Climate Change Adaptation & Land South Coast Region of Western Australia

A background paper for the Climate Adaptation Addendum to Southern Prospects 2011-2016.
Prepared by Dr Julia Fry for South Coast NRM.

SOUTHCOAST NATURAL RESOURCE MANAGEMENT

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Abbreviations used in this report.

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
APSIM	Agricultural Production Systems sIMulator
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CRC	Cooperative Research Centre
DAFF	Department of Agriculture, Forestry and Fisheries
DAFWA	Department of Agriculture and Food, Western Australia
NRM	Natural Resource Management
SWWA	South West Western Australia

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Contents

1 - Forward

The background papers to the *Climate Adaptation Addendum of Southern Prospects 2011-16* are a series of detailed technical documents on the potential impacts of the South Coast region's changing climate and how people are adapting to it.

They papers were commissioned by South Coast NRM in 2014 and were part of the Regional Natural Resource Management Planning for Climate Change - Stream 1 project of the Australian Government.

The background papers synthesise the current information on the effect of climate change on each natural resource theme, community capacity to adapt and how people are already adapting. They also document some of the gaps. The papers provide useful background for community consultation through South Coast NRM reference groups. The reference groups have used the papers to develop climate adaptation goals and outcomes for *Southern Prospects 2011-2016.*

South Coast NRM recommends the papers are best read in conjunction with *Fry (2015) A Changing Climate- South Coast of Western Australia* and information on the CSIRO and Bureau of Meteorology Climate Change in Australia website *www.climatechangeinaustralia.gov.au/en/.*

Climate change planning at South Coast NRM will be flexible and adaptive and so information on climate and its impacts will be continually reviewed.

- Kaylene Parker, Climate Change Project Leader, 2015

2 - Introduction

"The performance of the land is driven by climate, land characteristics and land management ...in a drying and variable climate land management practices need to be able to respond quickly to changing conditions," (DAFWA 2013, p4).

Increasing variability in climate is likely to be a major factor impacting on the land resource in the South Coast region in the near future. There has already been a strong trend to warmer temperatures and lower rainfall in parts of the region. Significant warming and more dry seasons are likely, under future climate projections and there may be more summer rainfall *(Bates et al. 2008; IOCI 2012; CSIRO, BoM 2014).*

These projections are general but may be relevant for much of the South Coast region. Nevertheless, it is important to stress that the South Coast has a range of climates and microclimates, so different geographic areas are likely to have different future climate responses to increased greenhouse gases and global warming.

Because of the complexity of climate systems there is also uncertainty in the climate projections, particularly those in relation to rainfall. The projections for the broad region of the south-west corner of WA (SWWA) are considered very robust because the climate models agree on the direction of change *(Hope et al. 2012, p42).*

Climate variability and change are the biggest risks to production and risk management is considered the best tool to manage them *(Loch et al. 2012, Australian Greenhouse Office 2006).* An ongoing and iterative risk management approach is a way of dealing with uncertainty *(Jones and Preston 2010).* The risks vary across the region and with soil type, so risk management needs to consider spatial variability across regional, catchment and farm scale.

If South Coast NRM is to support farmers to adapt to climate change, it will need to take account of regional and local climatic effects, as well as vulnerability in socio-economic (e.g. level of debt, attitude to risk) and biophysical (e.g soil type) terms. Farming systems need to be flexible and economically resilient because of the increase in climate variability and the uncertainty associated with climate projections.

Most farmers are at a higher risk because of the proportion of their business that has to be spent on inputs and the increase in associated debt.

Farmers in the South Coast region have always had to manage climatic variations such as very wet or very dry seasons, high winds, untimely frosts, rain at harvest and abnormal levels of weeds, pests and diseases. Many of these seasonal variations are likely to increase. *"In the short term, year-to-year climate variability may be more important than the longer term trends," (DAFWA 2013, p12).* Without global scale mitigation, major climate change is likely to begin to impact after mid-century.

Climate change projections developed from global scale models can show likely general trends but currently do not provide sufficient information at a local scale for most South Coast farmers to make decisions about major changes to systems or enterprises.

Monitoring of rainfall and temperature at a local scale will become increasingly important to evaluate climate scenarios and indicate potential climate shifts. The complexity of natural climate cycles, interacting with climate change driven by greenhouse gas pollution, makes predicting future climate even more difficult.

On the adaptation front, the relatively slow pace of climate change against an existing backdrop of high variability (multiple decades compared to the annual decision making environment of most farm businesses), together with the spatially explicit uncertainty in rainfall projections has generally made it difficult to identify specific and additional adaptation options that make immediate sense for agricultural businesses *(Keating et al. 2012, p 26).*

Jones and Preston (2010) and *Campbell (2011)* argue that *"a business as usual approach is unlikely to be enough to adapt to major climate change,"* however for South Coast farmers, *"business as usual is constant adaptation," (Jeremy Lemon, Lucy Anderton, DAFWA pers.com).* Farmers have had to adapt to large variations from season-to-season, thus many adaptations to climate change are likely to be based on the methods farmers currently use to manage seasonal variability *(Kingwell 2006; Moore 2012).*

The cost-benefit of adaptation to climate change will be an important factor in adoption of new practices. It will also be important for farmers to avoid maladaptation *(Stokes et al. 2010)*, i.e. to change varieties, enterprises, farming systems or management practices in a way that ultimately results in lower profitability and no benefit to the land resource, the shift in climate or global emissions.

Without global mitigation of greenhouse gas emissions, constant small-scale adaptation may not be enough for major climate shifts after mid-century.

Therefore many argue that transformative change in agricultural systems is needed. So-called 'transformative change' has high risk and high cost associated with it *(Howden et al. 2010a; Rickards and Howden 2012)* and there is currently no transformational, economically viable, farming system on the horizon for South Coast farmers.

This does not mean that transformational change as an option should not be explored further and there may be a point in the future where the costs of not changing exceed those of changing *(Rickards and Howden 2012)*.

Another major factor in adapting to climate change will be the resilience of farm businesses. Debt burden reduces a farmer's ability to cope with several adverse seasons or to adapt to the impact of other seasonal variations such as an increase in diseases or weeds *(Kingwell et al. 2013; Anderton 2014)*.

Farmers with a high level of equity can be more strategic in adapting their management to seasonal variations. This will become increasingly important in higher risk, large scale cropping operations in northern and north-eastern areas of the region. If the terms of trade continue to deteriorate it will make it harder for farmers to manage sequential dry seasons.

The belief by many farmers that the climate is always changing and it is all part of a natural cycle *(Donnelly et al. 2009)* could be a major obstacle to engaging landholders in discourse about adaptation to climate change and increased climate variability and risk.

The National Climate Change Adaptation Research Facility (2013) recommended that information *"be framed appropriately, for example, in terms of business and profitability rather than climate change"*.

Changes in climate will interact with all the other factors in the complex system that makes up a farm business and the ability of that business to look after the land resource.

South Coast farmers have had to manage the constraints of ancient soils and many of the soils in the South Coast region have major challenges in both very wet and very dry years. Farmers have adopted new technologies and practices that have had both production and NRM benefit.

A good example is no-tillage, which has significantly reduced wind erosion on sandplain soils. Other management practices such as liming to reduce sub-soil acidity and precision agriculture, can improve nutrient uptake and water use efficiency and have the potential to enable crops to adapt better to dry conditions as well as improve the soil resource.

This background paper examines the potential impact of increased climate variability and climate change projections on the land resource to 2030.

Principles to guide natural resource management of the land against the increased risks associated with climate change also need to include those that will maintain a community of resilient farmers, as well-informed land resource managers, within the landscape.

3 - Principles from Southern Prospects 2011-2016

Some principles for climate change adaptation:

- Uncertainty should not be a barrier to planning for climate change risks.
- There should be an adaptive planning, risk management approach, incorporating new climate information as it becomes available, with regular evaluation and monitoring.
- It should be recognised it is important to maintain resilient and sustainable agricultural businesses while protecting the land resource against the impacts of climate change.
- Climate risks should be integrated with other NRM risks in NRM planning.

Impacts of Climate Change on Agriculture & Forestry in the Region

Climate risk is the product of the consequences of climate change and the likelihood of those consequences *(Jones 2001)*.

Risk management analysis will be increasingly important in determining the impact of climate change. There are several tools to assist this process. It is important this is done in a participatory workshop environment and is a continuous and iterative process *(Australian Greenhouse Office, 2006; Jones and Preston 2010)*.

Climate risk analysis at a regional or sub-regional scale would examine the likelihood of a particular climate and the consequence for the environment, the land resource or farm businesses. Specifying the level of uncertainty (the likelihood) can help in planning and decisions about adaptation *(CSIRO, BoM 2007)*.

Information can assist in giving greater certainty to the two aspects of risk, the likelihood and the consequences *(CSIRO, BoM 2007)*. This background paper aims to provide information to assist the risk analysis process for the region. The South Coast region is diverse in climate and agricultural systems. Most of its sub-regions are based on catchments, so they also incorporate diverse agroclimatic areas.

There are several different ways of classifying agroclimatic zones, but in general the region can be divided into a high rainfall zone and a medium rainfall zone, with either the 750 or 600mm isohyet used as the high rainfall boundary depending on the classification system. The isohyets are moving westward *(Ludwig et al. 2009)* so in some areas land that was previously considered too wet has become prime cropping land.

Total landholding in the region during 2011-2012 was estimated by the Australian Bureau of Statistics (ABS) as more than 3 million ha with half in crop and slightly less than half as grazing land (*ABS, 2013a*).

Annual or perennial pastures for sheep and beef cattle grazing, forestry and viticulture dominate the high rainfall zone (parts of the Albany hinterland and Kent-Frankland sub-regions) but there are also small amounts of dairy and horticulture and intensive livestock industries. Farms in the higher rainfall areas tend to be smaller and many have off-farm income. There is increasing competition for high value land with urbanisation and sub-division for lifestyle properties. Many areas suited to horticulture, viticulture, intensive grazing and high rainfall forestry are likely to come under threat of sub-division in the future.

Broadacre farms dominate in the medium rainfall zones of all sub-regions. The main enterprises are cropping, with variable levels of grazing, mainly sheep and some cattle. Wheat and barley are the main crops, with some oats and increasing amounts of canola used as a profitable break crop to reduce disease.

There has been an increase in the proportion of cropping in this zone with the decrease in profitability of sheep. Most grazing is with self-replacing merino flocks grown for wool and prime lambs, but there has been an increase in specific breeds for meat sheep in recent years.

The mixture of enterprises enables farmers in this zone to increase or decrease the amount of cropping or livestock according to season and price. As the rainfall declines in the north and northeast the farms tend to be larger and often have no livestock. There has been a strong trend to farm amalgamation and increasing farm size or land holdings *(Kingwell and Pannell, 2005)*.

Declining rainfall is beginning to impact on some parts of the region. In the short-term it has not reduced production in most areas, but in the future, farmers will need to plan for the risk of a hotter, drier climate. Several general strategies for adapting to climate change have been suggested, with some outlined in *Appendix 1*.

The impact of climate change on commodity trading in other parts of the world will also affect farm businesses and their ability to adapt. Greater diversity in farming systems may enhance flexibility. South Coast farmers are constrained into producing commodities by factors such as distance from markets, but if they were able to shift to growing more specific products they may be less vulnerable to commodity market changes.

"Farming systems will need to be flexible and able to respond to the season as it unfolds," (Jeremy Lemon, DAFWA, pers. com.). The impact of climate change to 2030 will be different in different parts of the region, soil types and enterprises. Research is providing some information on likely impacts.

5 - Impacts on Different Enterprises

5.1 - Cropping

The main factors determining profitability of WA grain growers are climate variability, productivity growth and wheat prices. Rainfall in the growing season is the most important factor but the impact varies with rainfall zone *(Che et al. 2012)*. The interactions between temperature, rainfall, atmospheric carbon dioxide (CO_2), and soil type on grain production and quality, are complex *(Ludwig and Asseng 2005; Stokes and Howden 2008; 2010)*.

Increases in atmospheric CO_2, probable increases in temperature and changes in rainfall seasonality and intensity will impact on grain production and quality in both positive and negative ways *(Stokes and Howden 2010, p4)*. Increases in grain yield in response to increases in CO_2 could be negated by decreases in response to temperature. Until 2030, temperature and CO_2 impacts are likely to be much less than rainfall impacts.

An increased variability in rainfall will be a major risk factor in the near future and is also the most uncertain. *Ludwig et al. (2009)* modelled the observed lower rainfall in the 1975–2004 period relative to the 1945–1974 period and found it did not result in a reduction of the simulated yield.

It did reduce deep drainage and waterlogging which would have benefited soils in some parts of the region. For the Grains Research and Development Corporation's National Variety Trials program the South Coast is divided into three agroclimatic zones: *Agzone 3*, greater than 750mm; *Agzone 6*, 450mm-750mm and *Agzone 5*, less than 450mm *(Figure 1)*.

Much of the region is predicted to have a lower reduction in grain yields in response to climate change towards 2030 than other regions of WA *(Kokic et al. 2005; Van Gool and Vernon, 2005; 2006; Vernon and Van Gool, 2006 a,b; Van Gool, 2011)*.

Based on some fairly simple models using rainfall and temperature predictions, but with no allowance for the fertilisation effects of increased CO_2 *(Vernon and Van Gool 2006)*, the greatest impact of climate change on crop yields to the mid-21st century, was shown to be on wheat and canola in the hotter, dryer northern parts of the region in *Agzone 5*.

The limitations of these simple models should be recognised and responses will be different in different soil types. For example APSIM modelling showed an increase in yield on duplex soils in Esperance due to less waterlogging but a decrease in yield on sand or clay soils *(Farre and Foster 2010)*. Similarly, modelling by *Ludwig and Asseng (2006)*, has shown clay soils are the most vulnerable to dryer seasons and sandy soils are more vulnerable to higher temperatures.

On these soils, late maturing varieties may not increase yields because of their susceptibility to dry conditions and temperature respectively. Loam sand soils showed the most potential to adapt to climate change with longer season varieties of wheat. It is therefore very important to consider soil type in risk analysis and adaptation strategies.

Carmody et al. (2010) cited the DAFWA APSIM modelling showing variations in yield according to soil type and rainfall in the Southern Agricultural region to 2050. The modelling suggested that sandy and duplex soils would tend to show a 0–10 per cent yield increase in high rainfall parts of the region while the medium and low rainfall areas showed a decrease of 0–10 per cent.

There is likely to be a decline in yields on heavy clay soils in the Lakes and Mallee districts. There may be an increase in yields on Esperance sandplain soils and western parts could experience yield increases of more than 10 per cent on sandy soils.

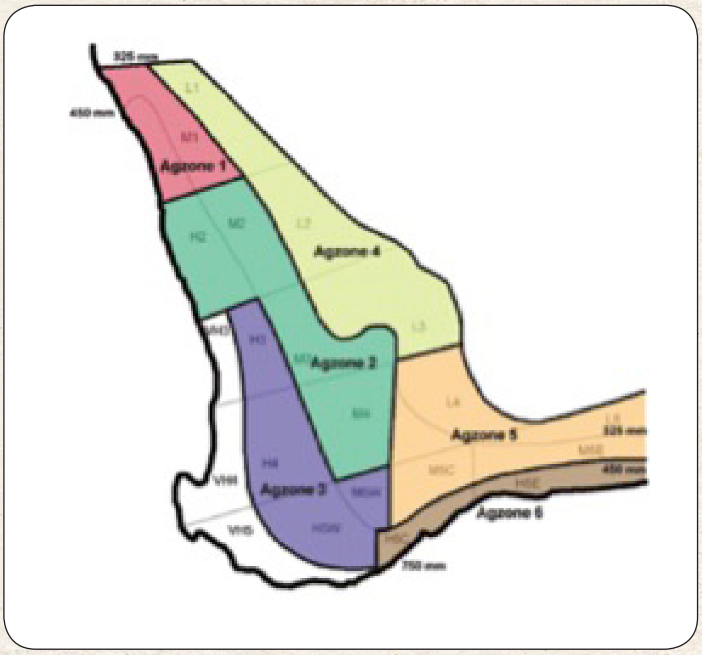

Figure 1: National Variety Trials, Grains Research and Development Corporation.

It is also likely that simple models overestimate the impact on yield *(Ludwig et al. 2009)*. The interaction between rainfall, water balance and the crop growth system is much more complex, with factors such as the date of break, distribution of rainfall during the growing season, intensity of growing season rainfall events and interval between rainfall events, all impacting on crop growth *(Ludwig et al. 2009; Anderton et al. 2013)*.

The soil's surface texture has a big impact on the amount of water getting to the sub-soil. Nevertheless many soil types in parts of *Agzone 5* are likely to be at risk from sequential dry seasons. The contraction in cropping is likely to be highest in the northern and north-eastern parts of the region, but it will depend on whether rainfall follows current projections or whether uncertain climate influences such as increasing north-west cloud bands bring more early winter rainfall *(Fry 2014)*.

Although any reductions in yield are likely to be relatively small to 2030, they do not give the whole picture in relation to farm profit. *"Although a 10 per cent reduction in yield doesn't sound a lot, it can translate into as much as 30 per cent reduction in profit," (Jeremy Lemon, DAFWA pers.com.)*. For a farm business with a high debt level this can be a critical threshold. After 2050, with no global mitigation of greenhouse gas emissions, under current climate projections, there is likely to be a major contraction of grain growing on the South Coast. The level of contraction will depend on the rapidity of warming and level and extent of growing season rainfall decline. The timing of the autumn break and spring rainfall will be critical factors. Future rainfall variations at a sub-regional and local scale are even more uncertain.

Other factors governing the sustainability of cropping, include risk and price management *(Anderton 2014)*. Climate change and variation is also likely to cause changes in abundance and distribution of pests and diseases *(Howden et al. 2010b)*. The effect on these also depends on the number of rainy days, the distance between rainfall events and the timing of rain. For example, in South Coast canola crops during 2013, some diseases reduced but others increased due to the timing of rainfall events *(Jeremy Lemon, DAFWA pers. com.)*.

Another risk is all research and development on agronomy and varieties in relation to the region's agriculture may become less relevant as the climate shifts *(Kingwell 2006)*. Whether frost risk will increase or decrease is uncertain. Increases in minimum temperatures may not translate directly into less frost risk. A southward movement of the sub-tropical ridge of high-pressure systems with associated clear skies, could increase frost risk in spring. Global Climate Models currently appear to be underestimating frost events *(Crimp et al. 2013)*. Changes in the number of frosts and their timing will be important in adaptation responses.

Two South Coast farmers discussed their strategies for dealing with increased climate variability.

Andrew Longmire, north of Salmon Gums (annual rainfall approximately 330mm).
"We rely on summer rainfall for sub-soil moisture. We have been getting more summer rainfall since about 1992. Every year is different and there is no pattern to the rainfall, we just have to work with it. We crop particular soil types depending on the season. We use liquid fertiliser in dry years. The main adaptation in the district is direct drill and chemical fallow."

Andrew's biggest risk are possible heat events in August/September. By using appropriate varieties with better heat tolerance, dry seasons, frost and boron, he believes low rainfall farming will still be possible at Salmon Gums.

By contrast, in the high rainfall zone, farmers have so far benefited from climate change by increasing their proportion of cropping. This is now the main income for many, who have more profitable farms as a result. There is a much smaller margin from prime lambs and beef than from wheat.

David Slade in the Kent catchment at Kendenup (annual rainfall approximately 600mm).
"We couldn't grow wheat 40 years ago. We're now getting Cranbrook to Tambellup weather. I have to accept the climate is changing, but I don't know whether it's due to all the clearing in the south-west or the warming of the sea."

The Slade business has benefited from drying climate by being able to put in a greater proportion of crop.

The inland limit of the Wheatbelt is roughly the 300mm annual rainfall isohyet in WA. This has already moved in the last few years.

It is likely that the 300mm rainfall isohyet will move to the south and west into the South Coast region with further drying of the climate, but the continuation of cropping will depend on access to drought tolerant varieties, soil amelioration to maximize water use efficiency and soil type.

On soil types where cropping may become too risky farmers may need to increase livestock in their systems. Options on some of the saline, clay loam soils include perennial fodder shrubs such as old man saltbush *(Lemon, personal comment).*

"As long as broadacre farmers in south-western Australia have on-going access to improved crop varieties and technologies that support the profitable growing of crops, especially wheat; and that they have access to farm management and business education then farmers are likely to be able to adapt to projected climate change.

"Provided a farmer's terms of trade does not become unduly adverse, and that farmers sensibly manage farm debt, then it seems highly likely that farmers who continue to rely on crop production, mostly wheat-growing, will persist as financially sound businesses in most parts of the study region, even in the face of projected climate change," (Kingwell et al. 2013).

Summary

Without adaptation, cropping may be at risk on some soil types of the lower rainfall areas of the region towards 2030, due to an increase in dry seasons but in general the region will be less affected than other areas of the WA grain belt.

On soil types where cropping may become too risky, farmers may need to increase livestock in their systems. Options on some of the saline, clay loam soils include perennial fodder shrubs such as old man saltbush. Fodder shrubs can take advantage of episodic rainfall.

These strategies can also have an NRM benefit. In some of these areas large scale cropping may only be an occasional strategy. An NRM risk is the potential off-site impact of extra nitrogen fertiliser used to offset the effect of CO_2 on grain protein levels.

5.2 - Grazing

The annual pastures, annual rye grass and subterranean clover, dominate most grazing systems in the region. In some parts, annual medics, serradella and biserrula are grown (*Revell et al. 2012).* Kikuyu, lucerne and tall wheat grass are the main perennials, although a range of other perennials and perennial fodder shrubs are grown in some salt affected landscapes.

New perennials are being trialled and others may become more suitable to the region as the climate changes. The proportion of perennials and annuals in grazing systems in the future will be determined by whether there are consistent increases in out of season rainfall. Livestock heat stress is less likely to be a factor in much of the region than in other regions, but sudden heat events may impact on dairy herds.

There are sheep and cattle breeds more resilient to heat stress, so some changes in breed may be necessary in northern and eastern areas in the long term. There may be impacts on the cost of fodder because of dry seasons in other parts of WA.

There will be a risk to water supplies, initially, particularly in the western sub-regions such as Kent-Frankland, Albany Hinterland and Pallinup-North Stirlings.

The ABS (2013b) estimates approximately 19,000 ML of water is used by agriculture in the region of which 14,000 is directly rainfall dependent (in dams or tanks). More efficient catchments and reducing evaporation will become important. There may be animal welfare issues and increased soil erosion risks with an increase in dry seasons.

If pasture production does decline, declines in production and profitability are expected to be significantly larger than declines in total pasture growth, because up to 50 per cent (depending on soil type) vegetation must be left to protect the soil resource *(DAFF 2012; DAFWA 2013).*

The impact of climate change on pasture in the South Coast region will be variable. The interaction between CO_2 and drought resistance will impact on patterns of seed softening, germination behaviour and efficiency of phosphorus and potassium uptake (*Revell et al. 2012, p840).*

There has been some pasture modelling relevant to the region for a merino x poll Dorset lamb production enterprise for the shires of Kojonup and Ravensthorpe *(Moore 2012; Moore and Ghahramani 2013; Ghahramani and Moore 2013).*

The modelling was part of a national level project using GrassGrow. The model does not perform as well for WA annual pastures as it does for eastern states pastures, and needs some modification *(Mike Hyder, DAFWA, pers. com.)* so the results should be regarded with some caution.

The modellers used production and financial data from Ravensthorpe and Kojonup with four different climate projections to 2030. It is important to note the wide range of profit predictions, depending on the particular climate projection.

In the Ravensthorpe district the models indicated increased CO_2 and temperature would increase legume content of the pasture. The rate of decline of dry pasture residues over summer would increase, resulting in an increased risk of wind erosion on sandy soils.

At current district average stocking rates of 2.5 DSE/ha, profit declined significantly in two climate scenarios with only marginal increases predicted in the other models. On average profit declined by 33 per cent, but with a large range across the climate projections (+5 per cent to -90 per cent.

In the Kojonup district (similar to the northern part of Kent-Frankland sub-region), increased CO_2 and temperature produced an increase in legume content of the pasture. This differs from current experience, *(David Slade pers. com.)* due to rainfall patterns in autumn. The modelling also predicted a decrease in dry matter over summer with increased run-off on the non-wetting undulating forest soils in the Kojonup district.

At current district average stocking rates of 6.5 DSE/ha for Kojonup, all projections showed profit increasing at an average of 17 per cent for the period out to 2030 (range between climate scenarios of -20 per cent to +40 per cent).

The modellers stated that the *"best strategies or practices are already known to many producers and are as applicable today as they will be in the future" (Moore 2012).*

If there is increasing summer rainfall perennials will provide summer feed. There may also be tactics to make more opportunistic use of summer rainfall.

There are NRM benefits from perennials in their impact on reducing water tables and increasing ground cover in summer, but adoption is slow because "in reality many of the available perennial options have greater costs and risks, with delayed returns and are more managerially complex than current practice," *(Bennet 2009, p19).* There is a risk of increased locust plagues with an increase in summer rainfall, summer active pastures, and changes in rainfall distribution in arid Australia.

Opportunities for improving NRM in livestock enterprises, during climate change, include confinement feeding in summer *(Moore 2012),* rotational grazing to feed on offer and groundcover *(Hyder pers com),* increases in perennials if there is out of season rainfall, increase in windbreaks and (depending on government policy), more integration of livestock production with carbon farming.

With an increase in dry seasons, the Slades at Kendenup, have used strategies such as reducing stocking rates, more rotational grazing, using satellite information to see when pastures are growing again and putting in roaded catchments on dams. David Slade has noticed more false breaks have caused a loss of clover in the pastures.

There may be future opportunities for more livestock in the farming systems in low rainfall areas using perennial fodder shrubs. An NRM risk is the introduction of new pasture species without adequate assessment of their potential as environmental weeds.

Summary

The biggest risk for grazing enterprises in the region will be water supplies, declining pasture production and decreased ground cover over summer. Reductions in stocking rate, rotational grazing, confinement feeding and improvements in harvesting and storage of water will be important adaptations.

The main NRM risks on catchments are the effects of increased harvesting of water, potential wind erosion or water erosion from loss of groundcover and the potential for environmental weeds from new pasture species.

5.3 - Viticulture and Other Horticulture

Although viticulture covers a relatively small area of the South Coast region, it returns a high value per ha. Most grapevines in the region are irrigated, so the biggest risk for South Coast viticulture in the future is adequate water supply.

Viticulture in the region relies on irrigation water from artificial catchments such as roaded catchments, with a small proportion from surface seeps and groundwater *(Lang et al. 2010)*. Vine water use is likely to increase with higher temperatures, and rainfall is likely to decrease in the main wine grape growing parts of the region. Evaporation is also likely to increase.

Although Denmark has the benefit of a cooler coastal climate, the projected rainfall decline to 2030 is between 2 and 3 per cent with a consequent streamflow decline ranging from 10 - 13.5 per cent *(Smith et al. 2009)*. In a current 600mm annual rainfall area at Frankland, there are currently 534 ha of roaded catchments with 1 ha of roaded catchment needed to harvest sufficient water to irrigate 2.5 ha of vines *(Lang et al. 2010)*.

The cost benefit of roaded catchments for increasing the water catchment area has to be considered for each business. A benchmarking study conducted over the summer of 2008-2009 by DAFWA *(Lang et al. 2010)* found the majority of roaded catchments were poorly maintained, reducing the net surface water harvested from the catchments.

Over an average sized roaded catchment of 25 ha there was a potential loss of 65ML of harvestable water due to poor maintenance of roaded catchments. This variation in performance was expected to be typical of the region indicating a huge potential for efficiency gains. Cost of annual maintenance was the main barrier for vineyards.

Some larger corporate vineyards are bituminising catchments *(Overheu, DAFWA, pers com.)*. Lang et al. (2010) also found water savings can be made by using a monolayer (Aquatain®) on stored water in dams to reduce evaporation. Water trading may also be an option for some viticulturalists. The impact of increased capture and storage of water on the rest of the catchment area is likely to become an increasing NRM problem in viticulture areas. Up until 2030 temperature is unlikely to be a risk to viticulture in the region. Higher temperatures increase the speed of sugar development, acid degradation and change flavour in grapes *(Ward 2009)*. Cool climate varieties may be more restricted but other varieties such as cabernet sauvignon and shiraz may benefit from warmer conditions.

The temperature range for Mt Barker in 2050 (16.5-17.5 °C) is projected by a climate model to be close to the current range for a normal vintage at Margaret River *(Ward, et al., 2009)*. The risks are greater seasonal variability, an increase in warmer years and greater temperature fluctuations *(Ward, 2009)*. These risks may be greater for Mt Barker and Frankland than Denmark, which has a greater maritime influence. Increases in fire frequency and consequent smoke damage are also likely to be a risk for quality.

Ward (2009) predicted that changes in patterns of vine planting are likely, rather than reduced production. The region has a range of microclimates and providing water efficiency measures can be introduced, may become suited to a broader range of varieties as the temperature increases to 2030. Horticulture, other than viticulture, is a small industry mainly in the high rainfall parts of the Albany Hinterland and Kent-Frankland sub-regions, but it will be adversely affected by declining rainfall and water shortages. Main crops are olives, berry fruits and seed potatoes. Cherries and other stone fruit are also grown, reduced chilling will impact on these crops.

The impact of climate change on pests and pathogens is unknown. Competition for productive land with good quality water supplies will be a major threat to viticulture and horticulture. In the future, saltwater intrusion from rising sea levels, may impact on a small area of horticulture in the western part of the region.

Urbanisation and peri-urbanisation is a threat and is likely to increase if the South Coast becomes a desirable location as the west coast becomes hotter. Planning for climate change beyond 2030 will be important for the horticultural industries.

Summary

To 2030, viticulture production is unlikely to decrease although there may be some changes in distribution of plantings and varieties. Water supply is the greatest risk for viticulture and other forms of horticulture, so water use efficiency will become more critical. Other risks are smoke damage with increasing fire frequency and competition for land. The main NRM risks are increased harvesting of water and increased irrigation.

5.4 - Forestry

There are more than 100,000 ha of *Eucalyptus globulus* (Tasmanian bluegum) plantations in the region and approximately 5,000 ha of *Pinus radiata (Gavin Ellis pers.com.)*. An important principle for South Coast forestry would be to aim for integrated outcomes of biodiversity, carbon sequestration, reduced reliance on fossil fuels (through using biomass energy), optimising streamflow and reducing salinity.

Carbon farming remains uncertain and highly dependent on government policy and economic viability, but South Coast NRM is mapping areas suitable for carbon sequestration. This will improve planning so forestry is better matched to land suitability. Commercial plantation forestry has declined recently, but the industry is consolidating after restructuring following the demise of managed investment schemes.

There has been a transition from plantations back to broadacre agricultural land (estimated at 10-20,000 ha *Gavin Ellis pers. com.)* There are a number of NRM risks associated with this including increases in soil erosion, the need for appropriate soil amelioration and changes in hydrology such as rising groundwater levels and salinity. Nevertheless much of the reversion from bluegum plantations is occurring in areas that were at the rainfall margin for *E. globulus* and with a drying climate they proved to be not productive enough to be profitable. The 10-year rotation system of bluegum and broadacre agriculture in suitable areas may be an effective way to combat rising groundwater tables in the higher rainfall areas, but the system will depend on the economic viability of forestry.

The biggest problem for forestry is that due to the length of time to harvest (10 years for bluegums and 30 years for pine), it is more difficult to be flexible in relation to sudden changes in climate. Reductions in rainfall and an increase in dry seasons would be a threat to growth rates in plantations in the region.

There is plenty of uncertainty in relation to the impacts of CO_2, rainfall, temperature and disease and many of these are likely to be site specific. Local level bioclimatic modelling could be useful when there is more certainty in local climate projections. It is likely than some *E. globulus* plantings will be at risk *(Battaglia et al., 2009; ABARES, 2011)*.
In high rainfall areas, plantations of *E. globulus* have reduced streamflow and salinity.

Modelling has suggested streamflow has reduced by more then 18 per cent in parts of the region as a result of plantations in the catchment. For example, at Mt Lindsay in Denmark, it's estimated streamflow would increase from 17 to 23 GL if all plantations were removed, but at the cost of increasing salinity *(Smith et al. 2009)*.

In the Denmark catchment, bluegum plantations have reduced stream salinity at the Mt Lindsay gauging station, from 700 mg/L in 1991 to 540 mg/L in 2009 *(Ward et al. 2011)*. The Denmark River is expected to reach potable levels in the next decade but it is dependent on maintaining the level of plantations or deep rooted vegetation in the catchment. Future tree plantations need to be planted to balance their impact on salinity reduction and the risk to streamflow and water supply.

Growth may increase with increased carbon dioxide but may be offset by decreases in rainfall and increases in insect pests or fungal pathogens *(Battaglia et al. 2009; Booth et al. 2010)*. There is likely to be complex interactions between climate change and the impact of insect pests or fungal pathogens on some forestry trees. Trees under stress are likely to be more susceptible to insect attack and the impact of climate change on pests and pathogens is unknown.

Battaglia et al (2009) modelled the impact of climate projections from a high rainfall site in the region and suggested *E.globulus* and *Pinus radiata* plantations in the high rainfall zone (>1,000mm), where soils are fertile and deep, may increase production but with higher risk.

They also suggested eastern and northern extents of the *E. globulus* and *P. radiata* estates were likely to decrease in production with an increase in risk and high uncertainty. The effects of increased mortality when hot and dry events occur during critical phases of plantation growth, will be an important factor *(Battaglia et al. 2009)*.

Monitoring of tree health, pests and diseases, water use, impacts on streamflow, impact of CO_2 and wildfire risk will be important *(National Climate Change and Commercial Forestry Action Plan 2009-12, 2009)*. Monitoring for the risk that any forestry species may become woody weeds will also be important. Although the current rate of removal of blue gums is probably mainly driven by market changes and unsuitable locations, some are also likely to be due to recent climate change.

Summary

Forestry offers opportunities for improving NRM through increases in biodiversity, reducing salinity and sequestering carbon. Risks from forestry and climate change include impacts on streamflow, increased wildfire and potential increases in pests and fungal pathogens.

Climate change may be a factor in reducing bluegum plantations in some western catchments (such as the Denmark River) which along with lower rainfall will increase the risk of salinity. It will be important to get the right balance between sufficient streamflow to dilute saline water and lowering water tables to reduce salinity.

5.5 - Intensive Animal Industries

Poultry, dairies and piggeries are the main intensive livestock industries. There has been an increase in outdoor piggeries and poultry farms in the region in recent years *(Overheu, DAFWA, pers com.).*

Heat stress and water supply are likely to be the biggest factors with climate change. Dry seasons may impact on dairy herds in the western part of the South Coast. Design of buildings for energy and water use efficiency will be important *(Miller et al. 2010)*, but there is likely to be a further increase in free-range systems with consumer demand.

6 - Mitigation (Carbon Farming)

Mitigation can include sequestration such as the removal of CO2 by capture and storage of carbon through carbon farming (planting trees or increasing soil carbon), or by abating greenhouse gases, such as reducing nitrous oxide emissions from crops or methane from livestock.

It can also be as simple as using less fuel on and off farm.

If carbon farming is to provide an income, the returns would need to exceed project costs and be comparable with those from agriculture. Even though afforestation may be targeted to marginal land there are likely to still be opportunity costs.

The risks associated with the permanence of carbon plantings may be reduced by harvest cycles *(Sudmeyer et al. 2014).*

A 25-year option is part of the proposed Emissions Reduction Fund *(Australian Government, 2014)*

5.6 - NRM Risks for the Soil Resource

The main NRM risks for the soil resource in the region are sub-surface acidity, water repellence and salinity in some areas *(DAFWA 2013).*

The likely impact of climate change on each of the NRM risks listed in *Southern Prospects 2011-2016* are outlined in *Table 1.*

When changes to land management are considered to address particular issues, they need to be within the context and understanding of climate and land characteristics, otherwise unexpected and unwanted consequences may result (DAFWA 2013, p170).

Risk management is the best way to consider impacts and potential adaptations. Brundell et al. 2011 used a risk matrix as a tool in the risk management process.

Appendix 2 shows an example of an impact risk matrix and vulnerability matrix for the South Coast for grazing (for more detail on risk assessment see *Fry, 2014, South Coast Climate Background paper).*

Developing a risk matrix can help identify the impacts, adaptive responses and risk and vulnerability associated with climate change *(Brundell et al. 2011).*

Mitigation can sometimes have other benefits to farmers. For example:

- Liming acid soils used for cropping can reduce nitrous oxide emissions from nitrification following summer/autumn rainfall *(GRDC 2012).*
- Controlled traffic farming has the potential to reduce fuel use and emissions *(DAFWA 2010).*
- Increasing windbreaks and shade trees to reduce heat stress in livestock.

Increasing carbon in the soil may be of benefit but is difficult to measure and varies across relatively small spatial areas *(Hoyle et al. 2104).*

If soil carbon was used as part of carbon farming, the verification process is likely to be too costly at likely offset prices or government funding. Reducing methane emissions from livestock through more efficient feed conversion has the potential to increase productivity and be part of emissions reduction.

NRM Issue	Interaction with Climate Change to 2030
Sub-surface acidity	Sub-soil acidity reduces water use efficiency, which will become increasingly important in dry seasons. In turn reduced rainfall may reduce acidification because of less leaching of the soil profile and lower pasture and crop yields *(Overheu pers. com.).*
Water repellence	Management of water repellence will become more important with an increase in dry seasons. Measures, such as stubble and other biomass retention, which increase soil carbon and reduce erosion risk, also increase water repellence. Nevertheless recent research showed an increase in water infiltration under stubble retention overrode the water repellence effects on soil moisture (*Roper et al. 2013*).
Phosphorus export	There is an increased risk of losing phosphate from farms with intense rainfall events but this will depend on soil type and slope. With good stubble management, cropping has the potential to reduce P export compared to grazing.
Salinity	Risks are different in different hydrozones *(DAFWA 2013).* The impact of rainfall on salinity is uncertain in the zone of ancient drainage. Salinity equilibrium may be delayed because of lower rainfall *(DAFWA 2013).* Some areas, such as the North Stirlings, are approaching equilibrium. With less rainfall, there is potential long-term for less flushing of salinity in high rainfall, high slope areas in some landscapes. There are risks for increased stream salinity in western areas and areas that have not reached equilibrium.
Wind erosion	There is potential for an increase in wind erosion in dry seasons. Maintaining groundcover will be important.
Waterlogging	There is likely to be a decrease in waterlogging in some soil types (e.g. duplex soils) with lower winter rainfall. There is a risk of increases in flooding and inundation if there are intense summer rainfall events.
Water erosion	There is an increased risk of water erosion, depending on slope, with intense rainfall events, particularly in late summer and autumn. There may be a decreased risk in high rainfall areas as rainfall declines and with reduced rainfall events at the break of season (*DAFWA, 2013*). Rainfall events after dry seasons will increase the risk. Water erosion is a particular risk on sodic duplex soils of the South Coast *(DAFWA, 2013)*
Structural decline and sub-surface compaction	These were labelled as low risk in the main body of *Southern Prospects 2011 - 2016* but they are an increasing problem in shallow soils and red soils, due to surface sealing and hardpan development, as a result of increased cropping *(DAFWA 2013).* Wet soils are more susceptible so risk will relate to rainfall.

Table 1: NRM risks land and climate change.

Through the Sheep Cooperative Research Centre, DAFWA has conducted research on reducing methane emissions from sheep. However, the future capacity through genetics or management is uncertain.

Although carbon farming has some potential, there are also some risks. Identifying areas and soil types most suited to carbon plantings is currently underway as a part of the Stream 1 Climate Change Project.

DAFWA sums up the current situation in relation to carbon farming *(DAFWA 2013; Sudmeyer et al. 2014, p ix): "Anyone considering carbon farming must consider returns on capital, administrative costs and issues pertaining to permanence and land use change. Given likely low medium term carbon prices, offset income alone will not be enough to make most carbon farming projects economically viable. Carbon farming activities need to return multiple economic and environmental co-benefits to be attractive to land managers."*

In its 2014 White Paper the Australian Government suggests aggregation of small carbon farming projects to make them more cost effective.

South Coast NRM is using the Multi-Criteria Analysis Shell for Spatial Decision Support software (MCAS-S) to provide guidance to carbon farming activities.

7 - Achievements

There have been a number of activities in the region by South Coast NRM, sub-regional groups, DAFWA, grower groups and individual farmers.

- In 2008/09 South Coast NRM funded a climate change analysis project which included:
  - A coastal vulnerability assessment.
  - Sourcing of NRM datasets.
  - Climate change projections from DAFWA (temperature and rainfall).
  - Assessment of vulnerabilities.
  - Regional information sessions.
  - A workshop for risk assessment and adaptation.
  - Consultation with key stakeholders.

The resulting report *(Coffey Environments, Marsden Jacobs Associates, MP Rogers and Associates, Gaia Resources (2009) South Coast NRM Climate Change Whole of Landscape Analysis and Options for the South Coast Region* is available from South Coast NRM. The report suggests options for adaptation to climate change and also identifies that a key issue was a lack of understanding or lack of belief by landholders towards climate change.

- North-Stirlings-Pallinup Natural Resources and the Gillamii Centre developed *Farming in a Variable Climate, 2011* on their website. this showed rainfall data for 10 towns so farmers could track how the season was progressing compared to the wettest 10 per cent of years and the driest 10 per cent of years. Video interviews with farmers discussing how they were adapting to a drier climate were also availble for viewing on the website.

- The *Changing Climates Agribusiness* forum was held in the Southern Agricultural region with 30 agribusiness attending. During the forum, a workshop was conducted to identify priority agribusiness needs for climate change adaptation which mapped out extensive opportunities for joint action and collaboration. (*Blake and Shea 2009).*

- DAFWA developed a report card on the land natural resource. This is a summary of current knowledge of status and trend of the land resource and the data are being collated to the South Coast NRM region.

- Pasture modelling for different climate projections in WA Mediterranean environments was carried out for sites in the Kojonup and Ravensthorpe districts. The model needs to be better adapted to WA pastures.

- DAFWA employee Lucy Anderton conducted a MSc UWA study of farmers adapting to climate variation. The study has approximately 34 farm businesses from the South Coast region.

- A review of the literature on climate change and broadacre agriculture was held *(Kingwell, Anderton et al. 2013).*

- DAFWA employee Mike Hyder conducted a grazing systems analysis project at Mt Barker Research Station. This project examines in detail, sheep production from perennial pastures in different seasons. There has also been extensive work on best practice on managing ewes.

- DAFWA has set up 24 weather stations in the South Coast region which will give a better geographical coverage and improve risk management for farmers. Most of the weather stations report data every 10 minutes, which assists farmers to make tactical decisions such as spraying and irrigation and can also be used as a strategic risk management tool *(DAFWA nd).* Over time the data will provide detailed climate information covering a wide geographical area.

- In March 2006, DAFWA held stakeholder consultations in Katanning, Ravensthorpe and Albany as part of phase 1 of the *Western Australian Greenhouse Strategy.* Community input included experiences and adaptations to past climate change and thoughts about the impacts of climate change in the future. *(See Morgan et al. 2008)*

- In 2008 DAFWA held workshops on climate change and viticulture *(see Ward, 2009).*

- The National Adaptation and Mitigation Initiative has involved main grower groups in the grain belt. A major focus of the project is the conservation of soil moisture via fallowing and effective weed control and the use of varietal mixes or 'shandying' to reduce the frost risk posed by early sowing.

- The Western Australian No-till Farming Association has research into farm level adaptation strategies to a variable and changing climate at Cunderdin, much of which has relevance to the South Coast.

- The DAFWA, CSIRO, Landgate project *Pastures from Space* provides remote sensing of pasture biomass (feed on offer), which when combined with soil and climate data can give estimates of pasture growth rate. So far it has only been adopted by a small number of farmers but has the potential to improve management in dry seasons through rotational grazing.

- Feed on offer (FOO) and groundcover, library of photos. Farmers are able to search on South Coast areas. It is currently mainly for annual pastures and also gives photos of ground cover levels.

- DAFWA provides statistical rainfall forecasts and modelled plant available soil water at the start of the growing season and risk of frost. These forecasts theoretically can assist tactical decision making and pre-season planning. In practice the seasonal forecasts are generally of low value unless there are strong climate drivers in one direction.

- DAFWA projects as part of the Sheep Cooperative Research Centre on methane emission mitigation.

- The DAFWA AcCLIMATise project aims to build climate risk management capacity of the agricultural industry through the development and delivery of an integrated information package, tools and training *(DAFWA 2010).*

- DAFWA web pages relating to carbon farming opportunities - *www.agric.wa.gov.au/climate-land-water/carbon-farming* supported by bulletin (4856) and fact sheets for NRM groups *www.agric.wa.gov.au/climate-change/carbon-farming-project-fact-sheets.*

8 - Current Community Capacity

8.1 - Adaptation Capacity

Capacity to adapt to climate change and variability has economic, social, technological and biophysical components. It can depend on a range of individual farmer and farm business factors *(Brown et al. 2012; Fisher et al. 2014, Anderton , 2014)*. There is also a considerable academic literature on adaptive capacity reviewed in *Rickards (2013)*. Some of the main factors affecting a landholder's ability to adapt farming systems are shown in *Table 2*.

SOCIO ECONOMIC	ATTITUDE to RISK
	Level of education
	Age
	Debt to equity and debt to income ratio and attitude to debt.
	Succession plans
	Off-farm income or assets
	Farmer networks
	Attitude to climate science and information
BIOPHYSICAL	Rainfall zone
	Soil types
	Amount the climate has changed in recent decades
	Size of farm
	Distribution of land holdings

Table 2: Factors affecting adaptive capacity.

Successful farming in the region depends on skilful risk management.

The region's farmers are already skilled in adapting to variable seasons, but there is strong evidence that climate variability is increasing and this will require even greater flexibility and strategies for resilience.

The region's wide range of rainfall also means farmers can learn from other farmers in lower rainfall areas.

Strategies such as multiple holdings in different climate zones, not cropping in dry seasons, minimum inputs in dry seasons and partial cropping to soil type are being used by successful farm businesses. Others include:

- Reducing debt in good seasons and using income equalisation schemes to make businesses more resilient.
- Identifying soil zones and managing them to their constraints.
- An increase in planting of perennial pastures and a concurrent increase in knowledge of agronomy and grazing management of perennial pastures.
- A high level adoption of management practices, such as minimum till and stubble retention, which increase water use efficiency and reduce erosion.
- Increase in controlled traffic farming is decreasing compaction and improving rainfall penetration and also decreases greenhouse emissions from agricultural activities *(from discussions with DAFWA staff)*.

Grower groups provide links to research and development and local farm trials for adaptation to climate change.

Some farmers are using pasture data from satellites to adjust stocking rates and improve decision-making in a variable climate. This has not had high levels of adoption but may become more necessary in the future. Level of debt can drive adaptive capacity. For example, farm businesses with low levels of equity can become locked in to taking a risk with cropping even in poor seasons *(Anderton pers. com.)*. Banks can also limit a farmer's options *(farmer interviewee)*.

In the short term, flexibility or plasticity in farm management seems to be an important aspect of adaptation to climate change. *Rodriguez et al. (2011)* used modelling to demonstrate that until 2030, farmers who could vary crops and inputs and respond quickly to environmental factors would be able to respond to climate shifts more effectively, in terms of profit and risk. Beyond 2030 and with projections of more severe climate change out to 2070, the benefits disappeared.

There is strong evidence, providing there are no climate shocks and the change in climate follows the current projections to 2030, that most South Coast farmers have the capacity to adapt. If there is no mitigation and greenhouse gases continue to rise in the near future, adaptation beyond 2030 will be a much greater challenge.

8.2 - Mitigation Capacity

Mitigation capacity means the region's capacity to reduce greenhouse gas emissions and enhance greenhouse gas sinks, such as implementing energy efficiency measures like using less fuel, reducing emissions from crops or animals or capturing carbon through planting trees. Storing carbon in soil is more contentious.

There is uncertainty as to the potential of soils to store carbon and as discussed above, monitoring of soil carbon would be difficult to implement *(Sanderman et al. 2010; DAFWA 2013)*. *Hoyle et al. (2014)* surveyed 261 sites with a range of soil types (rainfall from 421-747mm), on the Albany sandplain. They found average soil organic carbon stocks for land use–soil type combinations ranged from 33 to 128 t C/ha (0–0.3 m).

Modelling suggested the top soil is largely saturated and the additional storage capacity is limited to sub-soil below 0.1m.

Where topsoil is not saturated, boosting biomass production and reducing erosion are ways to increase soil organic carbon *(DAFWA 2013)*.

The economic benefits of biochar are still not proven and there are no economical supplies *(GRDC 2013)*.

9 - Gaps

9.1 - Climate Information

- Climate projections specific to different parts of the region, particularly information that includes topographical and microclimate effects. Evaluation of climate projections at local scales.
- Building 'climate change literacy' for farmers and agribusiness such as improving the understanding of climate science, its limitations and benefits. Use tools such as the GRDC's *Climate Kelpie*.
- Improvements in seasonal predictions.

9.2 - Farming Systems

- Increasing work with the region's grower groups to incorporate practical adaptations for climate variability.
- R and D specific to regional and sub-regional climate scenarios.
- Information on best management practices for particular soil landscape types in response to climate change in the region.

9.3 - Carbon Farming (biosequestration)

- Improved understanding of the carbon economy and its uncertainties.
- Better information on the opportunities and risks in voluntary and mandatory carbon trading markets.
- Information on impact of land management on soil organic carbon.
- A need for quantification of biosequestration level and biomass production of agroforestry species for biodiversity plantings and those suited to South Coast soils. Growth rates of trees for carbon farming in South Coast soils and rainfall.
- Better information on costs and benefits of integration of trees into south coast agricultural systems.
- Information on biofuels and bioenergy feedstocks.

9.4 - Socio-Economic

- Better understanding of factors limiting adaptive capacity.
- Vulnerability assessments at enterprise and local scale.

9.5 - Water Supply

- Better agricultural water planning.
- Extension of information on better storage and use of on-farm water.
- Information on water efficiencies.

9.6 - Modelling

- More modelling and data on reductions in streamflow in specific catchments, capture and storage.
- More detailed crop modelling based on local soil types and climate scenarios.
- Modifications to pasture/climate models to make modelling more relevant to the region.

9.7 - Monitoring

- Soil monitoring.
- Monitoring of changes in weeds, pests and diseases.
- Monitoring of climate at a wider range of locations.
- Evaluation of interaction between climate change and other NRM risk.

10 - Measures and Indicators

- Land resource condition, such as the DAFWA Report Card on Natural Resources *(DAFWA 2013).*
- Off-site impacts such as P and N export, sediment export, salinisation of waterways.
- Land management skills.
- Climate adaptation skills.
- Knowledge and understanding of climate change in the region.
- Level of mitigation, such as ha of carbon plantings (this is highly dependent on government policy).

11 - Trade-offs

- Increasing water capture and storage will impact on the wider catchment area.
- Increasing streamflow by reducing tree plantations in the high rainfall zone will increase salinity and conversely an increase in forestry will increase biosequestration of carbon but could reduce streamflow in some landscapes.
- Some low yielding land may be used for carbon farming. This may represent an economic trade-off in some years where high grain prices and appropriate rainfall might have led to higher than normal yields.
- Some strategies may have benefits for some NRM problems but be a disadvantage for others. This will require consideration of the relative cost benefit for a particular soil type and farming system. For example, an increase in livestock in farming systems could increase perennial fodder shrubs or pastures, and thereby reduce water tables and salinity in some landscapes, but will also increase greenhouse gas emissions.
- The use of stubble for biomass energy production could have benefits such as additional income for growers and improved disease management through its removal from paddocks. But this must be weighed against the costs of removing stubble such as loss of organic carbon from the system, increased risk of wind erosion, and nutrient depletion *(DAFWA 2010).*
- In forestry there is likely to be a trade-off between productivity and using local species to increase biodiversity.
- In some areas there may be a trade off with land use change from farming to conservation plantings with a benefit for biodiversity but loss of farming community.
- There is a trade-off between risk (such as in new enterprises and farming systems) and return in both NRM and economic benefits.

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13 - Glossary

Adaptive capacity. The ability of a system to adjust to climate change (including changes in variability and extremes) so as to moderate potential damages, to take advantage of opportunities, or to cope with the consequences *(Pittock 2003).*

Climate change. A change in the state of the climate that can be identified by changes in the mean (and/or the variability), and that persists for an extended period, typically decades or longer *(IPCC 2007).*

Incremental change. Maintaining existing activities and building on existing technologies. It is reactive and proactive.

Roaded catchment. A roaded catchment is designed to increase the amount of run-off from the catchment above a storage dam. The "roads" of a roaded catchment are generally parallel ridges of earth with batters (or side slopes) that cause run-off to be directed into troughs or channels. The surface is lined with clay and compacted to make it smooth and impervious to reduce infiltration and increase run-off. *(Lang et al. 2010 p2).*

Transformational change. Major changes in enterprises, land use and human and social capital. It is largely proactive and strategic.

Vulnerability. A combination of exposure, sensitivity and capacity to adapt to the changing climate *(Brundell et al. 2011).*

14 - Appendix 1

Some Adaptation Options

There are a large number of adaptation options in the literature. Some of the general recommendations include:

- Altering varieties and species, soil amendment for better water use efficiency,
- Conserving soil moisture with biomass.
- Altering timing of cropping.
- Better seasonal forecasting.
- Better decision making tools at seeding time.
- Reducing inputs in poor seasons.
- Not cropping some soil types.
- Relating inputs to likely yields.

Nichols et al. (2007) suggested mixtures of pastures provide the best way to adapt to variable climate. Other options are to include strategic shrub reserves and grazing crops to allow for pasture deferment in autumn/winter *(Revell et al. 2012).*

A fallow in the rotation is an adaptation in low rainfall areas. For example, a study with the Birchip cropping group in South Australia examined adaptation options in relation to projected climate change. Some of these adaptations have relevance to the lower rainfall areas of the South Coast region and are already being used by some farmers.

They included the implementation of additional 'fallow' or 'pasture' components in the rotation and the enhancement of current residue retention practices.

The additional 'fallow' or 'pasture' adaptation served to improve median yield production by between 4 to 55 per cent for a modest global warming scenario, depending on region and positioning of the fallow in the rotation *(Crimp et al. 2008).*

In the 300mm rainfall area in Wheatbelt the fallow *"minimises that risk because we're using it for conserving moisture," (Andrew Thomas quoted in Gray et al. 2011).*

Forestry adaptation measures include species that are more tolerant of warmer and drier climatic conditions could be planted as existing stands are harvested, and thinning regimes could be adjusted to reduce competition for water within stands *(ABARES 2011).*

Others have listed a range of adaptation options for WA farmers. For example, from *Gray et al. (2011):*

- Building infrastructure (ie grain and seed grain storage, water storage reserves)
- Undertaking planning (ie agistment alternatives and when to use them)
- Providing excess resources (ie reserve feed and grain) and developing social capital (ie a mutually-supportive network including fellow farmers).
- Diversification of crops.
- Extending the opportunities for both on- and off-farm income.
- Greater use of off-farm labour to increase the speed of operations.

From *Carmody et al. (2010):*

- Opportunity cropping.
- Managing for biodiversity to maintain ecological function and managing for soil health to increase the resistance of farming systems and its capacity to recover from an imposed stress.
- Using decision tools and risk management strategies to manage productivity within and between seasons
- Addressing major subsoil constraints to improve access to moisture and lift water use efficiency of crops and pastures e.g. liming, gypsum, deep-ripping, claying.
- Using low input-opportunistic cropping systems including fallow in the northern low rainfall area to reduce risks.
- Making every hectare count to improve productivity
- Establishing perennial systems (trees or pasture) on marginal country and where required to manage salinity or serious erosion.
- Switching to a combination of lot feeding and controlled grazing to maximise pasture use using variable-rate technology to match inputs to soil type and plant-available water wherever possible.
- Not planning to crop every year in the mallee or substantially reducing cropping area and frequency
- Increasing the proportion of land in cereal each year to lower risk.
- Timing sowing to improve production planning on increased fodder storage for late breaks and drought-proofing
- Increasing use of dual-purpose crops (ie grazing/cereals).

Others *(Overheu pers. com.).*

- Stubble mulching.
- Green manuring.
- Fallowing.
- Soil moisture monitoring.

Adaptation options from *Coffey et al. 2009:*

- Develop alternative crops/strains/livestock for changed conditions.
- Modify systems, ie types of forestry trees grown/pastures/crops.
- Identify most likely new invasive species.
- Identify better ways to store/reduce use of water.
- Take a more integrated approach to primary production areas and conservation areas i.e. recognise ecosystem services.
- Develop best management practices for adoption of selective land use strategies based on land suitability.
- Develop regional monitoring and evaluation programs for erosion and other land use risks.
- Ensure agroforestry for carbon sequestration includes a positive biodiversity and social outcome, using planning mechanisms.
- Improve seasonal forecasting to allow effective planning and implementation of agribusiness.
- Develop resilient farming and diverse systems.
- Improve soil biology to reduce inputs.
- Fund and advise farmers to add/protect/manage biodiversity on their properties.
- Educate farmers so they might recognise the value of vegetation in the farming system.

Adaptation options for Viticulture (*Ward, 2009,* planning and managing water resources and use by:

- Increasing catchment efficiencies, harvesting rainfall for vineyard inter-rows, developing alternative water sources, reducing water loss from dam evaporation/leakage, increasing irrigation efficiency and adopting vineyard practices that conserve soil moisture and increase soil moisture availability.

Monitor bunch zone temperatures and moderate adverse canopy temperatures by:

- Growing more leaves in hot years to shade fruit.
- Leaf removal on SE or E side of canopy to capture the morning sun.
- Shoot positioning on NW or W side of canopy to shade fruit in the hot afternoon.
- Managing water to retain differential leaf cover and avoid heat stress.

15 - Appendix 2

Impact Risk Matrix and Vulnerability Matrix for Grazing on the South Coast

The impact risk matrix is part of risk management and is best carried out as a participatory exercise and at a local level. Climate risks will be different in different parts of the region and for different enterprises. This is an example only, which shows how risks and vulnerability can be related to elements of climate projections *(Brundell et al. 2011)*.

Risks for each element in a sheep grazing system.

Element	Pasture	Groundcover	Stock Water Supply/ Welfare	Soil Health	Economic	NRM
More sequential dry seasons.	Lower amount of feed on offer, reduced stocking rates, reduced dry feed in summer.	Poor growth on some soil types, better growth with less water-logging on some duplex soils.	Reduced water supply.	Increased risk of wind erosion. Soils drier for longer.	Need to spend more on supplementary feeding. Costs of increasing water capture and storage Possible need to de-stock.	Increased erosion Impacts of increased water harvesting on catchment.
More days over 35°C.	Potential for death of some perennial pastures.	Less groundcover.	More evaporation. Heat stress for stock.	Less groundcover.	Cost of water infrastructure, reduced pasture.	Increased opportunities for shade trees.
Increased summer rainfall.	Assists with sub-soil moisture if late in summer.	Groundcover will be important to protect soil from summer rainfall events.	Opportunity to increase water capture with increase in roaded catchments.	Potential for soil erosion, inundation and flooding.	Economic benefit from perennial pastures.	Water erosion in some catchments, Increased opportunities for perennial pastures.
Decreased summer rainfall.	Less dry feed available.	Less groundcover, less opportunity for perennials.	Reduced water supply.	Low soil moisture at start of season.	Increased risk at start of season.	Increased wind erosion on sandy soils, Reduced opportunities for perennial pastures.
Less winter rainfall.	Different responses in different rainfall zones and soil types.	Reduced groundcover.	Reduced water supply.	Less waterlogging duplex soils, risk in low rainfall areas.	Increased labour needed to rotationally graze and monitor stocking rates.	Increase in water harvesting, impacts on catchments.
More variable seasons.	Pasture responses will vary according to type.	Increased risk for perennials.	Risk to water supply.	Impact dependent on soil type.	Higher risk.	Higher risk.

Potential Adaptation responses (assignment of vulnerability will depend on location and soil type).

Element	Pasture Growth	Groundcover	Soil Health/ Plant Available Mosture	Wind/Water Erosion	Socio-Economic
More dry seasons.	Reduce stocking rates, improve water catchment and storage, confinement feeding.	Monitor ground cover, adjust stocking rate.	Maintain ground cover to reduce soil dryness.	Maintain groundcover.	Need to spend more on infrastructure.
More days over 35°C.	Decrease in cattle/sheep, more heat tolerant breeds.	Decrease in grazing pressure to maintain surface cover.	Maintain ground cover to reduce soil dryness.	Maintain groundcover.	As above.
Increased summer rainfall.	Increase perennials in the mixture, manage summer weeds.	Increase in perennial pastures or fodder shrubs.	Increase perennials.	Potential for water erosion in some soils/ landscapes.	Economic benefit from summer fodder.
Decreased summer rainfall.	Reduce stocking rates, improve water catchment and storage,	Decrease in grazing pressure.	May need to reduce perennials in the system.	Maintain groundcover.	More supplementary feeding, less wool/ ha.
Decreased winter rainfall.	Monitor pasture growth and feed on-offer.	Decrease in grazing pressure.	Assess stocking rates, rotational grazing to feed on offer.	Assess groundcover.	As above.
More variable seasons.	Use mix of pasture species.	Monitor groundcover, increase or reduce stocking rates.	As above.	As above.	Maintain flexible system.

water

land

coastal and marine

cultural heritage

biodiversity

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