in summer and autumn but 15% less in winter and spring.

Long term rainfall records from this region indicate a general drying trend with a 5 to 10mm decline per decade for the last 50 years. This means a decrease of 25 to 50 mm has already occurred

Reduced rainfall would have large negative consequences for cropping and grazing across the SA MDB although recent studies show that cropping would be more affected than grazing (Bryan*, et al.*

2010b). Crop yields and pasture productivity are heavily reliant on rainfall and thus reduced rainfall would reduce the productivity of these systems (Stokes *et al.* 2008, Howden *et al.* 2010, Stokes *et al.* 2010).

Changed rainfall seasonality and totals will cause changes in vegetation cover, and in turn this will affect soil water balance and groundwater. There are also likely to be changes in the intensity and timing of rainfall events. Projections for changed timing of rainfall in the SA MDB are important because of the potential for greater reductions in rainfall during the primary growing season for winter cereals, the principal crop in the SA MDB. Also, a higher frequency of summer rainfall events will change the growth patterns of pastures and the availability of forage in broadacre grazing systems. Depending on the timing and quantity of summer rainfall, this may assist in refilling the soil profile allowing for earlier seeding, although the potential magnitude of this benefit requires further investigation.

There are indirect consequences of reduced rainfall such as lower risks of dryland salinity from reduced rainfall but conversely there are higher risks of soil erosion from reduced plant growth (Howden *et al.* 2010). Changes to rainfall intensity may also impact cropping systems, but are projected to be modest by 2050 (2% increase in intensity) coming from intensity that is relatively low in the first place (Hayman *et al.* 2011).

Increased temperatures will have a variety of direct and indirect consequences for broad acre agriculture. Higher temperatures will generally accelerate the rate of plant development thus reducing the duration of the growing season (Howden *et al.* 2010). This is likely to reduce crop yields (as the plants will have less time to photosynthesise) and thus produce biomass (particularly grain). However, alternative varieties and modified management regimes may counter these losses (Howden *et al.* 2010).

For grazing systems, higher temperatures will also affect pasture growth and have consequences for livestock. As with cropping systems increased temperatures will increase the rate of plant development. In situations where pasture growth is currently limited by low temperatures it is likely that growth rates will increase as average temperatures will be warmer, but again the duration of growth will be shorter. Higher temperatures may also have negative consequences for livestock directly with reduced animal productivity and reproductive rates due to heat stress. There may be opportunities to exploit hardier sub tropical breeds like those used further north in Australia. However, these species are generally less productive, have a lower fecundity and produce poorer quality meat.

Climate change will affect the distribution of pests, feral animals, disease and weeds with consequences for all dryland production systems. For example, desirable forage plants may be out competed by less suitable and palatable species that are more suited to the changing climate (Stokes *et al.* 2008).

Increased frequency of extreme weather such as large rainfall events or high wind intensity will have significant consequences for soil erosion. Increases in wind speed by 2070 are likely to be greatest in summer months (e.g. medium emissions scenario with midpoint of models projects a 7.5% increase in wind speeds) (Hayman *et al.* 2011), when soils in the landscape are dry and at their most vulnerable. Small amounts of topsoil removal can remove large amounts of soil nutrients having a significant effect on overall soil fertility.

Bryan *et al.* (2007) modelled the impact of climate change on agricultural production in and around the SA MDB. They looked at various crops including wheat, lupins, canola and lucerne under traditional and conservation (minimum tillage) management systems. They also examined various rotations including continuous cropping, crop-crop rotations and crop-grazing rotations with different crops and pastures, where applicable, and found each of these had reduced yield estimates with warming and drying climate scenarios. For example, under the most severe warming (4^{o} C hotter) and drying (25% less rain) they found a wheat yield decreased by one third[3]. They also examined the impact of these changes on environmental issues and found a reduced risk of dryland salinity through reduced deep drainage but dramatic increases in the risk of erosion due to reduced crop growth and vegetative cover. For example, under severe warming and drying the area of land at risk of dryland salinity decreased by 74% and the area at risk of wind erosion increased by more than 10 times (Bryan *et al.* 2010b).

2.2 Irrigated agriculture

Key messages

- 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.

Irrigated agriculture in the SA MDB is dominated by viticulture and horticulture. Viticulture in the region has an approximate gross value of $280 million and covers an area of 30,000 ha (ABS 2007). Horticulture in the SA MDB is dominated by fruit (e.g. citrus, stone and pome), nuts and vegetables with an annual gross value of more than $260 million over an area of approximately 14,500 ha (ABS 2007). With the exception of vegetables these are all largely high value perennial tree crops that take many years to establish and are dependent on irrigation water for their viability in the Riverland region, which is a semi-arid climate.

A warmer and drier climate with higher concentrations of CO_2 in the atmosphere will have a variety of effects on these industries. The most obvious effect on production systems will be decreased precipitation in Upper Murray catchments which will reduce flows into major storages (e.g. Hume and Dartmouth Dams) and result in less reliable water allocations for irrigation. This also applies to the various catchments of the Darling River system, which although provide less average inflow to the Murray, also contribute to irrigation supplies for River Murray system irrigators (i.e. water in the Menindee Lakes forms part of the shared supply for New South Wales, Victoria and South Australia). While desirable, accurately forecasting future irrigation allocations under various climate change projections is difficult because allocations will also be influenced by government policy such as the Murray-Darling Basin Plan as well as water delivery arrangements and how these interact with environmental water management practices (e.g. share of river transmission losses between the environment and irrigation).

The increased temperatures will also have an impact with higher demand for water and possible reduced vigour in plants due to heat stress. This combination of higher demand and less supply will put greater pressure on water use efficiency (Webb and Whetton 2010). Furthermore, increased temperature and water deficit stress will also adversely affect fruit quality in both viticulture and horticulture (Jones *et al.* 2005, Webb and Barlow 2008, Webb *et al.* 2008b). This may be in the form of sunburn or colourisation issues in the fruit which will effect market prices. Higher temperatures have also been found to alter the flavour and aroma of wine grapes with subsequent consequences for the wine itself (Mori *et al.*).

[3] These conditions are projected by some models under a high emissions future. See Hayman et al. 2011.

A warmer climate will result in a faster progression of the phenological and fruiting stages resulting in an early season for many grape varieties and horticultural crops (Webb *et al.* 2008a). For some vegetable crops (e.g. lettuce) it may be possible to achieve two crops within the timeframe of one under current climatic conditions (Pearson *et al.* 1997). However, increased water and heat stress may also cause some vegetable crops (e.g. lettuce, parsley, spinach) to bolt (premature flowering) and reduce the viability of these crops in the region (Webb *et al.* 2008a, Webb and Whetton 2010). Higher temperatures may also be a threat to crops that require chilling for setting fruit (e.g. stone and pome fruit) and may reduce the area suitable for these crops (Webb and Whetton 2010).

Reduced flows due to climate change in the SA MDB (extract from (Hayman *et al.* 2011).

The Murray Darling Basin Sustainable Yields Project[4] was released in July 2008. It estimates the current and likely future (2030) water availability in each catchment and aquifer for the entire Murray-Darling Basin, considering climate change and other risks, and surface-groundwater interactions. The mid-point (median) of the estimates suggests that in 2030 water availability in the Murray will be 14% less than for the period 1895 to 2006. This compares with the 10 year period from 1997 to 2006 which saw a 30% decline in water availability in the Murray.

Increased CO_2 concentrations are generally thought to increase plant growth through higher rates of photosynthesis (Webb and Barlow 2008). However, this may have mixed impacts on irrigated agriculture in the SA MDB. For example higher CO_2 levels have been shown to increase grape yields by up to 35% in some cases but this is without the corresponding increase in temperature expected as part of climate change. Furthermore, increased CO_2 concentrations may lead to increased plant vigour but this may not lead to improved yield in volume or quality. For example, in vines excessive vegetation can cause problems with within canopy shading whereby grapes do not receive enough sunlight (Webb and Barlow 2008). Similarly, higher levels of CO_2 can lead to lower protein and nitrogen concentrations and this can have flow on effects for fermentation or other forms of value adding (Webb and Barlow 2008).

For irrigated crops where the controlling limit of water availability is minimal, the increase in CO^2 and temperature may open new opportunities for crops and cropping practice that are currently not viable. For example, drier (less humid) conditions will likely reduce yield losses due to fungal diseases and some insect pests (Webb and Whetton 2010). Similarly, there will likely be a reduction in the number of frost days which will decrease the risk of frost damage on canopy and fruit development (Hennessy *et al.* 2007). Furthermore, some crops that were not previously suitable to the SA MDB may become suitable, e.g. tropical fruits that require higher temperatures or fewer frost days (e.g. avocados, pecan nuts, bananas) (Webb *et al.* 2008a, Webb and Whetton 2010).

2.3 Economic viability of traditional agriculture

Key messages

- 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.
- Current agricultural enterprises may remain viable despite reduced productivity if higher commodity prices are forthcoming.
- Alternative industries resulting from new markets (e.g. water trading, carbon) may be more profitable.

[4] http://www.csiro.au/partnerships/MDBSY.html

The impact of climate change on the economic viability of traditional agriculture such as broadacre cropping and grazing, and irrigated horticulture and viticulture is dependent on many variables. Some studies have examined the consequences on productivity of agricultural pursuits estimating changes in yield due to various factors such as temperature, rainfall and CO_2 (e.g. Wand *et al.* 1999, Tubiello *et al.* 2000). Most of these, as discussed above, find that there are potential consequences such as changes in yield or product quality with various other environmental consequences such as reduced risk of dryland salinity and increased risk of soil erosion. However, it is difficult to predict changes in commodity prices and other market conditions that may affect the viability of different industries into the future. For example, while production may decline for some industries, overall profitability may not be affected due to increased commodity prices. However, the development of other industries may reduce the viability of traditional agriculture despite overall profitability. For example, under some market conditions it may be more profitable to grow alternative crops for biomass or carbon sequestration (see Section 3: Emergent Industries).

2.3.1 Dryland agriculture

Dryland agriculture is highly dependent on climate to maintain production. Under a warming and drying climate crop and livestock yields are likely to decline. A recent study looked at dryland agricultural productivity in the Lower Murray, an area including the SA MDB and the Mallee and Wimmera Catchment Management Authorities (CMA) in Victoria (Bryan *et al.* 2010b). This study found average economic returns to broadacre cropping decreased substantially under climatic warming and drying while grazing was less impacted due to a smaller decrease in pasture productivity (Bryan *et al.* 2010b). Figure 1 shows the average economic returns from traditional agriculture and biomass production across the three management regions with increased warming and drying. This graph indicates that the economic viability of traditional agriculture in the SA MDB will suffer substantially under warming and drying scenarios while biomass production remains relatively unchanged. The reduced impact of climate change on the profitability of biomass production is due to the resilience of deep rooted perennials (e.g. oil mallee) to warming and drying.

It should be noted that both of the assessments depicted in Figure 1 (traditional agriculture and biomass) are calculated with static commodity prices. Changes in the price of traditional agricultural commodities (e.g. wheat, meat, wool) or biomass would alter the results.

For more details on the impact of biomass and other industries on traditional agriculture see Section 3: Emergent Industries.

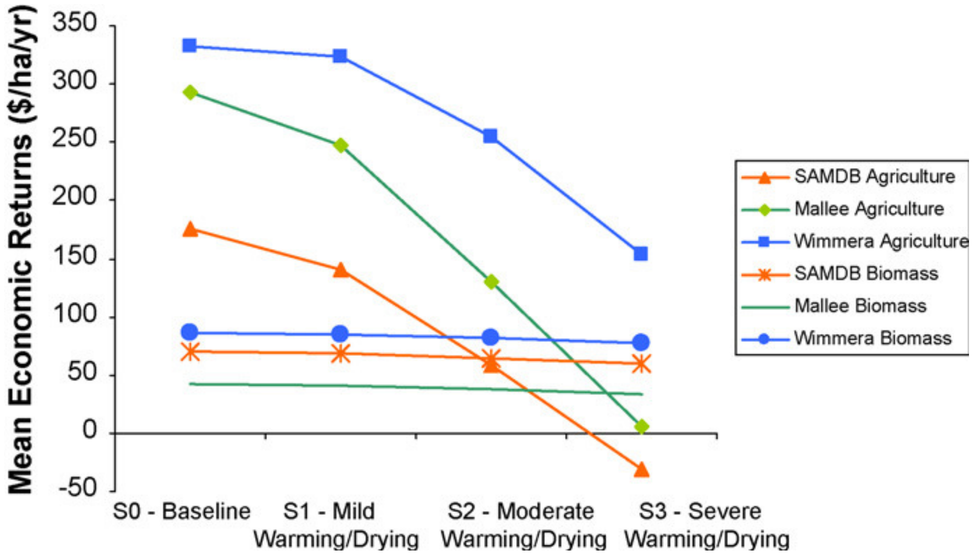

Figure 1: Average economic returns in the SA MDB, Mallee CMA and Wimmera CMA regions from traditional agriculture compared with the biomass production (@ $40/tonne for raw biomass) (Bryan *et al.* 2010b).See section 3.1.2: Biomass for a more detailed description of biomass production.

2.3.2 Irrigated agriculture

The profitability of irrigated agriculture is directly linked to the availability of water. Under climate change there is likely to be less rainfall, less stream flow, reduced water held in major storages and thus less water available for irrigation allocations. A recent study by Connor *et al.* (2009a) examined the economic impacts of potential climate change on irrigated agricultural production in the lower South Australian and Victorian irrigation districts. This study examined various levels of climate change and restrictions in water allocations in the SA MDB. Results indicate that the profitability of irrigation industries in these regions is heavily dependent upon water allocation (see Figure 2). Under severe climate change scenarios (with 35% of baseline water allocations) profits may be as low as 13% of baseline (Connor *et al.* 2009a). Furthermore, Figure 2 demonstrates that as water allocations fall below an annual average of 30% in the SA MDB irrigation industries in the region become unprofitable.

Another study was also completed recently by the Australian Institute for Social Research in collaboration with EconSearch which undertook an economic analysis of two hypothetical irrigation water restriction scenarios in the Riverland region using an input-output (I-O) model. In contrast to Connor et al (2009a) this study attempts to predict region wide economic impacts. While the model did not analyse specific climate change impacts, some inferences can be made given that one of the forecast impacts of climate change will be reduced flow in the River Murray.

The first modelled scenario was of the impact of a short term (i.e. one year) 25 per cent reduction in water availability in the Riverland. This could be a consequence of, for example, drought induced water restrictions. This found that gross regional product (GRP) for example, would be expected to fall by almost $30 million, or approximately 2.0 per cent of total Riverland GRP (approximately $1.5 billion in 2009/10). An indicative calculation was also prepared of the impact on property value, and council rates. This was conservatively modelled as being linked to a loss of property values of almost 2% per property, while Council rate revenue would be reduced by almost $0.5 million per year.

The second scenario assumed both a short and long term 25 per cent reduction in water availability (the best estimate is that in 2030 water availability in the Murray will be 14% less than the 1895 to 2006 period, CSIRO (2008)). The results of the simulated changes were a 4.7% decline in GRP and 4% decline in employment, but this diminished over the 10 year modelled period to 2.6% and 2.1% respectively. The diminishing effect is partly because of the assumed improvement in water use efficiency and, in the case of employment and population.

It should be noted that water markets and the ability to trade in annual water allocations from other growers or to buy entitlements from interstate could act to offset these impacts. If this was to be the case, the main issues will be whether South Australian growers can purchase sufficient volumes of water at a price they are willing to pay.

The potential impact of water trading is discussed further in Section 3.4: Water trading.

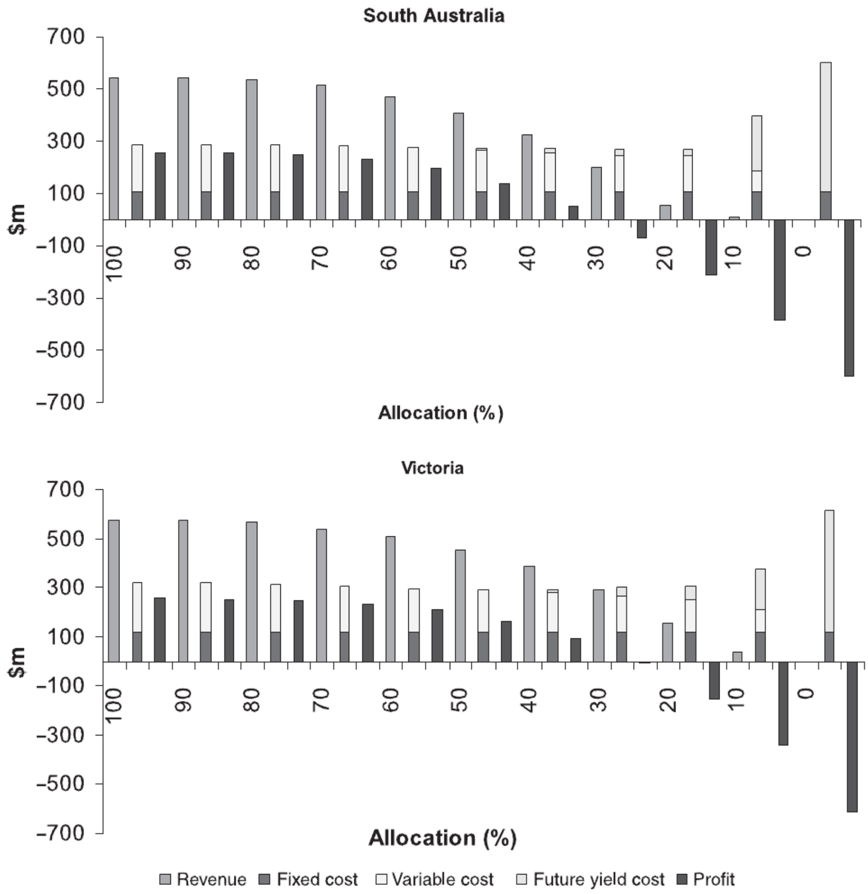

Figure 2: Estimated revenue, cost and profit of reduced water allocation for the South Australian and Victorian Lower Murray Irrigation Sectors (Connor *et al.* 2009a).

2.3.3 Global food prices and economic viability

It is important to note that none of the analyses discussed in the previous two sections looked at variation in food price. Figure 5 shows the Global Food Price Index from 2007 to early 2011 and demonstrates the volatility of food prices around the world over this period (Evans 2011). While not all of the food products that make up the Food Price Index depicted in Figure 5 are relevant to the SA MDB, it still demonstrates the volatility of food prices on the international markets.

There are many factors, both local and global, that influence the price of agricultural commodities around the world. For example, the last global food crisis in 2008 was a combination of food shortages as well as high oil and fertiliser prices and the policies of some governments, including food export bans and biofuels subsidies (FAO 2008, Evans 2011). There is also no doubt climate change itself will have a significant impact on the price of agricultural commodities, especially if production levels decline as a result of warming and drying. Furthermore, the global population is expected to increase dramatically over coming decades putting further pressure on the capacity of global agriculture to provide sufficient nutrition for the world's population and on commodity prices (Sheales and Gunning-Trant 2009).

Given the unpredictability of global food prices it is difficult to predict how they may vary in the future. Current predictions from the Food Agriculture Organisation and the OECD indicate that prices for some food types will remain above historic levels (FAO 2008, OECD 2011) but it is impossible to predict them accurately into the future, particularly under climate change. Nonetheless, increasing prices for agricultural commodities may improve the economic viability of irrigated or dryland agricultural commodities despite declining productivity. However, it should also be noted that the extent of this benefit may be commodity specific. For example, not all commodities that are currently achieving high prices internationally are grown in the SA MDB (e.g. global staple food and fibre crops).

Global food prices and their effect on food security are discussed further in Section 2.5: Food security.

2.4 Area under production

Key messages

- Climate change may result in a change in the area of land under different production systems.
- For dryland farming, this could mean less cropping and increased grazing. If alternative land uses such as growing biomass for electricity generation or growing crops for biofuels become economically viable, they may further add to the diversity of production systems.
- 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.

While the total area under all forms of agricultural production may remain about the same, there is likely to be a shift in the proportion of land associated with different forms of production. The climate itself will have a significant effect with some crops simply becoming unsuitable for production in areas where they are currently well suited. This may be the result of reduced rainfall limiting the area available for cropping (Howden *et al.* 2008) or unsuitably warm winters reducing the amount of fruit set in horticultural crops (Webb *et al.* 2008a). As discussed in the previous section, crops may suffer from significantly reduced yield but still be economically viable due to elevated commodity prices driven by both domestic and international markets. The point is that in the same way as adaptation has been going on now, there will be ongoing ownership changes and modifications to stocking and cropping practice. Despite modifications and adjustments some properties will become unviable as productivity declines and or variability in weather and commodity prices shake out those practices that cannot adjust sufficiently.

In dryland agriculture the largest driver of land change will likely be rainfall (Howden *et al.* 2008). A warming and drying climate will make marginal cropping and grazing systems more marginal and potentially unviable. Reduced rainfall may prevent crops that have previously been grown in certain regions being no longer suitable under climate change. It is quite possible that these areas will be suitable for another form of agricultural food production such as grazing. There may be cost associated with this change in land use, i.e. grazing is not as profitable as cropping, but the land will still be used in food production. However, with the potential introduction of market or policy instruments (e.g. a price on carbon or minimum usage of biofuels) other land uses may become more profitable. Some recent studies (e.g. Bryan *et al.* 2008, Bryan *et al.* 2010a, Bryan *et al.* 2010b) examined the viability of alternative land uses which may drive land use change. These studies show that under climate change alternative land uses, such as growing biomass for electricity generation or growing crops for biofuels, may become more economically viable than traditional food agriculture. Some of these production systems (e.g. biomass) will also have other environmental effects such as reduce risk of salinisation and erosion.

This shift in production systems can be seen in the recent drought and changes in land use throughout the irrigation districts of the River Murray. Reduced rainfall over a sustained period created an 'operative drought' where supply (low inflow) was insufficient to meet the needs of all uses (municipal, industrial, irrigation) (Pulido-Velazquez *et al.* 2006). As water became more expensive, it was traded from less valuable to more valuable production systems. This was because

(a) growers in the former could generate more revenue from the sale of water than they could through applying it to their own productive systems and (b) growers in more valuable production systems were willing to pay higher prices because they had invested in perennial plantings that could not go without water for the season, whereas pasture grass could. For example, growers with relatively low value annual crops that do not have significant opportunity costs involved with establishment (e.g. growing pasture for dairy) could generate more revenue by selling their annual water allocation and either leave land fallow or revert to alternative dryland systems and buy in dry feed (e.g. spent grain). Conversely, growers with high value crops that have very high opportunity and establishment costs were able to buy in water to maintain their crops.

Figure 3 and Figure 4 demonstrate the change in irrigated land use over time in the Riverland district and region south of Blanchetown respectively. Each of these sets of maps shows land use in growing seasons from 2003 to 2009. In both Figure 3 and Figure 4 the maps depicting land use in 2003-2004 and 2005-2006 remain relatively unchanged. However, as the drought became more severe in 2007-2008 there were some obvious land use changes. In the Riverland (Figure 3), which is dominated by high value crops such as stone fruit, citrus and vines, there is less change. Nonetheless, there is an increase in the amount of ‘Land in transition’, which is largely land that has been left fallow or is in transition to dryland uses, and minor increases in the amount of vegetables and field crops. In the region below Blanchetown (Figure 4) there are much more dramatic changes. In 2003-2004 this area is dominated by livestock uses which consist mostly of dairy cattle. However, over the course of the drought the land use changes dramatically with significant increases in the amount of ‘land in transition’.

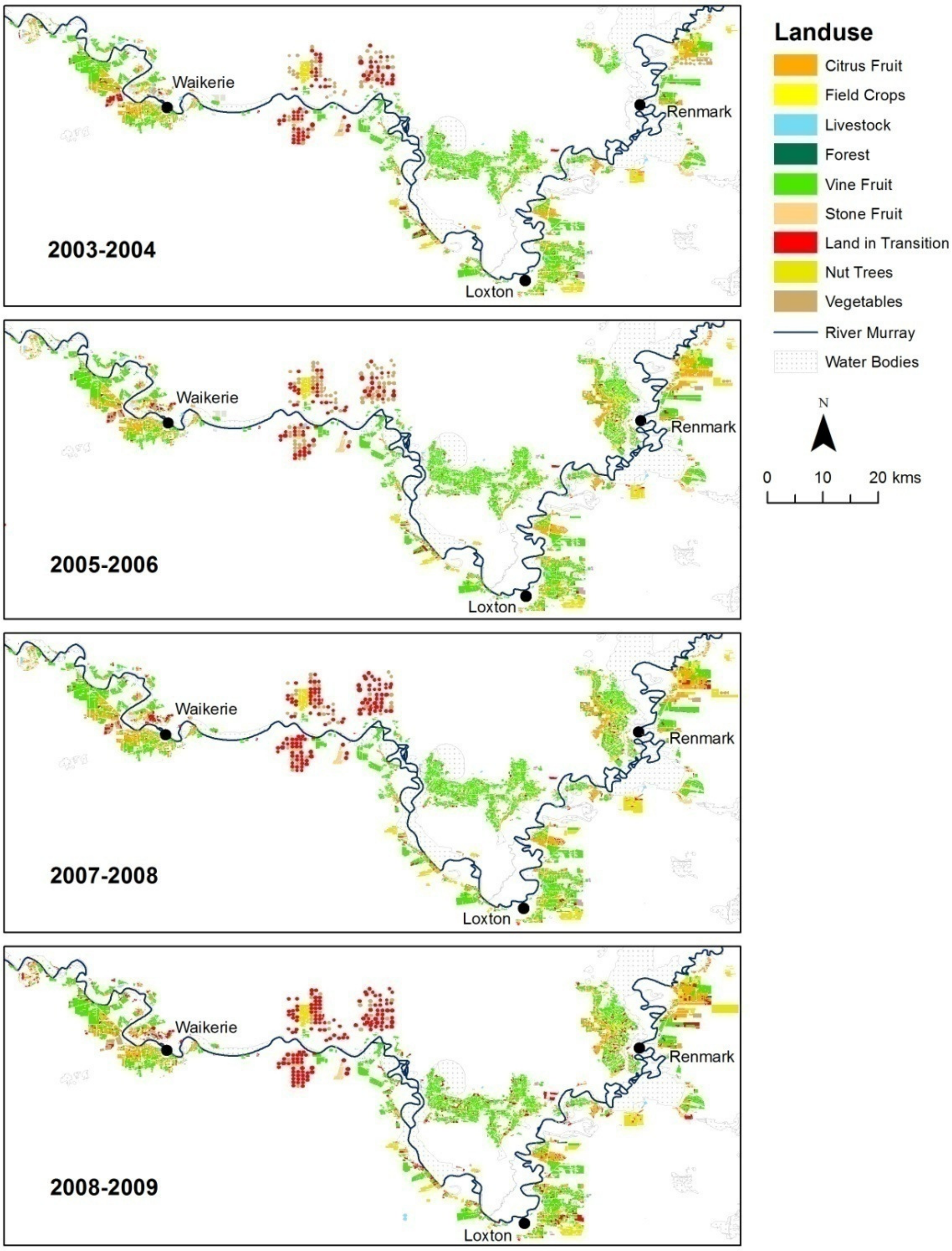

Figure 3: Time series demonstrating change in irrigated land use in the Riverland from 2003 to 2009 derived from River Murray irrigated crop survey annual datasets. The data used to create this map was provided by the SA MDB NRM Board, Central Irrigation Trust, Renmark Irrigation Trust, Department for Water and the Department of Environment and Natural Resources.

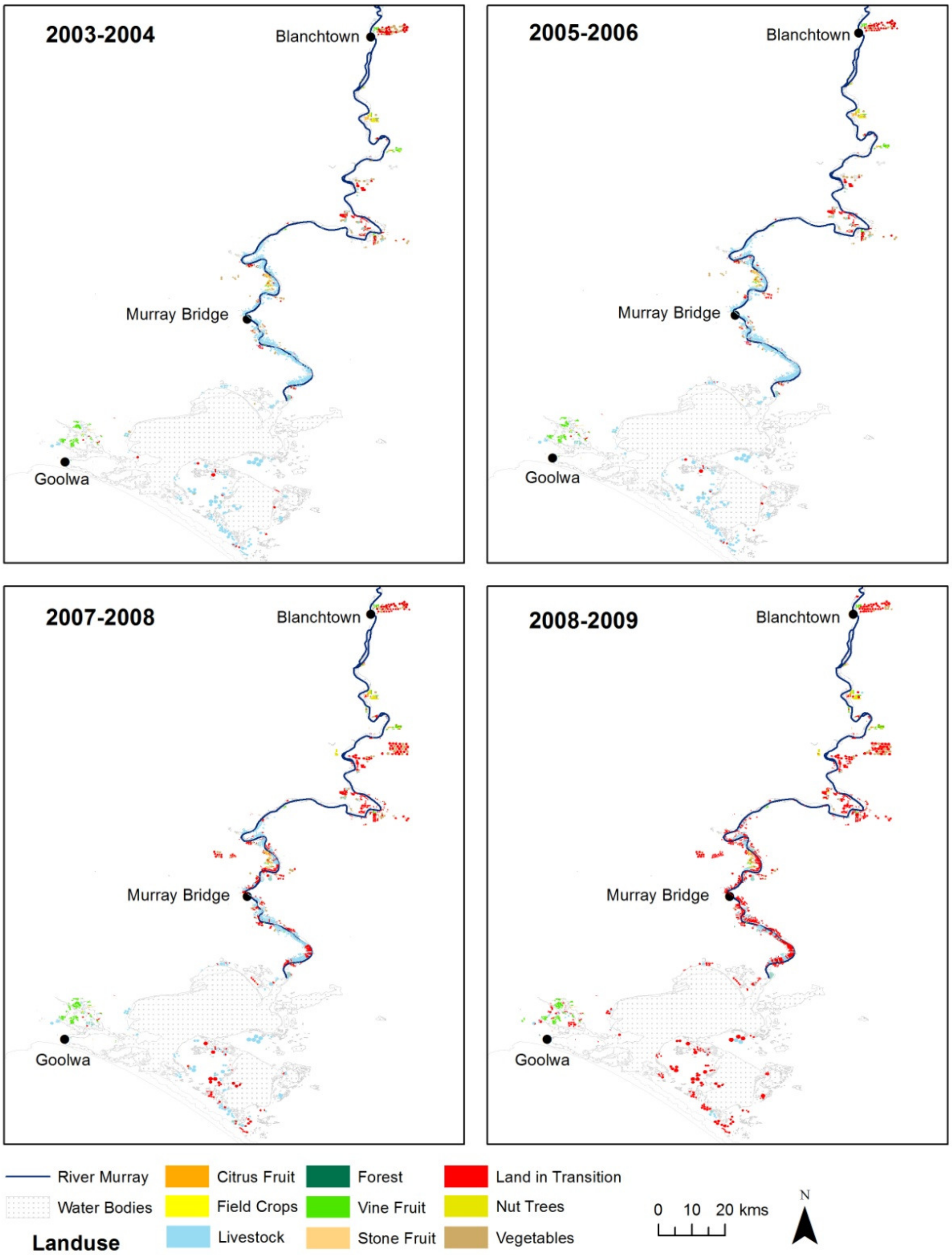

Figure 4: Time series demonstrating change in irrigated land use south of Blanchetown from 2003 to 2009 collected by the South Australian Murray-Darling Basin Information Centre. The data used to crate this map was provided by the SA MDB NRM Board, Central Irrigation Trust, Renmark Irrigation Trust, Department for Water and the Department of Environment and Natural Resources.

The potential impact of possible emergent industries such as biofuels and biomass will be discussed further in Section 3: Emergent industries.

2.5 Food security

Key messages

- Food security is about everybody within communities having sufficient physical, social and economic access to food.
- Australia produces twice as much food as it consumes, the rest is exported.
- 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.

2.5.1 Global food security and Australia

Food security is generally defined as all people in a community having 'physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO 2010). Within this context, food security has five main facets (PMSEIC 2010):

- The availability of sufficient food for all people;
- Equitable physical and economic access to food at all times;
- Access to culturally acceptable food, produced and obtained in ways that do not compromise people's dignity, self-respect or human rights;
- Access to nutritious food that is produced in environmentally sustainable ways; and
- reliable access to a stable food supply.

There is no threat of food shortages in Australia, as the nation produces twice the amount needed to feed itself with the rest being exported to other countries (Moir and Morris 2011). Nonetheless, Australian markets are also subject to the pressures of global commodity markets and as such may experience price inflations along with the rest of the world. However, there is very little risk that Australia will be unable to feed itself or face a threat to its food security that fits the description above.

The most recent example of a threat to global food security was the global food price spike in 2007 and 2008. The seriousness of this crisis showed how sensitive the world is to a sudden decline in the availability of food. The risk of future food shortages is increasingly likely under climate change as production levels struggle to match population requirements. The people most severely affected by the 2007/2008 crisis were the urban poor from developing and low income countries. In many cases physical shortages and significantly declining affordability resulted in reduced nutritional intake or tradeoffs with other necessary expenditures like health and education (Sheales and Gunning-Trant 2009). In developed countries such as Australia, increases in the price of food and in the cost of living may have affected lifestyle choices around food and other consumables but the physical availability of food, and thus nutritional intake, was not under threat (Sheales and Gunning-Trant 2009). Despite the relative surety of food security within Australia there are serious economic and cultural ramifications associated with international food commodity prices and food shortages.

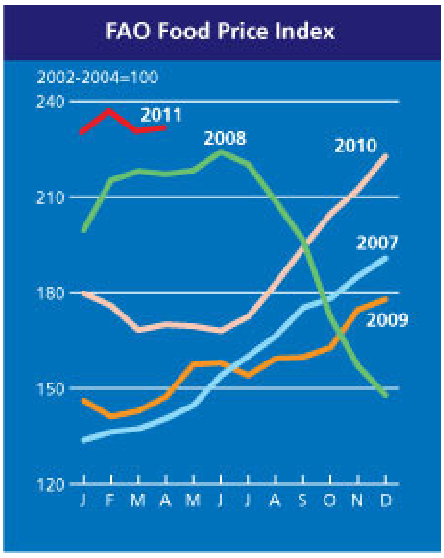

Figure 5: Global Food Price Index from 2007 until early 2011 (Evans 2011).

2.5.2 Alternative land uses

The increasing international demand for cereals and oilseeds as feedstocks for the production of ethanol and bio-diesel can have significant consequences for global food security. Particularly in the United States and Europe, substantial amounts of these crops are being diverted to the production of these biofuels. This phenomena is seen, at least in part, to be a contributing factor to the international food crisis of 2008 (Rosegrant 2008, World Bank 2008). In the United States an estimated 25% of the domestic corn crop is used in the production of ethanol and as a result there is less available for export and as a feed stock for livestock (Sheales and Gunning-Trant 2009). Similarly, in the European Union, 40% of the entire canola crop is now used for the production of bio-diesel (Sheales and Gunning-Trant 2009).

Projected climate change and the adoption of policy instruments such as a carbon price may see farming for biofuels or biomass increase in Australia and, as a consequence, a decrease in food agriculture. This is likely to have little effect on global food prices, given the relatively small proportion of food commodities that Australia contributes to global trade. However, there may be local consequences of this changing land use. For example, traditional industries from particular regions may shift or disappear completely. This will have consequences for infrastructure and labour markets and also require cultural adjustments as people come to terms with different production systems and landscape changes.

A more detailed discussion of the viability of alternative land uses can be found in Section 3: Emergent industries.

3 Emergent industries

Key messages

- Biofuel 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 biofuels 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.

3.1 Alternative energy

Production of biofuels and biomass are potential alternative land uses that may become increasingly viable if policy response to mitigate climate change include putting a price on carbon emissions.

Biofuel is a liquid fuel such as biodiesel, often produced from canola and other oil seed crops, and ethanol, produced from wheat and corn. Biomass production is growing trees which are used as a fuel source for the production of electricity and, in some cases, includes the production of secondary products such as oils and activated carbon (Bryan et al. 2008). Recent studies (Bryan et al. 2010a,b; Bryan et al. 2008) in the SA MDB have looked at the potential of biofuels and biomass agriculture under different climate change scenarios. These studies examined how alternative land use options would be affected by different markets and policy options and what the likely economic and environmental consequences would be.

Putting a price on carbon (based on information contained in the Clean Energy Plan)[5]

A carbon price will put a price on every tonne of carbon dioxide pollution released into the atmosphere by the country's biggest emitters. This will require around 500 businesses to pay for their pollution under the carbon pricing mechanism. The aim is that the carbon price will create a financial incentive to reduce carbon pollution that will flow through the economy.

For the first three years, the carbon price will be fixed like a tax, before moving to an emissions trading scheme in 2015. In the fixed price stage, starting on 1 July 2012, the carbon price will start at $23 a tonne, rising at 2.5 per cent a year in real terms. From 1 July 2015, the carbon price will be set by the market.

A price on carbon pollution will create incentives to reduce pollution and invest in clean energy.

This will change Australia's electricity generation by encouraging investment in renewable energy like wind and solar power and the use of cleaner fuels like natural gas. Emissions from agriculture will not be subject to a carbon price.

[5] Australan Government (2011). Securing a clean energy future: The Australian Government's Climate Change Plan. Commonwealth of Australia

3.1.1 Biofuels

Biofuels are seen as a potential opportunity for increased profitability and a source of renewable transport fuel with a particular view to climate change adaptation. First generation biofuels are an existing low-carbon alternative for the transport sector (Tilman *et al.* 2001). However, there is some concern, both in Australia and around the world that this would be at the cost of food and fibre production (e.g. wheat used to produce ethanol rather than provide a source of food).

A recent study (Bryan *et al.* 2010a) examined the impact and viability of biofuels agriculture in the SA MDB and some neighbouring regions.

Figure 6 shows some of the results from this study and demonstrates that in some cases biofuel agriculture is more profitable than traditional food agriculture. However, the results indicate that carbon price is in fact the largest driver of economic viability and that increasing climate change has negative consequences on biofuel production. This is because the crops used in the production of biofuel (e.g. canola and cereals) are equally susceptible to the effects of climate change whether produced for biofuel or for food. The adoption of biofuel production may provide some greenhouse gas abatement by sourcing transport fuels from a renewable source. However, it is not clear that this would be significant and food security and environmental concerns may outweigh the potential benefits (Bryan *et al.* 2010b).

Thus biofuel production will likely be adversely affected by climate change. However, there are some policy instruments associated with climate change, namely a price on carbon, that will benefit the production of biofuels. If suitable policy mechanisms are introduced, the production of biofuels in the SA MDB may benefit producers through increased demand for certain cereals and oil seeds. The issues associated with food security are discussed in more detail in Section 2.5: Food security.

Comparing climate change scenarios

A number of sections in this report draw on modelling results for climate change scenarios presented in Bryan *et al.* (2010b). How do their scenarios compare with the climate projections for the SA MDB region presented in Table 2 of Hayman et al. 2011, which has been prepared as part of the broader *Strengthening Basin Communities Program Planning component Consultancy*?

Bryan *et al.* (2010b) describe scenario 1 (S1) as a 1 °C increase in temperature and 5% decrease in precipitation*.* Using data in Table 2 of Hayman *et al.* (2011), by 2070, these conditions are forecast by all models under a medium and high emissions future and all but a few models under a low emissions future.

S2 is 2 °C increase in temperature and 15% decrease in precipitation. By 2070 this level of temperature rise is forecast for at least half of the models under a medium and high emissions future. This level of rainfall decline is forecast under at least half of the models for a high emissions future and at least 10% of the models under the medium emissions future.

S3 is 4 °C increase in temperature and 25% decrease in precipitation. By 2070 this level of temperature rise is forecast for less than 10% of models under a high emissions future. This level of rainfall decline is forecast under at least 10% of the models for a high emissions future.

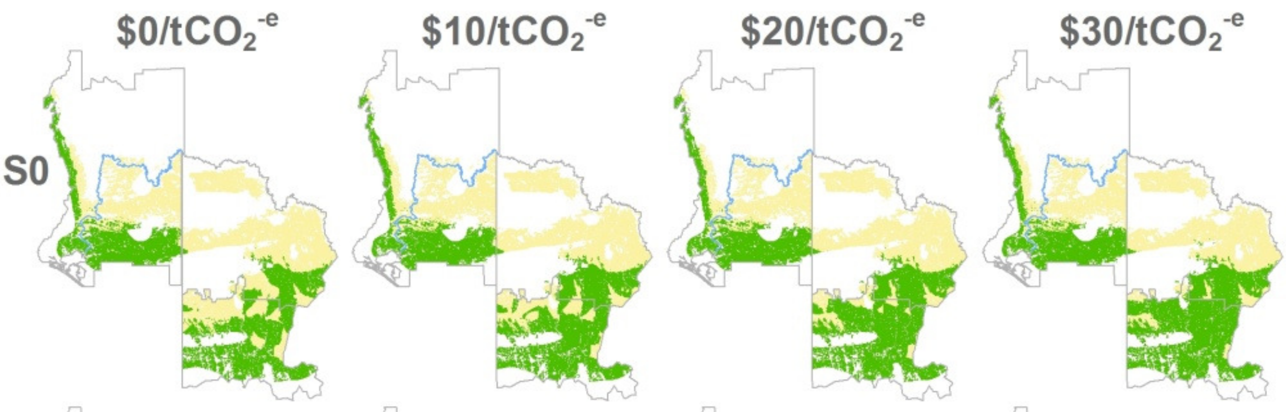

Figure 6: Economically viable areas (dark shade) for biofuels agriculture (when profitability of biofuels agriculture > profitability of food agriculture) under different climate change scenarios (S0, S1, S2 and S3) and carbon subsidy price scenarios (\$0 $t^{-1}CO2^{-e}$, \$10 $t^{-1}CO2^{-e}$, \$20 $t^{-1}CO2^{-e}$ and \$30 $t^{-1}CO2^{-e}$) (Bryan *et al.* 2010b). $t^{-1}CO_2^{-e}$ is tonnes of CO_2 equivalents, S0 is the current climate, S1 is 1 ^{o}C increase in temperature and 5% decrease in precipitation, S2 is 2 ^{o}C increase in temperature and 15% decrease in precipitation, S3 is 4 ^{o}C increase in temperature and 25% decrease in precipitation.

3.1.2 Biomass

Woody biomass production for electricity generation is seen as an opportunity to keep land under production in a drying and warming climate. Trees or other crops are grown by producers and the biomass is sold for the generation of electricity through various forms of combustion. It has been shown to have significant potential for both economic and environmental benefits. Biomass production has the potential to be more resilient than traditional agriculture to climatic warming and drying because native tree species are better suited to warmer and dryer conditions (Bryan *et al.* 2010b). There are also other environmental benefits from biomass production such as the mitigation of salinity and wind erosion as well as biodiversity conservation benefits (Bryan *et al.* 2010b). Several authors have also found that biomass production for the renewable production of electricity is more efficient than biofuel production (Campbell *et al.* 2009, Ohlrogge *et al.* 2009).

Recent studies (Bryan *et al.* 2008, Bryan *et al.* 2010b) have examined biomass production for electricity generation in the SA MDB under various climate and market scenarios. Potential biomass crops in the SA MDB include some species of Mallee eucalypts. Figure 7 shows the results from one of these studies (Bryan *et al.* 2010b) in the dryland areas of the SA MDB as well as some neighbouring regions. The results from this study indicate that biomass production becomes more viable with increasingly severe climate change compared with traditional agriculture. This is because the productivity of traditional agriculture (e.g. cropping and grazing) decreases with warming and drying while the biomass crops (e.g. mallee trees) are less effected. Furthermore, the introduction of a price on carbon would make biomass production ever more viable. Another of these studies (Bryan *et al.* 2008) examined the viability of growing woody species in the River Murray Corridor of the SA MDB NRM region. This study found that more than 350, 000 ha (more than 50% of dryland areas) within the corridor are potentially viable with income generated from carbon markets, electricity generation and other by-products. This type of production would also provide benefits such as reduced risk of erosion, a substantial reduction in salinity within the River Murray and the reduction of over 1.7 million tonnes of carbon emissions[6], which based on a carbon price of $23 per tonne CO2 equivalent is worth $39 million.

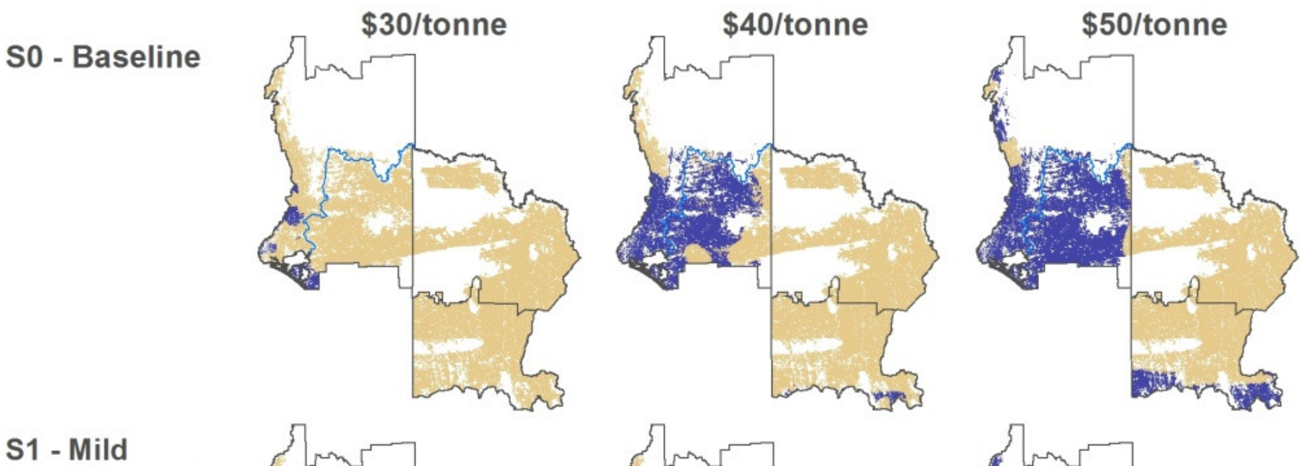

Figure 7: Economically viable areas (dark shade) for biomass agriculture (when profitability of biomass agriculture > profitability of food agriculture) under climate change and carbon subsidy price (Bryan *et al.* 2010b).

3.2 Forests for carbon

Another alternative land use is planting forests to sequester (store) carbon. This is a land use option that is based on the establishment of a price on carbon and producers would receive an income from carbon dioxide equivalent permits. Essentially receiving money to sequester carbon by growing trees and offset carbon dioxide released into the atmosphere elsewhere. A coal fired power station, for example, may buy offsets in the form of trees planted to sequester carbon dioxide.

Several recent studies have looked at the potential for planting trees for carbon in South Australia and the SA MDB. Crossman *et al.* (2010) found large parts of SA would become viable for reforestation under the introduction of a price on carbon. Bryan *et al.* (2010b) found that there are substantial environmental benefits such as reduced deep drainage, less risk of dryland salinity, less soil erosion and biodiversity benefits. While planting trees for carbon could generate some income and other environmental benefits it is likely to be much less profitable than biofuels and biomass and will not provide additional energy or co-product benefits (Bryan *et al.* 2010b).

3.3 Ecosystem services

Ecosystem services are generally defined as the benefits people obtain directly or indirectly from natural or semi natural ecosystems (Millennium Ecosystem Assessment 2005). These services can include the production of tangible products such as food, drinking water and raw materials supplied by these living systems. Ecosystems can also provide less tangible products such as amenity and cultural value that are much more difficult to specify an economic value.

Despite considerable arguments between the share of environmental flows to the River Murray and water to agriculture, there is increasing evidence to indicate that amenity value is also important. Recent studies show that amenity value, which contributes to tourism, recreation and lifestyle benefits, can have a significant economic value. This value is gaining significant community support to rival traditional agricultural pursuits (Howard 2008). Experience from the recent drought in the MDB goes some way to confirm these findings. As media coverage of the drought intensified, tourism along the river was seen to decrease as potential visitors were discouraged by the expectation that the area's amenity value had decreased.

The Riverland Strategic Tourism Plan (Riverland Strategic Tourism Plan Steering Committee 2006), written before the most extreme water shortages occurred, forecast the potential threat to the region's image and destination appeal, due to water shortages and reduced flow. This ultimately did occur and seriously affected demand for Riverland Tourism products (e.g. houseboat holidays) which are only now starting to recover.

Under a warming and drying climate there is likely to be increased pressure on the environment and ecosystem services. Reduced rainfall and river flows can have a real impact on local economies outside the traditional aspects of agriculture.

3.4 Water trading

Water trading is an increasingly important aspect of agribusiness in the SA MDB and other irrigation districts in Australia (Frontier Economics 2010). With growing population and wealth there are growing rates of water diversion for different uses, such as industrial, irrigation and municipal. When the number of diversions on average is larger than the amount of inflow an operative drought occurs: this is a period when supply is insufficient to meet all consumptive and environmental water demands (Pulido-Velazquez *et al.* 2006). Climate change predictions for increasing frequency and intensity in low inflow periods in many of the world's arid and semi-arid basins (Ragab and Prudhomme 2002), point to an increased likelihood of such operative droughts.

The impact of water markets can be seen from experiences in the southern MDB from the recent drought, which contains Australia's most active water markets. The experiences here show that they are an efficient means to distribute water during periods of operational drought and allow water to be traded between growers of different crop types. In the latest drought for example, horticulturalists with permanent crops like citrus, vines, stone fruit and almonds in the South Australian Murray imported 150 GL of water from mostly rice growers and farmers of other annual irrigated crops in the Murrumbidgee catchment in New South Wales, increasing their effective allocation by 35% (Mallawaarachchi and Foster 2009). The estimated benefits of these transactions were $31 million in South Australia and $4 million in New South Wales. There has also been an improvement in water use efficiency since the introduction of water trading in Australia with significant declines in the application of irrigation water per hectare. Water use per hectare declined from 8.7 megalitres per hectare in 1996 to 4.2 megalitres per hectare in 2005 (OECD 2010). This trend cannot be entirely accounted for by trading induced efficiencies though, for example, drought also drove changed irrigation practices and over this period many wineries requested higher baume' content in their wine which reduced water application rates to vines (pers. comm. Rod Ralph).

Water markets are also being used for means other than topping up low allocations. For example, some growers have sold their entitlements and now rely entirely on the annual allocation market to source their water. As such reductions in future allocations to their entitlement is of less concern than whole of Murray system allocations and pricing (i.e. the Murray market can currently draw on at least 9 entitlements types with different security classes for annual allocations whereas most SA Murray irrigators would currently have only one security class). While this strategy may have initially been influenced by drought conditions, continuing low prices for annual allocations mean that it is still being adopted by many irrigators.

The impacts of climate change on irrigation and water trading were assessed by Connor *et al.* (2009b). They examined the ability to trade water in mild, moderate and severe climate change scenarios for high value irrigated horticulture and wine in the Lower Murray region. Their results indicate that net returns for Victorian and South Australian agriculture decline 19% and 54% respectively in the absence of water trade but by only 5% and 11% with the possibility of water trade.

Despite the advantages, there are also adverse environmental effects of water trading. Since the introduction of water trading in Australia, there has been an increase in the use of surface water that was previously left in-stream. Increases in irrigation efficiency generally result in less drainage and thus less return flows to the environment. Connor *et al.* (2008) estimate that the incentive created by the introduction of water markets in the Lower Murray region would have been sufficient to induce efficiency savings of 113 GL (11% of regional irrigation diversions) and reduce irrigation drainage and return flows by 50%.

It is reasonable to conclude that, the impacts of water trade during recent MDB droughts have been considerable. Benefits are likely in the range of several $100 million to over $1 billion per year during the last two to three years of operative drought. This is in comparison to a gross farm gate value of MDB irrigation of $4 billion AUD in 2006-07 (Ashton *et al.* 2009). Water trading stands to provide significant financial benefits to water users as operative droughts are more likely to occur with increased warming and drying.

4 Impact on tourism

Key messages

- 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.

4.1 Background

Tourism is a significant industry in the Murray-Darling Basin, generating approximately $10 billion in revenue per annum based on Regional Tourism Profiles prepared by Tourism Research Australia (Tourism Research Australia 2011b). The basin comprises 24 tourism regions either wholly or partly within the basin. There are 4 tourism regions overlaying the South Australian part of the Murray-Darling Basin, namely the Riverland, Murraylands, Fleurieu and Limestone Coast, of which the Riverland and Murraylands regions are entirely within the basin. Currently there are 2,000 tourism businesses in the SA Murray Darling Basin region generating approximately $250 m per annum (Tourism Research Australia 2011b). Tourism revenue in the Murraylands and Riverland comprises 4.1% of the total revenue generated by industries in the region (Tourism Research Australia 2011a).

The River Murray is the major drawcard used to promote a holiday in the region as is highlighted by the names of the two main tourism regions along the River Murray. Together, the tourism regions use the houseboat as its flagship accommodation symbol, and there are about 800 houseboats available for hire or private use (pers. comm. Peter Tucker – Houseboat Hirers Association).

The two most popular experiences given by visitors to the regions include "food and wine" and "nature based" (Tourism Research Australia 2010).

Responses to a recent survey of what a Riverland holiday offers (Advanced Tourism 2011) included :

- "houseboats and shacks";
- "quietness, casual, relaxing";
- "beautiful scenery";
- "red cliffs, sunsets, solitude";
- "scenery, nature, peace";
- "water means relaxation".

The survey found that "Consumers were still in a positive frame of mind about the idea of a river holiday" and they "would like to know more".

4.2 Drought and flood impacts

The consequences of the recent and longest drought in the River Murray in 130 years has had a significant impact on tourism, due to negative publicity surrounding issues that were visually alarming, livelihood threatening and dangerous. As such they generated much political debate and media publicity. Some examples of the negative publicity included :

- Reduction in river flows to the sea and high costs of dredging to keep the Murray Mouth open;
- Vast exposure of shorelines, jetty infrastructure and stranded boats around Lakes Albert and Alexandrina;

- The widely publicised risk of acid sulphate development in Lake Albert and river bank collapse below Lock 1;
- Drastic measures to reduce evaporative losses from several high profile wetlands including the closure of Banrock Station wetland complex and Lake Bonney in the Riverland;
- Visible deaths and decline in red river gum health along the entire river length and its floodplain;
- Photographs of exposed river sand bars published in daily newspapers created the impression that the River Murray was dry.

The combined effect of such consequences created a negative perception of the river and lower lakes and helped to cause a significant downturn in tourism in the South Australian Murray Darling Basin. The occupancy of houseboat accommodation dropped from 62% in 2005 to 35% in 2009/10 (pers. comm. Peter Tucker, Houseboat Hirers Association).

Overall, the tourism industry experienced a downturn due to the negative perceptions of drought followed by some negative consequences of flooding including increased mosquito activity and increased risk of contracting several viruses carried by mosquitoes (pers. comm. Paula Bennet, Riverland Tourism Association).

Unfortunately the recent high Murray River flows that followed the drought, coincided with the tragic Brisbane River floods which did not help to attract people back to the River Murray for a holiday. Houseboat occupancy has recovered only slightly from 35% to 38% in the summer and autumn of 2011, which is not surprising given that many houseboat hire operators did not encourage hirers to travel on the faster flowing river due to risk of boat damage and reduction in available mooring sites.

4.3 River Murray Regional Impacts

A study of drought impacts along all of the tourism regions adjacent to the River Murray from Albury NSW to the Lower lakes in South Australia (2,500 km) (Tourism Research Australia 2010) found that between 1999 and 2008 the drought appears to have adversely impacted on overnight visitation and duration of stay in the Murray River region compared to other tourism outcomes (e.g. day trips and average expenditure per day). In particular the following impacts were identified:

- Overnight visits to the Murray River region have declined on average by 2.2 % per annum over the period 1999-2008, compared to averages decline of 1.3% for comparable regions;
- Around 20% of survey respondents who had visited the Murray River region indicated that the drought has impacted on their travel behaviour. As a result of the drought it is estimated that 9% of past visitors have visited the Murray River region less often, 5% reduced their duration of stay, 5% reduced expenditure and 2% no longer visit;
- Around 12% of the survey target audience were people that had never visited the Murray and rejected the possibility of visiting the Murray within the next 5 years. Of these, 22% indicated that drought is one of the factors contributing to their lack of interest in visiting the Murray River region in the next 5 years.

Economic modelling carried out for this study estimates that the drought may have resulted in a fall in direct tourism expenditure of $69.9 million in 2008. If the drought had not occurred, it is estimated that total tourism expenditure in the Murray River region would be 5.1% higher than actual levels in 2008. Over the entire drought period (1999-2008), a reduction in direct spending of $351.4 million is estimated to have occurred.

Clearly a small portion of this reduced spending will have occurred in the South Australian River Murray tourism regions.

4.4 Riverland Tourism Industry Review

In 2010 the three Riverland Councils engaged a consultant to review the performance of tourism in the Riverland tourism region (Advanced Tourism 2011). The review acknowledges the impacts of the recent drought generated by negative publicity, however, it highlights the lack of resilience in the regional tourism industry to cope with such publicity, due to several other factors, and it recommends several strategies to grow the tourism economy.

The report identified that visitor numbers to the Riverland have dropped by 35.8% since 2000 which is a far greater downturn than that experienced by Adelaide (21.4%) and regional South Australia (27.7%) over the same period.

The impacts of climate change were not part of the review.

The main changes recommended by the review include:

- New governance structure and operating budget for the local tourism industry;
- Destination marketing of the Riverland region;
- Increased use of the internet by tourism operators to promote their businesses;
- Increased use of on-line booking systems (e.g. WOTIF, Travel.com.au) by tourism operators.

4.5 Relative impact of Climate Change versus the recent long term drought

Whilst the tourism industry is shaped by the landscapes (i.e. nature based elements) and farming industries (i.e. food and wine elements) within the region, the primary drawcard for river based tourism is the presence of water in the river and lakes, and the ability to know that water is present. During the entire drought period, the water levels in the River Murray above Lock 1 did not drop below pool level, and yet there was a perception that the river was dry above Lock 1.

Several strategies have since been used to counter this including the use of web cams overlooking the river. In early 2011, albeit after river flows had increased, the SA Tourism Commission launched a $3 million campaign — *"Go with the flow"* — to counter the negative publicity of low flows and promote River Murray holidays. The campaign results have yet to be quantified.

During the recent drought, river flows were reduced to those experienced in the driest 10% of years in the last 100 years, resulting in a reduction in end of system flow by more than 68%. It will be somewhat comforting for the tourism industry to know that under the best estimate of climate change impact that the end of system flow may only be reduced by 23%, and therefore will not be as severe as occurred in the recent drought

In addition, the Murray Darling Basin Plan (Murray-Darling Basin Authority 2010) is seeking to increase the amount of water returned to the environment by between 3,000 GL and 7,000 GL per annum, representing a minimum increase in end of system flow by 58%, which will help to counter the long term reduction in end of system flow caused by climate change.

Critical in the Murray Darling Basin Plan reforms will be a commitment to increasing the frequency of small (35,000 ML/d to 60,000 ML/d) and medium (65,000 ML/d to 90,000 ML/d) flood flows of suitable duration to maintain the biodiversity of flora and fauna that enhance nature based tourist experiences. These experiences include bird-watching, bushwalking, canoeing, photography, fishing, hunting and yabbying. It is not yet clear how the Murray Darling Basin Plan will address this need, although the minimum quantum of water sought for the environment (3,000 GL) has the capacity to enhance the frequency of flood flows.

In addition, the focus on icon sites under The Living Murray program will continue to protect the highest biodiversity areas in the region such as Chowilla floodplain and the river corridor, where several environmental flow regulators are planned to enable managed flooding during low flow periods in the river.

Hence, tourism development strategies can be built with some confidence that a reliable water level can be maintained along the entire length of the Murray River in South Australia, and biodiversity will be enhanced and maintained in the long term.

4.6 Strategies to develop a more resilient river tourism industry and regional economy

Tourism is well placed to grow in the South Australian Murray Darling Basin to broaden the economy of the region, thereby increasing the resilience of the overall economy in a warmer and drier climate. The tourism industry is in a prime position to benefit from the development incentives now available in regional Australia (i.e. Regional Development Australia Fund, Riverland Sustainable Futures Fund) because it can grow the economy without extracting further water, and in the likelihood that there will be a reduction in horticulture over the coming decade, due to the higher costs of water and the opportunity sell water allocations, the importance placed on tourism will increase.

Key strategies to grow the tourism economy include those outlined in the draft report — *Towards 2015 and Beyond, Working with Riverland businesses to grow the visitor economy* (Advanced Tourism 2011), (see Section 4.4: Riverland Tourism Industry Review).

Maintaining and promoting easily accessible information about river levels (e.g. web-cams and regular flow updates) will be essential to renew confidence in returning to the region for a river based holiday.

5 Impact of sea level rise

Key messages

- Global sea levels have risen approximately 200 mm since 1870.
- Climate change is expected to increased global average sea levels by 18-59 cm by 2100.
- Impacts of sea level rise include; inundation by sea water, increased coastal erosion, soil salinity and salt water intrusion of aquifers.

5.1 Introduction

Coastal zones of Australia are recognised as playing a critical role in the economy and the broader Australian community. Coastal zones contribute to the economy through industries including fishing, tourism, construction, shipbuilding, mineral exploration and mining. Furthermore, coastal zones also contribute to the broader community through the provision of recreation activities and are seen as being part of the national identity (DCC 2009).

Global sea levels have been increasing over the last century. Since 1870 the mean global sea level has risen by approximately 200 mm (CSIRO and The Bureau of Meteorology 2010). Sea levels rise because water expands as they oceans warm and land-based ice melts, which increases the volume of the oceans and thus the height (often called thermal expansion) (IPCC 2007a, ICAM 2009).

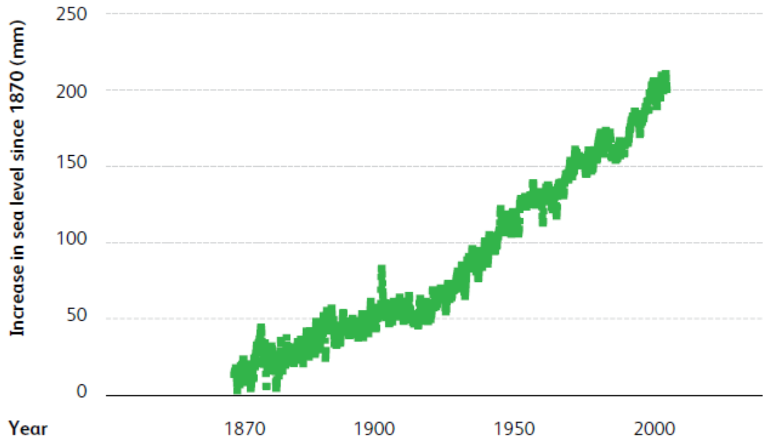

Figure 8: Observed global mean sea level since 1870 (CSIRO and The Bureau of Meteorology 2010)

Climate change is projected to increase global average sea levels by 18 – 59 cm by 2100 (IPCC 2007b). However, the impact of sea level rise will also be felt through changes in extreme sea level events, called storm surges. Storm surges are localised regions of higher sea level caused by a combination of falling atmospheric pressure and high velocity winds generated as a part of storm events. There are also many other factors that effect the severity of storm surges including the direction of the storm relative to the coast, the shape of the sea floor and the proximity of bays, headlands and islands (ICAM 2009). Climate change may increase the frequency of storm surges even if there is not an increase in the frequency of extreme weather events (e.g. cyclones). Higher sea levels will result in storm surges that exceed a given intensity more often (CSIRO 2011).

5.2 Impacts of sea level rise

The potential impacts of sea level rise for the coastal areas are significant. Broadly the impacts include; inundation by sea water, increased rates of coastal erosion, increased soil salinity and salt water intrusion of aquifers (CSIRO and The Bureau of Meteorology 2007, Nicholls *et al.* 2007). In areas not subject to human development, these impacts will change the shape of coastlines and alter the equilibrium of natural ecosystems and the associated biodiversity (Nicholls *et al.* 2007). For example, beaches and coastal areas may suffer from increased erosion with subsequent effects for land adjacent to the shore that may be inundated. This will have dramatic impacts on ecosystems adjacent to the ocean such as the Coorong and Young Husband Peninsula. It should be noted that, while ecosystems such as the Young Husband Peninsula are at risk, they also offer some resilience as sand dunes and vegetation are able to buffer the impacts of extreme weather and storm events (ICAM 2009). However, for many costal areas, particularly those near developed areas, natural sand dunes and vegetation have been displaced reducing the resilience of the coast. Sea level rise will also dramatic consequences for human development (Abel *et al.* 2011). Erosion and inundation with salt water can compromise freshwater aquifers, reduce the fertility of agricultural land and destroy coastal development with devastating consequences for assets (e.g. buildings, cities, crops), communities and livelihoods.

5.3 Local government

As a part of their commitments to the Local Government Association Mutual Liability Scheme the Alexandrina and Coorong District Councils recently carried out an assessment of the impacts and adaptation options around climate change and sea level rise. They identified a range of potential impacts of sea level rise that are specific to the councils themselves. These were (LGA 2010, 2011);

- Inundation of development planning zones
- Inundation and flooding of existing development and transport network
- Erosion of sand from coastal areas leading to stability issues with local government infrastructure (buildings, roads, water and sewerage systems)
- Damage to buildings, water infrastructure and recreation facilities from storm surge
- Increase in soil salinity and damage to buildings and infrastructure
- Salt water intrusion of aquifers and contamination of water supply
- Stormwater system becomes redundant due to failure of system
- Management of events on coastal foreshore
- Emergency management of inundated areas
- Constrained retreat of salt marsh and mangroves due to levees and road infrastructure.

Strategies to protect coastal areas and reduce the impacts from sea level rise can fall under three broad categories; structural defences, accommodation and retreat (ICAM 2009). Structural defences can be in the form of engineered barriers through to strategically placed wetlands or sand dunes (as mentioned above) that provide protection from the impacts of higher seas and increased storm events (Abel *et al.* 2011). The implementation of structural defences can be expensive and is generally only considered appropriate for high value assets with no prospect for relocation like cities (Abel *et al.* 2011). The accommodation strategy is based on adjustments in the way people live such that they can continue to use land but do so in such a way to reduce the impact of sea level rise. Examples include; elevating structures (e.g. building on stilts), flood proofing buildings and early warning systems to allow time for evacuation in case of emergencies. Retreat strategies involve the planned and managed development of coastal zones such that development is progressively moved away from the threat when the opportunity arises or assets are under immediate threat. The implementation of retreat strategies typically involves the gradual implementation of development restriction such that at risk assets are not renewed or redeveloped.

6 Impact of mining

Key messages

- Known mineral deposits in the SA MDB include heavy mineral sands, gypsum, coal, uranium, copper, gold, silver, lead and zinc.
- Mining is heavily dependent on the availability of water and as such will likely be negatively impacted by a warming and drying climate.

The mining and resources sector is a major part of South Australia's economy. In November 2010, it employed around 7,700 people and was the state's largest export earner (Spoehr and Molley 2011). While much of the activity in South Australia's mining and resources sector is in the north of the state, mining also contributes to the economy of the South Australian Murray-Darling Basin.

Within South Australia, the Murray Basin (which in mining terms is a sedimentary basin that also extends into NSW and Victoria) holds a range of prospective commodities such as heavy mineral sands, gypsum, coal and uranium (PIRSA Minerals 2010). The Department of Primary Industries and Resources South Australia reports that heavy mineral sands in the Murray Basin have become a major exploration focus with a number of discoveries in recent years. Several deposits have been identified in "beach faces" of the Loxton and Parilla Sands, including the Mindarie, Oakvale, Perponda and Mercunda prospects. One mineral sands exploration company states that "The Murray Basin ... is regarded as a world class mineral sands province" (BEMAX Resources Limited 2005).

Mineral resources elsewhere in the SA MDB include copper-gold and silver-lead-zinc mineralisation near Kanmantoo, being mined by Hillgrove Resources, and zinc at Strathalbyn, being mined by Terramin Australia.

One of the biggest impacts of climate change on mining will be water availability. The National Water Commission (National Water Commission 2010) recognises that while nationally mining uses limited water, there are a number of regions where mining is the primary consumer of water. Access to sustainable water resources for mining may become increasingly important in the SA MDB. If reduced agricultural activity was to occur and the region were seeking economic production from other sectors, mining may also be water limited.

The NWC states that:

> *"In these regions, or where water systems are approaching or at full allocation, current and future mining developments could, if not adequately managed and regulated, impact on surface water or groundwater systems at a regional scale."*

And further:

> *" Secure access to and delivery of water are critical to the productivity and development of the minerals, petroleum, energy generation, pulp and paper (MPEPP) and other industrial sectors in Australia. A national report by ACIL Tasman (2007) found that the availability of water is a constraint on further investment and expansion of the MPEPP industries and suggested that the potential value of lost production, due to the unavailability of water of suitable quality, is high."*

In South Australia, water resources for mining are managed, as they are for irrigation and urban supply, through a framework contained primarily within the *Natural Resources Management Act 2004* which aims to achieve sustainable development outcomes. Further to this, Action 48 of the State's water plan, Water for Good, requires:

"mining ventures to provide their own water supplies within the sustainable framework of natural resources management planning, and regional water demand and supply plans."

However, while mining may be impacted by climate change in similar ways as irrigation, such as through reduced rainfall, lower dam inflows and reduced groundwater recharge, it will have a greater ability to purchase water rights than many competing water uses because of the higher value per ML of its outputs. Hence, it could be argued that it will be comparatively less susceptible to climate change driven reductions in water availability.

There may also be some novel ways for mining to access water. For example, desalination of brackish groundwater or using treated waste water from nearby industrial or urban areas. Hillgrove Resources' copper and gold mine at Kanmantoo provides a good example of the latter.

Using recycled water at Hillgrove's Kanmantoo Copper Mines.

Hillgrove Resources' is in the process of establishing its Kanmantoo Copper Mines project. The company describes the region in the Adelaide Hills as one of the most under explored and prospective base metal provinces in Australia, with "outstanding potential for copper-gold and silver-lead-zinc mineralisation". The Kanmantoo mine development is set to go into production in late 2011 and will employ approximately 150 people.

The majority of process water for the mine will come from treated waste water from the District Council of Mt Barker's Wastewater Treatment Plant via a 15km pipeline, which Hillgrove has helped to build. The Laratinga Plant takes wastewater from Mt Barker and Nairne, which have been identified in the 30 year plan for Greater Adelaide as area for further major population growth.

http://www.hillgroveresources.com.au/kanmantoo-project.html

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Attachment A

The following is an edited extract of a report prepared by the Australian Institute for Social Research and EconSearch for the Murray-Mallee Local Government Association titled “A Practical Guide to Using the RISE Model for Economic Impact Analysis in the Murray Mallee LGA Region”. The Australian Institute of Social Research was one of the project team members for this Climate Change Adaptation Project.

1 MODELLING THE IMPACT OF CHANGES IN WATER ALLOCATION IN THE MDB

This section of the report provides a summary of recent work undertaken by the Australian Institute for Social Research in association with the EconSearch Pty Ltd. for the Murray Mallee Locate Government Association on changing water allocations in the Murray Darling Basin in the context of the MDBA Plan. The current process of water reform in the Murray Darling Basin, as encapsulated in the Guide to the Proposed Basin Plan (Murray Darling Basin Authority 2010), is a dynamic and complex process with potentially profound implications for the future of irrigation-dependent regional economies. The process is also, however, characterised by considerable uncertainty.

1.1 Specification of the Hypothetical ‘Final Demand’ Scenarios

Two simple, hypothetical irrigation water restriction scenarios were developed to demonstrate some of the features of the RISE impact model developed by EconSearch (see Appendix 1 for details about the model).

The model provides the ability to measure impacts over time and thus to differentiate the effects of a short-term reduction in irrigation water diversions (e.g. due to drought) from a permanent reduction (due to climate change or water reform).

The model’s assumptions can be varied to account for the impact of improvements in labour productivity. Productivity improvement can offset negative regional economic impacts.

The model’s assumptions can be varied to account for employees who remain in the region after they lose their job (i.e. the level of regional migration). The consumption expenditure of these individuals and their families would be otherwise ‘lost’ to the region in a standard I-O model and regional economic impacts would tend to be overestimated.

Two scenarios have been specified:

1. The impact of a short term (i.e. one year) 25 per cent reduction in water availability in the Riverland. This could be a consequence of, for example, drought induced water restrictions.
2. The impact of a long term (i.e. ten year) 25 per cent reduction in water availability in the Riverland. This could be a consequence of, for example, a water entitlement buyback program to increase environmental flows.

1.1.1 Scenario 1

Model inputs and assumptions

Under a short-term (1 year) 25 per cent reduction in water availability, the following response was assumed. The context is that of recent years where most growers have used their excess water entitlements (if any) to make up the shortfall in annual allocations. Additionally, many growers have traded in the temporary market to meet their shortfall. Faced with a reduction of 25 per cent in allocation, the following response has been assumed:

- cease watering 10 per cent of crop area (assume no yield and minimal management costs on that area)
- reduce irrigation rate on remaining 90 per cent of area by approximately 17 per cent (to meet the 25 per cent reduction in allocation)
- no water trading
- per cent per hectare yield reduction in response to 17 per cent less water
- overall reduction in production of 16 per cent

These assumptions are summarised in Table 1.1.

Table 1.1. Scenario 1 assumptions

Assumptions	
Reduction in water allocation	25%
Reduction in area	10%
Irrigation rate reduction on remaining area	17%
Yield reduction in remaining area	7%
Aggregate reduction in production	16%

This set of assumptions can be translated into a profile of expenditure changes by irrigators. The Riverland wine grape sector has been used to illustrate the scenario. Table 1.2 provides the costs and returns for a typical 20 hectare vineyard in the Riverland. Costs are categorised as either variable or overhead costs.

The baseline column shows the costs and returns prior to the 25 per cent reduction in water allocations. The adjacent scenario 1 column shows the changes to those values given the assumed responses detailed in Table 4.1. For example, the area irrigated is shown to drop by 10 per cent under scenario 1, from 20 to 18 ha. In reality, most growers cannot afford not to water their grapevines due to the climate. The assumption here is that just enough water is applied to keep the vines alive but insufficient to produce a crop.

The final column in Table 1.2 shows the allocation of each item of expenditure to the relevant input-output sectors. Under this scenario are assumed to remain the same which implies the short-term reduction in water availability does not induce property amalgamations or structural change that would not otherwise occur.

The next step in the impact analysis is to scale up the vineyard level changes to the regional level. In a detailed analysis, this may require a model of a range of vineyard types and sizes to be prepared to properly represent the diversity in the industry. Here, however, the expenditure pattern of the 20 hectare vineyard is assumed to be representative of the industry as a whole.

For this analysis, a regional wine grape growing industry of approximately 24,000 ha was assumed. On this basis the reduction in expenditure at a region-wide level can be calculated and is illustrated in Table 1.3.

Table 1.2. Costs, returns and I/O sector allocations, baseline and scenario 1, Riverland region

			Baseline	Scenario 1	I/O Allocation
Irrigated area [a]	ha		20	18	
Average price	$/t		300	300	
Average yield	t/ha		28	26	
Sale of winegrapes	$/ha		8,250	7,700	
Irrigation rate	ML/ha		6.9	5.7	
Water allocation	ML		138	103	
Water entitlement	ML		138	138	
		$/unit	**Total**	**Total**	
Income					
Sale of winegrapes			$165,000	$138,600	
Gross Income			$165,000	$138,600	
Variable Costs					
Disease sprays	$/ha	209	$4,185	$3,767	10% RTrade, 90% Imports
Pest sprays	$/ha	26	$512	$461	10% RTrade, 90% Imports
Nutrient sprays	$/ha	60	$1,207	$1,087	10% RTrade, 90% Imports
Herbicides	$/ha	225	$4,508	$4,057	10% RTrade, 90% Imports
Fertiliser	$/ha	298	$5,958	$5,362	10% WTrade, 2% Tport, 88% Imports
Contract operations	$/ha	1,708	$34,155	$30,740	100% ServAg
Freight	$/ha	682	$13,634	$12,271	100% Road Transport
Fuel	$/ha	277	$5,532	$4,979	10% RTrade, 90% Imports
Labour	$/ha	351	$7,026	$6,324	100% W&S
Irrigation costs	$/ML	259	$35,629	$26,722	60% Water, 20% Elect, 10% Other Mach & Equip, 10% Imports
Land based levy [b]	c/$	0.01	$97	$97	100% Govt Admin
Water based levy	$/ML	5.30	$729	$729	100% Govt Admin
Total Variable Costs			**$113,173**	**$96,594**	
Gross Margin			**$51,827**	**$42,006**	
Overheads					
Labour			$37,473	$37,473	100% W&S
Consumables			$6,140	$6,140	25% Elect, 5% RTrade ,70% Imports
Maintenance			$5,457	$5,457	30% OthMach&Equip, 30% ConTS, 20% RTrade, 20% Imports
Depreciation			$13,771	$13,771	100% GOS
Insurance			$5,337	$5,337	10% Finance & Insurance, Imports 90%
Professional services			$4,093	$4,093	80% Prop & Bus Serv, 20% Imports
Office/administration			$7,777	$7,777	30% RTrade, 20% Comm'n, 30% Govt Admin, 20% Imports
Total Overheads			**$80,047**	**$80,047**	
EBIT			**-$28,220**	**-$38,041**	50% W&S, 50% GOS

Source: EconSearch analysis.

Table 1.3. Change in winegrape growers' demands from local industry, scenario 1, Riverland region.

Sector	$m
Local Industry Expenditure	
Services to agriculture	-4.554
Other machinery and equipment manufacturing	-1.188
Electricity supply	-2.375
Water, sewerage, drainage	-7.126
Wholesale trade	-0.079
Retail trade	-0.213
Road transport	-1.834
Total Local Industry Expenditure	**-17.368**
Primary Inputs	
Wages and salaries	-7.484
Gross operating surplus	-6.547
Imports	-3.800
Total Primary Inputs	**-17.832**
Grand Total	**-35.200**

Model results

The outcomes for the impact analysis are summarised in Table 1.4, both in absolute and relative terms. Gross regional product (GRP) for example, would be expected to fall by almost $30 million, or approximately 2.0 per cent of total Riverland GRP (approximately $1.5 billion in 2009/10).

Table 1.4. Impact results (direct + indirect), scenario 1, Riverland region

	Impact	Share of regional total
Gross Regional Product ($m)	-29.5	-2.0%
Employment (No. fte jobs)	-138	-0.9%
Household Income ($m)	-15.2	-2.1%
Population (No. persons)	-73	-0.2%

Source: EconSearch analysis.

An indicative calculation has been prepared of the impact on property values, and council rates. Based on the results for Scenario 1 in terms of employment, GRP and population, Table 1.5 (an extension of Table 1.4) represents a calculation of the wealth and Council revenue challenge of the scenario. A loss of regional population of 73, and of regional employment of 138 jobs, is conservatively modelled as being linked to a loss of property values of almost 2% per property, while Council rate revenue would be reduced by almost $0.5 million per year.

Table 1.5. Impact results – household value and council rates, scenario 1, Riverland region.

	Base (i.e. yr 0)	After Shock	Change in value	% Change
No of Households	15,488	15,455	-33	-0.2%
Median Real Household Income ($'000)	47.5	46.6	-0.9	-1.9%
Residential Properties	10,325	10,324	-1	0.0%
Industrial/Commercial Properties	1,000	1,000	0	0.0%
Agricultural Properties	4,500	4,498	-2	0.0%
Underlying Residential Property Value ($'000)	282.0	276.8	-5.2	-1.9%
Underlying Industrial Property Value ($'000)	500.0	489.9	-10.1	-2.0%
Underlying Agricultural Property Value ($'000)	170.0	166.6	-3.4	-2.0%
Council Rate Revenues ($m)	21.9	21.5	-0.4	-1.9%

Source: EconSearch analysis.

While SA Murray irrigators clearly suffered financial stress as a result of the recent drought, access to the water market enabled many growers to acquire water that would not have been available otherwise in the state. Water markets enabled many growers to trade water into SA from NSW and Victorian irrigators to offset reduced allocations experienced in the seasons from 2006-07 to 2010/11, none of which saw irrigators receive more than a 67% allocation. While not included in the model, it could therefore be argued that the use of water markets could be used by some growers to offset future reductions in annual water availability and thus offset the reductions in gross regional product. This is reinforced by a National Water Commission (2010) report, which concluded that the total production benefits of water trading in 2008-09 was $370 million, of which South Australia received a net benefit of $271 million.

1.1.2 Scenario 2

Model inputs and assumptions

Under a long-term, 25 per cent reduction in water availability, the following response was assumed. As for scenario 1, the context is that of recent years where most growers have used their excess water entitlements (if any) to make up the shortfall in annual allocations. Additionally, many growers have traded in the temporary market to meet their shortfall. Faced with an additional and permanent reduction of 25 per cent in allocation, the following response has been assumed:

- region wide crop area to fall by 25 per cent (assume no yield and minimal management costs on that area) – assumed that this will be achieved through water trading with permanent transfers from those leaving the industry to those remaining;
- region wide production (and GVP) to fall by 20 per cent – assumed that land taken out is less productive than that remaining;
- no productive alternative use of land removed from irrigated horticultural production;
- water use efficiency improves over time so that yields per hectare increase by 1 per cent per annum; and
- economy wide labour productivity improvement of 0.5 per cent per annum over 10 years.

These assumptions are summarised in Table 1.6.

Table 1.6. Scenario 2 assumptions

Assumptions	
Permanent reduction in water allocation	25%
Permanent reduction in crop area	25%
Initial reduction in regional production	20%
Annual improvement in water use efficiency	1.0%
Annual economy wide increase in labour productivity	0.5%

This set of assumptions was transformed into a profile of output changes by irrigation sector which can be represented in the RISE model as a profile of changes in final demand. The Riverland irrigated agriculture sectors, winegrapes, vegetables and fruit and nuts, have been used to illustrate the scenario. Table 1.7 provides the simulated changes in final demand for each of the three sectors over a 10-year period.

Table 1.7. Changes in final demand, scenario 2, Riverland region

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Change in Output [a]	-20%	-19%	-18%	-17%	-16%	-15%	-14%	-13%	-12%	-11%
Change in GVP:										
Viticulture ($m)	-43.8	-41.6	-39.4	-37.2	-35.1	-32.9	-30.7	-28.5	-26.3	-24.1
Vegetables ($m)	-4.2	-4.0	-3.8	-3.5	-3.3	-3.1	-2.9	-2.7	-2.5	-2.3
Fruit and Nuts ($m)	-39.3	-37.3	-35.3	-33.4	-31.4	-29.4	-27.5	-25.5	-23.6	-21.6

[a] Change relative to the baseline estimate for 2009/10 derived from the Riverland RISE model.
Source: EconSearch analysis.

Model results

The results of the simulated changes in final demand, in both absolute and relative terms, are presented in Table 1.8. For each of the impact indicators (GRP, employment, household income and population) the negative impact on the regional economy is shown to be diminishing over time. This is partly because of the assumed improvement in water use efficiency and, in the case of employment and population impacts, partly due to the underlying labour productivity assumptions.

Table 1.8. Impact results (direct + indirect), scenario 2, Riverland region

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Gross Regional Product										
GRP ($m)	-68	-64	-61	-58	-54	-51	-47	-44	-41	-37
Share of regional total (09/10)	-4.7%	-4.4%	-4.2%	-4.0%	-3.7%	-3.5%	-3.3%	-3.0%	-2.8%	-2.6%
Employment										
No. fte jobs	-638	-603	-569	-534	-500	-467	-434	-401	-368	-336
Share of regional total (09/10)	-4.0%	-3.8%	-3.6%	-3.4%	-3.2%	-2.9%	-2.7%	-2.5%	-2.3%	-2.1%
Household Income										
Household Income ($m)	-25	-23	-22	-21	-20	-18	-17	-16	-15	-14
Share of regional total (09/10)	-3.4%	-3.3%	-3.1%	-2.9%	-2.7%	-2.6%	-2.4%	-2.2%	-2.1%	-1.9%
Population										
No. persons	-343	-325	-306	-288	-269	-251	-233	-216	-198	-181
Share of regional total (09/10)	-1.0%	-1.0%	-0.9%	-0.9%	-0.8%	-0.8%	-0.7%	-0.6%	-0.6%	-0.5%

Source: EconSearch analysis.

An indicative calculation has been prepared of the impact on property values, and council rates. Based on the results for Scenario 2 in terms of employment, GRP, population, etc., Table 1.9 (an extension of Table 1.8) presents a calculation of the wealth and Council revenue challenge of the scenario. Residential property values are modelled as declining significantly, with a subsequent drastic impact on Council rate revenue.

Table 1.9. Impact results – household value and council rates, scenario 2, Riverland region

	Base (ie yr 0)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
No of Households	15,488	15,333	15,341	15,350	15,358	15,367	15,375	15,383	15,390	15,399	15,406
Median Real Household Income ($'000)	47.5	46.3	44.8	43.3	42.0	40.6	39.4	38.3	37.2	36.3	35.3
Residential Properties (number)	10325	10,320	10,320	10,321	10,321	10,321	10,322	10,322	10,322	10,322	10,323
Ind/Commercial Properties (number)	1000	998	998	998	998	998	999	999	999	999	999
Agricultural Properties (number)	4500	4,491	4,491	4,492	4,492	4,493	4,493	4,494	4,494	4,495	4,495
Underlying Residential Property Value ($'000)	282.0	275.2	266.1	257.5	249.2	241.3	234.2	227.6	221.3	215.4	209.9
Underlying Industrial Property Value ($'000)	500.0	469.7	471.1	472.5	474.0	476.1	476.8	478.9	480.3	481.7	483.8
Underlying Agric Property Value ($'000)	170.0	159.7	160.2	160.7	161.1	161.9	162.1	162.8	163.3	163.8	164.5
Council Revenues	22	21.1	20.6	20.2	19.8	19.4	19.0	18.7	18.3	18.0	17.8

Source: EconSearch analysis.

Permanent water reductions clearly reduce the long term potential water availability for irrigators in the Riverland. However, if there were to be reduced entitlements overall in the Riverland as a result of, for example, Government buy back policy this can be offset by using the permanent water market to trade interstate entitlements into South Australia. Other options include growers using the temporary trade market to buy in water on an annual basis and simply owning no permanent entitlements. What becomes important in both instances is whether general business conditions remain favourable enough for growers to continue to produce crops.

2 A SCENARIO DEMONSTRATION OF ESTIMATING 'NEW INDUSTRY' IMPACTS – SCENARIO 3

In order to demonstrate the data requirements and process by which 'new industry' impacts are measured using the RISE v3.0 model, a hypothetical irrigation expansion scenario development scenario in the Murraylands region was developed. Description of the scenario, input data estimation methods and the results of the analysis follows.

2.1 Model inputs and assumptions

The Mallee Prescribed Wells Area (PWA) *Annual Water Use Report* indicates that 6,700 hectares was irrigated using approximately 40.5 GL in 2008/09 (Arnold 2010). With the Water Allocation Plan for the Mallee PWA yet to be finalised, and the process of volumetric conversion of existing licences (currently expressed in terms of irrigation equivalents (HaIE)) still to be settled, there is some uncertainty about future allocations for irrigators. Nevertheless, at an aggregate level, there appears to be some scope for further expansion of irrigated horticulture within the region.

In 2008/09, there were 3,800 hectares of potatoes grown using 25.5 GL of water. This represented 56 per cent of the total irrigated area and 63 per cent of total water use. According to Arnold (2010) growers have plans to expand irrigated area by around 700 hectares over a five year period.

Potato production has been used to illustrate the expansion scenario. Because the costs and returns for potatoes are different to other vegetable and tree crops, the expected expanded potato production can be entered into the RISE model as a new industry.

Table 2.1 provides the costs and returns for a representative 35 hectare centre pivot operation in the Mallee PWA. Costs are categorised as either variable or overhead costs. The final column in Table 2.1 shows the allocation of each item of expenditure to the relevant input-output sectors.

The next step in the impact analysis is to scale up the centre pivot level income and expenditures to the regional level. As with the vineyard analysis under scenario 1, in a detailed analysis, this may require a model of a range of potato production system types and sizes to be prepared to properly represent the diversity in the industry. Here, however, the expenditure pattern of the 35 hectare centre pivot is assumed to be representative of the industry as a whole.

For this analysis, the growth in the regional potato industry was estimated to be approximately 700 ha that would occur over a 3-year period (50% in year 1, additional 30% in year 2 and final 20% in year 3). On this basis the expenditure by local industry as well as wages and salaries and employment can be calculated and is illustrated in Table 2.2.

Table 2.1. Costs, returns and I/O sector allocations, baseline for scenario 3, Murraylands region

	Unit		Base	I/O Allocation
Irrigated area	ha		35	
Average price	$/t		400	
Average yield	t/ha		40	
Sale of potatoes	$/ha		16,000	
Irrigation rate	ML/ha		6.7	
Water allocation	ML		235	
Water entitlement	ML		235	
		$/unit	**Total**	
Income				
Sale of potatoes			$560,000	
Gross Income			$560,000	
Variable Costs				
Disease sprays	$/ha	595	$20,825	10% RTrade, 90% Imports
Pest sprays	$/ha	206	$7,208	10% RTrade, 90% Imports
Nutrient sprays	$/ha	65	$2,259	10% RTrade, 90% Imports
Herbicides	$/ha	215	$7,537	10% RTrade, 90% Imports
Fertiliser	$/ha	629	$22,006	10% WTrade, 2% Tport, 88% Imports
Contract operations	$/ha	250	$8,750	100% ServAg
Freight	$/t	30	$1,200	100% Road Transport
Fuel	$/ha	1,613	$56,471	10% RTrade, 90% Imports
Labour	$/ha	4,092	$143,206	100% W&S
Irrigation costs	$/ML	259	$60,763	60% Water, 20% Elect, 10% Other Mach & Equip, 10% Imports
Land based levy [a]	c/$	0.012	$148	100% Govt Admin
Water based levy	$/ML	5.30	$1,243	100% Govt Admin
Total Variable Costs			**$331,615**	
Gross Margin			**$228,385**	
Overheads				
Labour			$49,964	100% W&S
Consumables			$8,186	25% Elect, 5% RTrade ,70% Imports
Maintenance			$7,277	30% OthMach&Equip, 30% ConTS, 20% RTrade, 20% Imports
Depreciation			$18,361	100% GOS
Insurance			$7,115	10% Finance & Insurance, Imports 90%
Professional services			$5,457	80% Prop & Bus Serv, 20% Imports
Office/administration			$10,369	30% RTrade, 20% Comm'n, 30% Govt Admin, 20% Imports
Total Overheads			**$106,730**	
EBIT			**$121,655**	100% GOS

Source: EconSearch analysis.

Table 2.2. Data for RISE model new potato industry development, scenario 3, Murraylands region

Sector	Year 1 ($m)	Year 2 ($m)	Year 3 ($m)
Local Industry Expenditure			
Services to agriculture	0.088	0.140	0.175
Other machinery and equipment manufacturing	0.069	0.111	0.139
Electricity supply	0.130	0.208	0.259
Water, sewerage, drainage	0.365	0.583	0.729
Construction trade services	0.009	0.014	0.017
Wholesale trade	0.022	0.035	0.044
Retail trade	0.114	0.183	0.228
Road transport	0.424	0.679	0.849
Communication services	0.008	0.013	0.017
Finance and insurance	0.028	0.046	0.057
Property, business services	0.022	0.035	0.044
Government administration	0.173	0.277	0.346
Total Local Industry Expenditure	**1.452**	**2.323**	**2.904**
Primary Inputs			
Wages and salaries	1.632	2.611	3.264
Gross operating surplus	1.376	2.201	2.752
Imports	1.170	1.872	2.340
Total Primary Inputs	**4.178**	**6.685**	**8.356**
Total Turnover	**5.630**	**9.008**	**11.260**
Employment (fte)	**27**	**44**	**54**

Source: EconSearch analysis.

With the development of an additional 700 ha under irrigation means that area will no longer available for the current land use. From a modelling viewpoint, this needs to be included in the analysis as a negative change in production and can be simulated in the RISE model as a negative change in final demand. Assuming an average yield of 1.5 tonnes per hectare and a grain price of $300/tonne, would mean a fall in the value of regional grain production of around $315,000 by year 3.

2.2 Model results

The results of the simulated changes of a new industry with a small negative change in final demand, in both absolute and relative terms, are presented in Table 2.3. For each of the impact indicators (GRP, employment, household income and population) the impact on the regional economy is shown to be increasing over time as the expansion occurs over a 3-year period. By year 3 gross regional product (GRP), for example, would be expected to increase by around $9 million, or approximately 0.7 per cent of total Murraylands GRP (approximately $1.4 billion in 2009/10).

Table 2.3. Impact results (direct + indirect), scenario 3, Murraylands region

	Impact			Share of regional total
	Year 1	Year 2	Year 3	(Year 3)
Gross Regional Product ($m)	4.6	7.3	9.1	0.7%
Employment (No. fte jobs)	45	71	89	0.6%
Household Income ($m)	2.4	3.9	4.9	0.7%
Population (No. persons)	23	37	46	0.1%

Source: EconSearch analysis.

Appendix 1. An Overview of Economic Impact Analysis using the Input-Output Method

Economic impact analysis based on an input-output (I-O) model provides a comprehensive economic framework that is extremely useful in the resource planning process. Broadly, there are two ways in which the I-O method can be used.

First, the I-O model provides a numerical picture of the size and shape of an economy and its essential features. The I-O model can be used to describe some of the important features of an economy, the interrelationships between sectors and the relative importance of the individual sectors.

Second, I-O analysis provides a standard approach for the estimation of the economic impact of a particular activity. The I-O model is used to calculate industry multipliers that can then be applied to various development or change scenarios.

The input-output database

Input-output analysis, as an accounting system of inter-industry transactions, is based on the notion that no industry exists in isolation. This assumes, within any economy, each firm depends on the existence of other firms to purchase inputs from, or sell products to, for further processing. The firms also depend on final consumers of the product and labour inputs to production. An I-O database is a convenient way to illustrate the purchases and sales of goods and services taking place in an economy at a given point in time.

As noted above, I-O models provide a numerical picture of the size and shape of the economy. Products produced in the economy are aggregated into a number of groups of industries and the transactions between them recorded in the transactions table. The rows and columns of the I-O table can be interpreted in the following way:

- The rows of the I-O table illustrate sales for intermediate usage (i.e. to other firms in the region) and for final demand (e.g. household consumption, exports or capital formation).
- The columns of the I-O table illustrate purchases of intermediate inputs (i.e. from other firms in the region), imported goods and services and purchases of primary inputs (i.e. labour, land and capital).
- Each item is shown as a purchase by one sector and a sale by another, thus constructing two sides of a double accounting schedule.

In summary, the I-O model can be used to describe some of the important features of a state or regional economy, the interrelationships between sectors and the relative importance of the individual sectors. The model is also used for the calculation of sector multipliers and the estimation of economic impacts arising from some change in the economy.

Using input-output analysis for estimation of economic impacts

The I-O model conceives the economy of the region as being divided up into a number of sectors and this allows the analyst to trace expenditure flows. To illustrate this, consider the example of a vineyard that, in the course of its operation, purchases goods and services from other sectors. These goods and services would include fertiliser, chemicals, transport services, and, of course, labour. The direct employment created by the vineyard is regarded in the model as an expenditure flow into the household sector, which is one of several non-industrial sectors recognised in the I-O model.

Upon receiving expenditure by the vineyard, the other sectors in the regional economy engage in their own expenditures. For example, as a consequence of winning a contract for work with vineyard, a spraying contractor buys materials from its suppliers and labour from its own employees. Suppliers and employees in turn engage in further expenditure, and so on. These indirect and induced (or flow-on) effects[7], as they are called, are part of the impact of the vineyard on the regional economy. They must be added to the direct effects (which are expenditures made in immediate support of the vineyard itself) in order to arrive at a measure of the total impact of the vineyard.

It may be thought that these flow-on effects (or impacts) go on indefinitely and that their amount adds up without limit. The presence of leakages, however, prevents this from occurring. In the context of the impact on a regional economy, an important leakage is expenditure on imports, that is, products or services that originate from outside the region, state or country (e.g. machinery).

Thus, some of the expenditure by the vineyard (i.e. expenditure on imports to the region) is lost to the regional economy. Consequently, the flow-on effects get smaller and smaller in successive expenditure rounds due to this and other leakages. Hence the total expenditure created in the regional economy is limited in amount, and so (in principle) it can be measured.

Using I-O analysis for estimation of regional economic impacts requires a great deal of information. The analyst needs to know the magnitude of various expenditures and where they occur. Also needed is information on how the sectors receiving this expenditure share their expenditures among the various sectors from whom they buy, and so on, for the further expenditure rounds.

In applying the I-O model to economic impact analysis, the standard procedure is to determine the direct or first-round expenditures only. No attempt is made to pursue such inquiries on expenditure in subsequent rounds, not even, for example, to trace the effects in the regional economy on household expenditures by vineyard employees on food, clothing, entertainment, and so on, as it is impracticable to measure these effects for an individual case, here the vineyard.

The I-O model is instead based on a set of assumptions about constant and uniform proportions of expenditure. If households in general in the regional economy spend, for example, 13.3 per cent of their income on food and non-alcoholic beverages, it is assumed that those working in vineyards do likewise. Indeed, the effects of all expenditure rounds after the first are calculated by using such standard proportions (i.e. multiplier calculations). Once a transactions table has been compiled, simple mathematical procedures can be applied to derive multipliers for each sector in the economy.

Input-output multipliers

Input-output multipliers are an indication of the strength of the linkages between a particular sector and the rest of the state or regional economy. As well, they can be used to estimate the impact of a change in that particular sector on the rest of the economy.

Detailed explanations on calculating I-O multipliers, including the underlying assumptions, are provided in any regional economics or I-O analysis textbook (see, for example, Jensen and West (1986)). They are calculated through a routine set of mathematical operations based on coefficients derived from the I-O transactions model, as outlined below.

[7] A glossary of I-O terminology is provided in Appendix 3.

Appendix 2 Glossary of Input-Output Terminology

Basic price is the price received for a good or service by the producer. It is also known as the producers' price. It excludes indirect taxes and transport, trade and other margins.

Changes in inventories (stocks) "consist of stocks of outputs that are held at the end of a period by the units that produced them prior to their being further processed, sold, delivered to other units or used in other ways and stocks of products acquired from other units that are intended to be used for intermediate consumption or for resale without further processing" (ABS 2008b).

Consumption-induced impacts are additional output and employment resulting from re-spending by households that receive income from employment in direct and indirect activities. Consumption-induced effects are sometimes referred to as 'induced effects'.

DECON model is a demographic-economic model based on a traditional input-output model. The introduction of a population 'sector' (or row and column in the model) makes it possible to estimate the impact on local population levels of employment growth or decline. The introduction of an unemployed 'sector' makes it possible to account for the consumption-induced impact of the unemployed in response to economic growth or decline**.**

Direct (or initial) impacts are an estimate of the change in final demand or level of economic activity that is the stimulus for the total impacts.

Employment is a measure of the number of working proprietors, managers, directors and other employees, in terms of the number of full-time equivalents and total (i.e. full-time and part-time) jobs. Employment is measured by place of remuneration rather than place of residence.

ess is an estimate of the proportion of employed who are not eligible for welfare benefits when they lose their job.

Exports (other) are a measure of the value of goods and services sold from the region/state of interest to consumers in other regions, interstate and overseas, net of sales to visitors to the region.

Final demand quadrant (components of) includes household and government consumption expenditure, gross fixed capital formation, changes in inventories (stocks), tourism expenditure and 'other' exports.

First-round impacts are estimates of the requirement for (or purchases of) goods and services from other sectors in the economy generated by the initial economic activity.

Flow-on impacts are the sum of production-induced impacts, consumption-induced impacts and offsetting consumption effects.

Government consumption expenditure includes "net expenditure on goods and services by public authorities, other than those classified as public corporations, which does not result in the creation of fixed assets or inventories or in the acquisition of land and existing buildings or second-hand assets. It comprises expenditure on compensation of employees (other than those charged to capital works, etc.), goods and services (other than fixed assets and inventories) and consumption of fixed capital. Expenditure on repair and maintenance of roads is included. Fees, etc., charged by general government bodies for goods sold and services rendered are offset against purchases. Net expenditure overseas by general government bodies and purchases from public corporations are included. Expenditure on defence assets that are used in a fashion similar to civilian assets is classified as gross fixed capital formation; expenditure on weapons of destruction and weapon delivery systems is classified as final consumption expenditure" (ABS 2008b).

Gross fixed capital formation (GFCF) includes government, private and public corporation expenditure on new fixed assets plus net expenditure on second-hand fixed assets, including both additions and replacements (see ABS 2008b for further detail).

Gross operating surplus and gross mixed income. Gross operating surplus (GOS) is a measure of the operating surplus accruing to all enterprises, except unincorporated enterprises. It is the excess of gross output over the sum of intermediate consumption, household income and taxes less subsidies on production and imports. Gross mixed income (GMI) is a measure of the surplus or deficit accruing from production by unincorporated enterprises (ABS 2008b). The National Accounts definition of this indicator, as specified in the 2004/05 National I-O table (ABS 2008a), includes drawings by owner operators (or managers). In the state model used in this project, drawings by owner operators have been included in household income.

Gross regional/state product (GRP/GSP) is a measure of the net contribution of an activity to the regional/state economy. GRP/GSP is measured as value of output less the cost of goods and services (including imports) used in producing the output. In other words, it can be measured as the sum of household income, 'gross operating surplus and gross mixed income net of payments to owner managers' and 'taxes less subsidies on products and production'. It represents payments to the primary inputs of production (labour, capital and land). Using GRP/GSP as a measure of economic impact avoids the problem of double counting that may arise from using value of output for this purpose.

Household consumption expenditure includes "net expenditure on goods and services by persons and expenditure of a current nature by private non-profit institutions serving households. This item excludes expenditures by unincorporated businesses and expenditures on assets by non-profit institutions (included in gross fixed capital formation). Also excluded is expenditure on maintenance of dwellings (treated as intermediate expenses of private enterprises), but personal expenditure on motor vehicles and other durable goods and the imputed rent of owner-occupied dwellings are included. The value of 'backyard' production (including food produced and consumed on farms) is included in household final consumption expenditure and the payment of wages and salaries in kind (e.g. food and lodging supplied free to employees) is counted in both household income and household final consumption expenditure" (ABS 2008b).

Household income is a component of GRP/GSP and is a measure of wages and salaries paid in cash and in-kind, drawings by owner operators and other payments to labour including overtime payments, employer's superannuation contributions and income tax, but excluding payroll tax.

Imports are a measure of the value of goods and services purchased by intermediate sectors and by components of final demand in the region/state of interest from other regions, interstate and overseas.

Industrial-support impacts are output and employment resulting from second, third and subsequent rounds of spending by firms.

Input-output analysis is an accounting system of inter-industry transactions based on the notion that no industry exists in isolation.

Input-output model is a transactions table that illustrates and quantifies the purchases and sales of goods and services taking place in an economy at a given point in time. It provides a numerical picture of the size and shape of the economy and its essential features. Each item is shown as a purchase by one sector and a sale by another, thus constructing two sides of a double accounting schedule.

Multiplier is an index (ratio) indicating the overall change in the level of activity that results from an initial change in economic activity. They are an indication of the strength of the linkages between a particular sector and the rest of the state or regional economy. They can be used to estimate the impact of a change in that particular sector on the rest of the economy.

Offsetting consumption effects are 'lost' consumption expenditure by the local unemployed before taking a job or 'new' consumption expenditure of those losing a job as they shift to welfare payments.

Output (Value of) is a measure of the gross revenue of goods and services produced by commercial organisations (e.g. farm-gate value of production) and gross expenditure by government agencies. Total output needs to be used with care as it can include elements of double counting when the output of integrated industries is added together (e.g. the value of winery output includes the farm-gate value of grapes). For sectors where superior regional data are not available, value of output by industry is allocated across regions on an employment basis, rather than in terms of the location of other factors of production such as land and capital.

Population impacts are a measure of the change in the number of people resident in the region as a result of employment growth or decline.

Purchasers' price is the price paid for a good or service paid by the purchaser. It includes indirect taxes and transport, trade and other margins.

Primary input quadrant (components of) includes household income, gross operating surplus and gross mixed income net of payments to owner managers, taxes less subsidies on products and production and imports.

Production-induced impacts are the sum of first-round and industrial support impacts. Production-induced impacts are sometimes referred to as 'indirect effects'.

rho is an estimate of the proportion of employees who remain in the region after they lose their job (negative employment impact) or the proportion of new jobs filled by previously unemployed locals (positive employment impact).

Taxes less subsidies on products and production (TLSPP) is defined as 'taxes on products' plus 'other taxes on production' less 'subsidies on products' less 'other subsidies on production'. Taxes on products are taxes payable per unit of some good or service. Other taxes on production consist of all taxes that enterprises incur as a result of engaging in production, except taxes on products. Subsidies on products are subsidies payable per unit of a good or service. Other subsidies on production consist of all subsidies, except subsidies on products, which resident enterprises may receive as a consequence of engaging in production (ABS 2008b).

Tourism expenditure is a measure of the value of sales of goods and services to visitors to the state or region.

Total impacts are the sum of initial (or direct) and flow-on impacts.

Type I multiplier is calculated as (direct effects + production-induced effects)/direct effects.

Type II multiplier is calculated as (direct effects + production-induced effects + consumption-induced effects)/direct effects.

Type III multiplier is a modified Type II multiplier, calculated by including a population and unemployed row and column in the 'closed' direct coefficients matrix of the standard I-O model. Calculated as (direct effects + production-induced effects + consumption-induced effects + offsetting consumption effects)/direct effects.