2011

Adaptation to climate change in desert contexts: comparing two Australian Local Government Areas

Athier Hussin
University of Wollongong

Adaptation to climate change in desert contexts: Comparing two Australian Local Government Areas

A thesis submitted in fulfilment of the requirements for the award of the degree

MSc (Research)

From

The University of Wollongong

By

Athier Hussin

School of Earth & Environmental Sciences

2011

Thesis Certification

CERTIFICATION

I, Athier Hussin, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Science, in the Department of Earth and Environmental Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Athier Hussin

1 July 2011

Table of Contents

List of Figures

List of Tables

Acknowledgements

For their guidance during the preparation of this thesis, I would like to express my gratitude and appreciation to my supervisors, Professor Lesley Head and Professor Gerald Nanson. I also would like to express my gratitude to the Iraqi Ministry of Higher Education and Scientific Research, for offering me the opportunity to study for an MSc degree in Geography in Australia. Finally, I would like to thank my family for their patience.

Abstract

As a result of the seriousness and intensification of the impacts of climate change, the study of adaptation and adaptive capacity has become more necessary. Most such studies have focused in Australia on the urbanised and coastal areas, but have not yet been extended to desert areas. This thesis examines the implications of, and adaptive capacity to, climate change for desert areas. In order to cover the Australian arid and semi-arid areas within this study, this research uses the town of Mildura as an example of a semi-arid area while the town of Broken Hill is used as an example of an arid area.

Although different models have been developed in order to obtain an accurate measure of adaptive capacity, the problems of simplistic measures of adaptive capacity still present a major obstacle for achieving an accurate assessment of adaptive capacity to climate change. Several indicators of adaptive capacity to climate change have been used in a variety of studies. However, this research argues that the selection of the best possible indexes of adaptive capacity in a specific region requires the identification of the climate stimuli and driving forces of social vulnerability within this region. This thesis indicates that the selection of three indicators (the demographic, socioeconomic and government policy indicators) of adaptive capacity is suitable in the two desert towns of Mildura and Broken Hill. Whilst a decline in rainfall and increases in temperature represent climate stimuli, the socioeconomic, demographic and government policy factors represent the driving forces of social vulnerability to climate change in these two towns.

Findings show that both towns have been affected by climate change, especially the impacts of climate change on water resources. The adaptive capacity of the town of Mildura can be considered high compared to that of Broken Hill. Furthermore, this research identifies several problems associated with applying the indicators of adaptive capacity: the difficulties in application of indicators in different contexts; difficulties in identification of appropriate scale; and uncertainty in measurement. In addition, there is uncertainty in predicting future adaptive capacity by using the current indicators. Moreover, the indicators do not discriminate between climate elements (such as temperature, rainfall, evaporation and wind) which have different individual impacts in different regions. Based on these findings, the argument is advanced that ‘measurable indicators’ are not appropriate to achieve an accurate measure of adaptive capacity to climate change. Instead, a more contextual approach is advocated.

Chapter 1

Introduction

1.1 Introduction

It is argued that human activities are the main cause of the increasing concentration of atmospheric greenhouse gases which change radiative balances and lead to the warming of the atmosphere. The global changes in temperature, precipitation and other climate variables are caused by high atmospheric concentrations of greenhouse gases. Since 1900, the average temperature of the earth's surface has risen by 0.6˚ ± 0.2˚C and this is higher than at any time in the past 1000 years (Hughes, 2003, p 423). The level to which ecosystems, food supplies, and sustainable development are at risk depends both on exposure to change in climate and on the capability of the impacted systems to adapt. Managing the risks of climate change requires development and assessment of planned adaptation initiatives (Smit and Pilifosova, 2001, p 881).

Reducing the vulnerability and realizing opportunities related to climate change can be achieved by planning anticipatory adaptation. Application of adaptation policies, programs and measures will give direct benefits, now and in the future. In addition, the costs of adaptation are less than the management or development costs (Smit and Pilifosova, 2001, p 879). Moreover, tracking and monitoring climate change could give a useful shape of adaptation through the early phase of climate change before climate effects begin to move outside the bounds of previous changes (Stokes and Howden, 2008, p 239). Therefore, 'understanding expected adaptations is essential to impact and vulnerability assessment and hence is fundamental to estimating the costs or risks of climate change' (Smit and Pilifosova, 2001, p 881). There are a number of studies about the implications of climate change, and the adaptive capacity to the impacts of climate change, for different contexts around the world and for different regions in Australia. However, it seems clear that the implications of climate change and the adaptive capacity to climate change for desert areas have not been explored in Australia. Accordingly, this research examines the implication of climate change and the adaptive capacity for desert areas in Australia by comparing the impacts of climate change on, and the adaptive capacity between, two towns in desert regions of Australia.

1.2 Aims

1.3 The broad aim for this thesis is to consider the implication of climate change for desert contexts in Australia, and to examine the adaptive capacity of two desert Local Government Areas (LGA), Mildura and Broken Hill.

In order to achieve this aim, the thesis has the following objectives:

1. Review the literature regarding climate change as it applies to the arid and semi-arid areas of Australia.

2. Assess the literature on adaptation and adaptive capacity to consider what indicators are likely to be most relevant to Australian desert town contexts.

3. Apply aims 1 and 2 to two case study areas, Mildura and Broken Hill (LGAs).

4. Critically assess the strengths and weaknesses of adaptive capacity indicators.

1.3 Definitions

1.3.1 Arid lands: these are characterised by low yearly rainfall of less than 250 mm. Evaporation is higher than precipitation and the vegetation is sparse.

1.3.2 Semi arid lands: these are characterised by moderately low yearly precipitation of 25 to 50 centimetres (254 mm to 508 mm). The vegetation is scrubby with short, coarse grasses and the lands are not utterly arid.

1.4 Australian deserts (arid and semi-arid regions)

The Australian arid and semi-arid areas comprise about three-quarters of the area of the continent. These areas are characterized by high variability in annual rainfall and the amount of evaporation is higher than the precipitation. For example, in the southern part of the arid zone annual evapotranspiration exceeds the rainfall by more than 1500 mm. Within these lands, therefore, precipitation is too low or too changeable to maintain cropping. In addition, the arid and semi arid areas are exposed to frequent and severe droughts as a result of climate change (McEwan, et al., 2006, p 2).

1.5 Overview of Desert Occupation in Australia

Only around 3% of Australia's population of 21 million (in 2008) lives in the desert areas of Australia and population densities are very low. The average density of population of those who are living in arid regions is 0.05 persons/km² and 0.23 persons/km² for population who are living within semi arid regions (Davies and Holcombe, 2009, p 3). Around half of the population of arid areas is living in five regional centres that focus on service and mining. The higher proportion of the population in desert areas consists of Aboriginal people (more than 20% of the population in arid and up to 12% in semi-arid regions). The Aboriginal population tends to be increasing; whereas the non-Aboriginal population tends to be decreasing within Australian arid and semi-arid regions (Davies and Holcombe, 2009, p 3).

1.6 Significance

Because the implications of, and adaptive capacity to, climate change for desert areas have not been explored in Australia, this research compares the impacts of climate change and the adaptive capacity of two LGAs in desert regions of Australia. Therefore, the study results will add new knowledge to the discipline. In addition, the Iraqi Government (Ministry of Higher

Education and Scientific Research) has sent me to Australia to study the desert. This project will enable comparisons to be made between Australia and other desert areas such as Iraq.

1.7 Methodology

This research examines the implication of climate change and the adaptive capacity for desert areas in Australia. In order to cover the Australian arid and semi-arid areas within this study, this research uses the LGA of Mildura as an example of a semi arid area while the LGA of Broken Hill is used as example of an arid area. In order to fill the gap in the literature regarding climate trends and projections for Australian arid and semi-arid lands, this research provides descriptions of the climate trends and climate projections for these regions within chapter 2. This is achieved through collecting information from meteorological reports, maps and websites (e.g., bom.gov.au). In addition, this research provides discussion and description of the climate trends and projections in the Mildura and Broken Hill towns and the surrounding regions (within each LGA). This is important for assessment of the climate conditions in the future for those two towns.

Because this research uses demographic, socioeconomic and government policy indicators of adaptive capacity in order to assess and compare adaptive capacity, statistics and data collection are relevant for those indicators. These statistics and data are on population, socioeconomic factors, agriculture and industry through accessing the websites of local governments and the ABS (Australian Bureau of Statistics). Moreover, library research is used to get a better understanding of the study area and to collect the information about the two desert towns - Mildura and Broken Hill. This research studies the impacts of drought as part of climatic changes on the economic sectors, such as agriculture, tourism and industry of the town of Mildura. The long term drought has caused a shortage of water for irrigation, resulting in greater impacts on the agricultural sector of Mildura. In addition, frequent drought has caused a low water supply in Broken Hill over time.

Analysis and assessment of three types of indicators of adaptive capacity to climate change (demographic, socioeconomic and the government policy indicators) are examined for their relevance and application in the context of the two selected towns. This is because there is uncertainty in the methods that have been used to identify and derive the indicators of adaptive capacity to the impacts of climate change. For example, many of the indicators that have been developed have not been designed to be transferable to other contexts, but have been independently designed by researchers purely for the purposes of their own research. An indicator that has been designed for a particular piece of research may therefore be unsuitable to be used in other research, whether or not the context is similar. This represents a challenge in the assessment of adaptive capacity to climate change in a variety of contexts.

1.8 Thesis outline

Chapter 2 reviews the climate trends in Australian arid and semi-arid lands, such as trends in rainfall, temperature and evapotranspiration. In addition, this chapter describes the climate

projections for Australian arid and semi-arid lands, including the rainfall projections, temperature projections and evaporation projections.

Chapter three reviews the indicators of adaptive capacity to climate change in different contexts and the possible adaptation strategies for desert areas with regard to agriculture, irrigation, socioeconomic issues and health.

Chapter four provides a discussion and description of the climate trends in Mildura and climate projections as well as an assessment of the climate conditions for this town in the future. In addition, this chapter provides information (such as the population, socioeconomic, agriculture, tourism and industry) about the Mildura LGA, in order to assess and compare the adaptive capacity with another desert area (that is the Broken Hill LGA) which is located in far western New South Wales.

Chapter five provides discussion and description of the climate trends in Broken Hill and climate projections in order to assess the climate conditions for this town in the future. In addition, this chapter provides information (such as the population, socioeconomic, mining and tourism) about the Broken Hill LGA, in order to assess and compare the adaptive capacity and climate change impacts with another desert area (that is the Mildura LGA).

Chapter six provides discussion and comparisons of the adaptive capacity and the impacts of climate change within the two desert towns Mildura and Broken Hill. In addition, this chapter provides a critical assessment of adaptive capacity indicators.

Chapter seven provides a summary of the research work and recommendations for more accurate indicators of adaptive capacity to climate change.

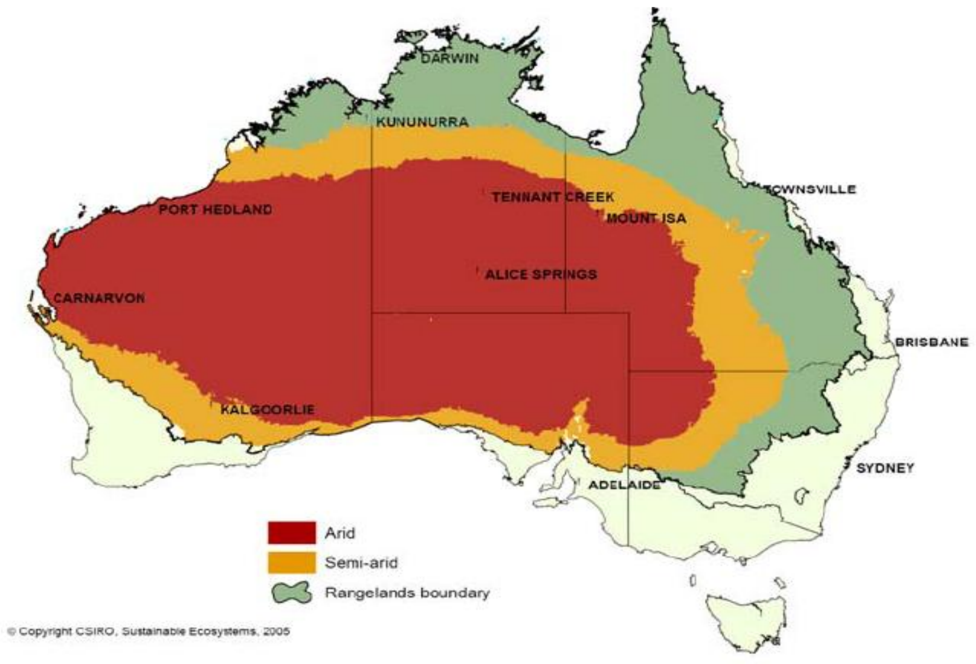
Chapter 2

A Review of Climate Change

For Arid and Semi-Arid Regions of Australia

2.1 Introduction and Chapter Structure

Climate conditions in Australian arid and semi-arid regions (Figure 2.1) have experienced changes over the past century and especially in recent years. There are differences in the characteristics of temperature and rainfall changes between western and eastern Australian arid and semi-arid regions. In order to fill a gap in the literature regarding climate trends and projections for Australian arid and semi-arid lands, this chapter provides descriptions of climate trends and climate projections for these regions. Section 2 of this chapter provides information about climate trends in Australian arid and semi-arid lands (trends in rainfall, temperature and evaporation), whilst information about climate projections for Australian arid and semi-arid regions has been provided in Section 3 (the rainfall, temperature and evaporation projections). A summary of past and probable future climate trends in Australian arid and semi-arid regions has been provided in Section 4. Section 5 of this chapter provides discussion about the impacts of climate change on the phenomenon of desertification in arid and semi-arid areas.



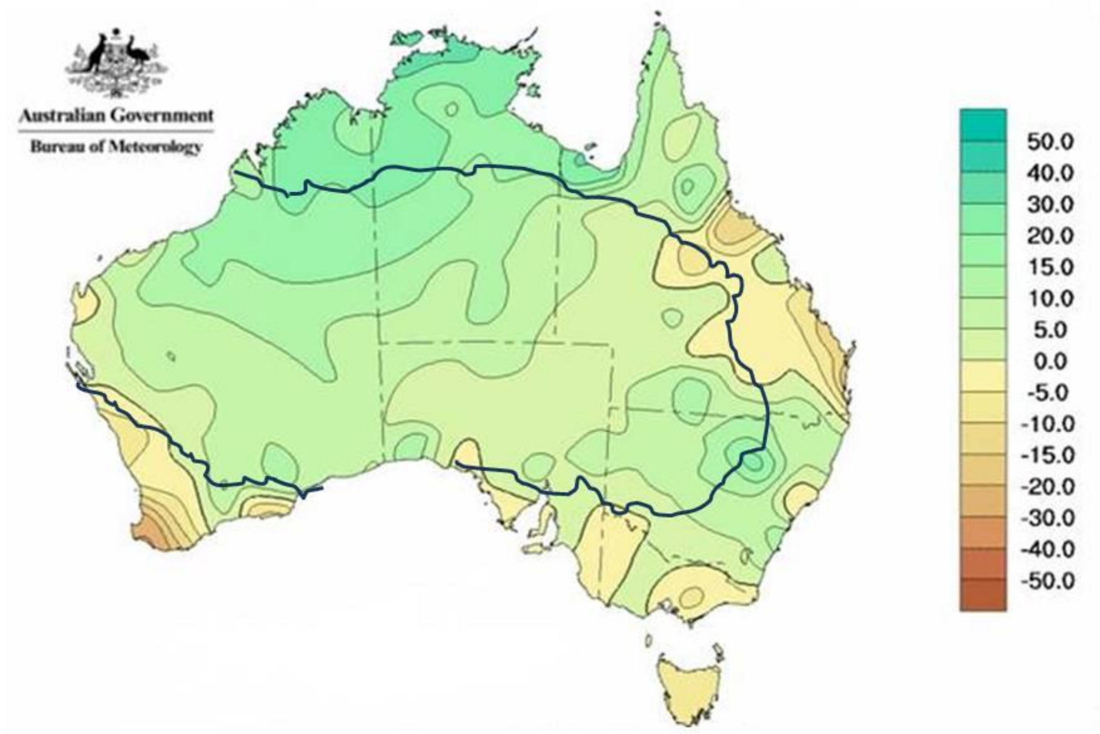
(Figure 2.1) Map of Australian Arid and Semi-arid Lands

(Source: Stokes et al., 2008, p 40)

2.2 Climate Trends in Australian Arid and Semi-arid Lands

2.2.1 Trends in Rainfall

Trends in rainfall have been calculated by CSIRO for the whole of Australia and for each state from 1910 to 1995 by averaging the daily data (24-hour total) from 397 stations. From 1910-1995, annual total rainfall increased by14% in Victoria, and there were increases of 15-18% in New South Wales, the Northern Territory and South Australia (Hennessy et al., 1999, p 1). While there were increases of 10-30% in Western Australia, the amount of annual total rainfall declined in eastern Queensland between 5% and 15% (Figure 2.2). As can be seen in Figure 2.2 most parts of the arid and semi-arid zone had slight increases in rainfall over this period.



(Outer boundary of arid and semi-arid areas)

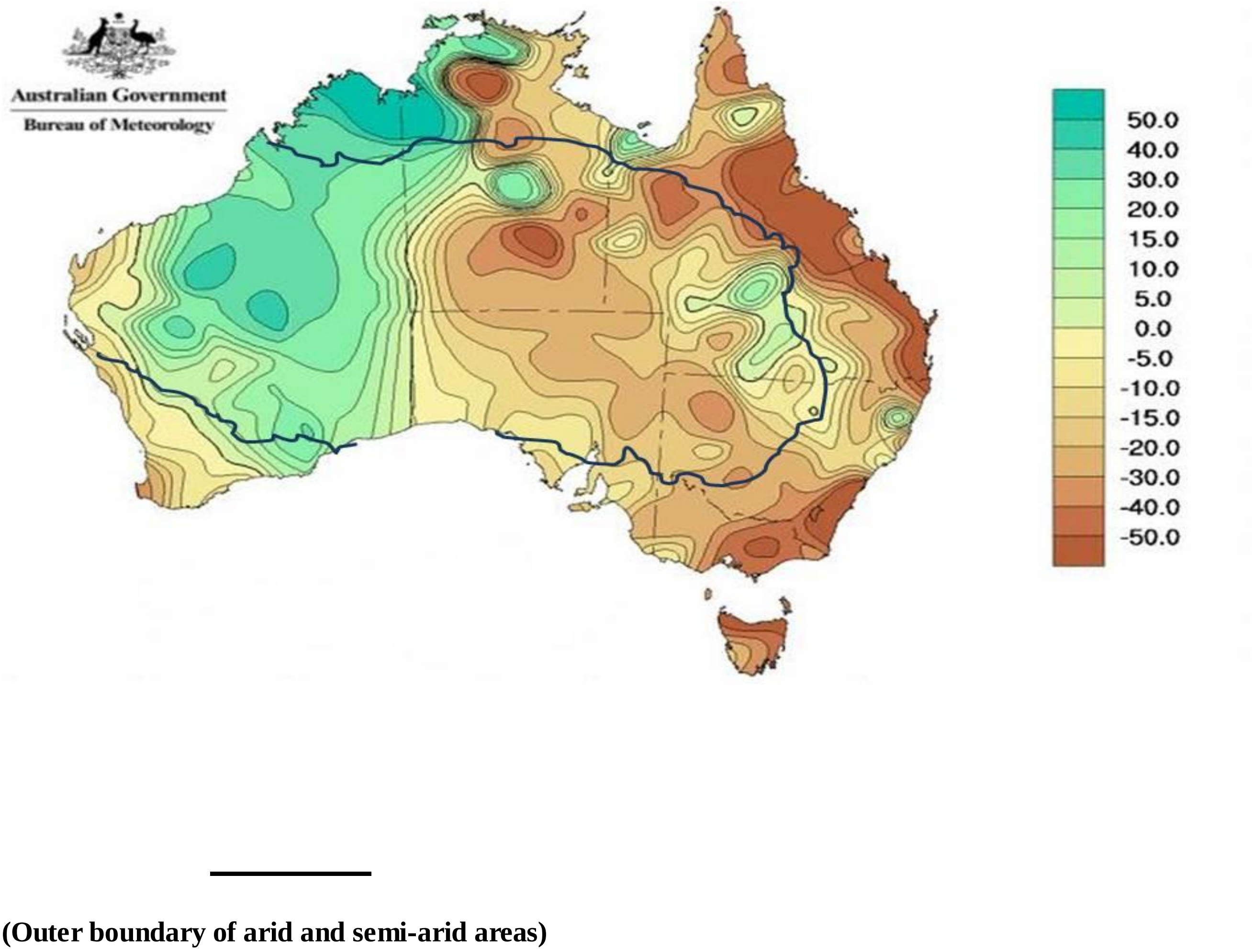
(Figure 2.2) Trends in Annual Total Rainfall in Australia 1910-2010 (mm/10 yrs)

(Source: www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

Between 1970 and 2007 the Bureau of Meteorology recorded that rainfall declined in north-eastern Queensland by 50 mm per decade, whereas in north-western Australia it increased by

50 mm per decade (Figure 2.3). Compared with the wetter decades of the 1950s and 1970s, the severe drought between 2001 and 2006 caused a decline in the amount of rainfall in eastern Australia as well as in some regions of Western Australia (McKeon et al., 2009, p 19). Since 1910, the higher rainfall has been related to increases in heavy rainfall events and the number of rain days. Wet days have increased by around 10% and heavy rainfall events have increased in summer, particularly in the east and north of Australia (Hughes, 2003, p 424). 'Lough (1993) found that periods of increased summer rainfall in Queensland were largely due to increases in heavy rainfall exceeding 50 mm/day' (Hennessy et al., 1999, p 2).

Furthermore, since 1970, rainfall trends have been characterised by increasing rainfall in western Australian arid and semi-arid regions (inland Western Australia and the Northern Territory) and a drop in the magnitude of rainfall in central and eastern Australian arid and semi-arid regions (central and eastern Queensland, much of New South Wales and much of South Australia). The amount of rainfall in the period from 1970 to 2010 increased by 10 mm to 60 mm per decade, whereas in eastern Australian arid and semi-arid lands, rainfall declined by 5 mm to 30 mm per decade (Figure 2.3).



(Outer boundary of arid and semi-arid areas)

(Figure 2.3) Trends in Annual Total Rainfall in Australia 1970-2010 (mm / 10yrs)

(Source: www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

In western Australian arid and semi-arid lands (inland Western Australia and the Northern Territory), the increase in rainfall over the 17 years between 1991 and 2007 occurred in summer and autumn. This included the regions that are located within the winter rainfall zones of the southern rangelands in Western Australia.

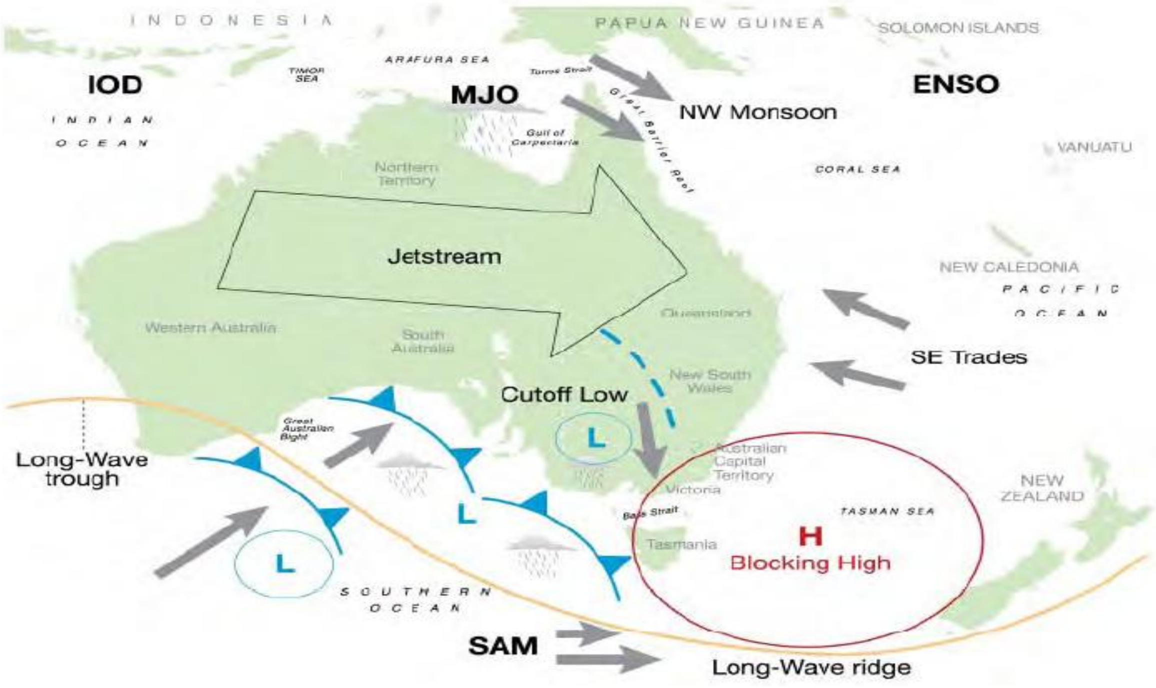
In eastern Australian arid and semi-arid lands (central and eastern Queensland, western New South Wales and north eastern South Australia), the decline in rainfall over the 17 years between 1991 and 2007 occurred in autumn (McKeon et al., 2009, p 19).

According to research by Verdon-Kidd and Kiem (2009) there are four climatic patterns (Figure 2.4) that influence Australia's climate. These are:

1. El Nino/Southern Oscillation ENSO- related ocean-atmosphere inconsistency that manifests as unusual warming (El Nino) and cooling (La Nina) of the tropical Pacific Ocean. El Nino causes warm dry conditions in south-east Australia (Verdon-Kidd and Kiem, 2009, p 3).
2. Inter-decadal Pacific Oscillation (IPO) - an infrequent (every 15-35 years) form of inconsistency of the tropical and extra-tropical Pacific Ocean. The IPO emerges to adjust the force and frequency of ENSO events; accordingly the positive (negative) stage is related to higher frequency of El Nino (La Nina) events and suppressed (improved) effects of La Nina (Verdon-Kidd and Kiem, 2009, p 3).

3. Indian Ocean Dipole (IOD) - a related ocean-atmosphere climate form that happens inter-annually in the tropical divisions of the Indian Ocean. During a positive IOD event, the sea surface temperature decreases in the north-east Indian Ocean (close to the north-west coast of Australia), whereas the sea surface temperature increases in the western equatorial Indian Ocean. Opposite settings exist during a negative IOD occurrence. A positive (negative) IOD event is responsible for the reduction of winter and spring rainfall in south-east Australia (Verdon-Kidd and Kiem, 2009, p 3).

4. Southern Annular Mode (SAM) - the most important form of atmospheric inconsistency over the southern extra tropics. The SAM represents a replacement of mass between the mid latitudes and the polar region which adjusts westerly winds over the southern extra tropics and entrenched frontal weather systems. The positive form of SAM has been related to a decrease in autumn rainfall in south-east Australia through a decrease in frontal systems (Verdon-Kidd and Kiem, 2009, p 4).

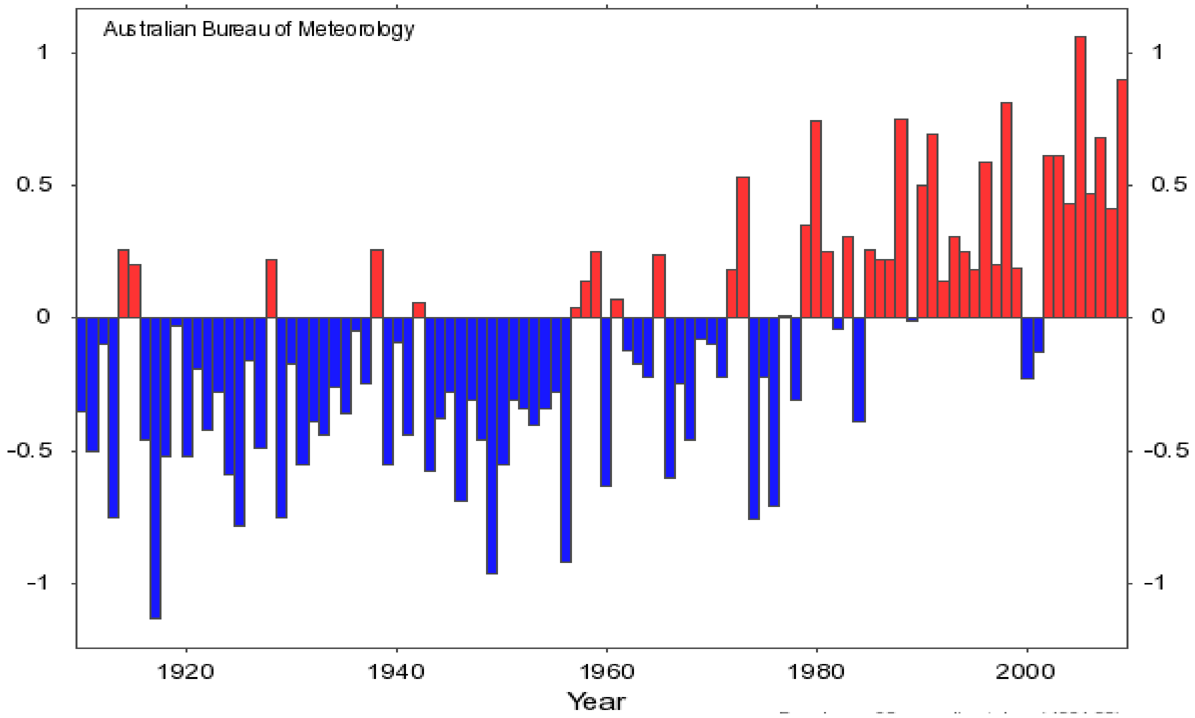


(Figure 2.4) The Main Drivers of Hydroclimatic Variability in Australia

(Source: Kiem et al., 2010, p 8)

2.2.2 Trends in Temperatures

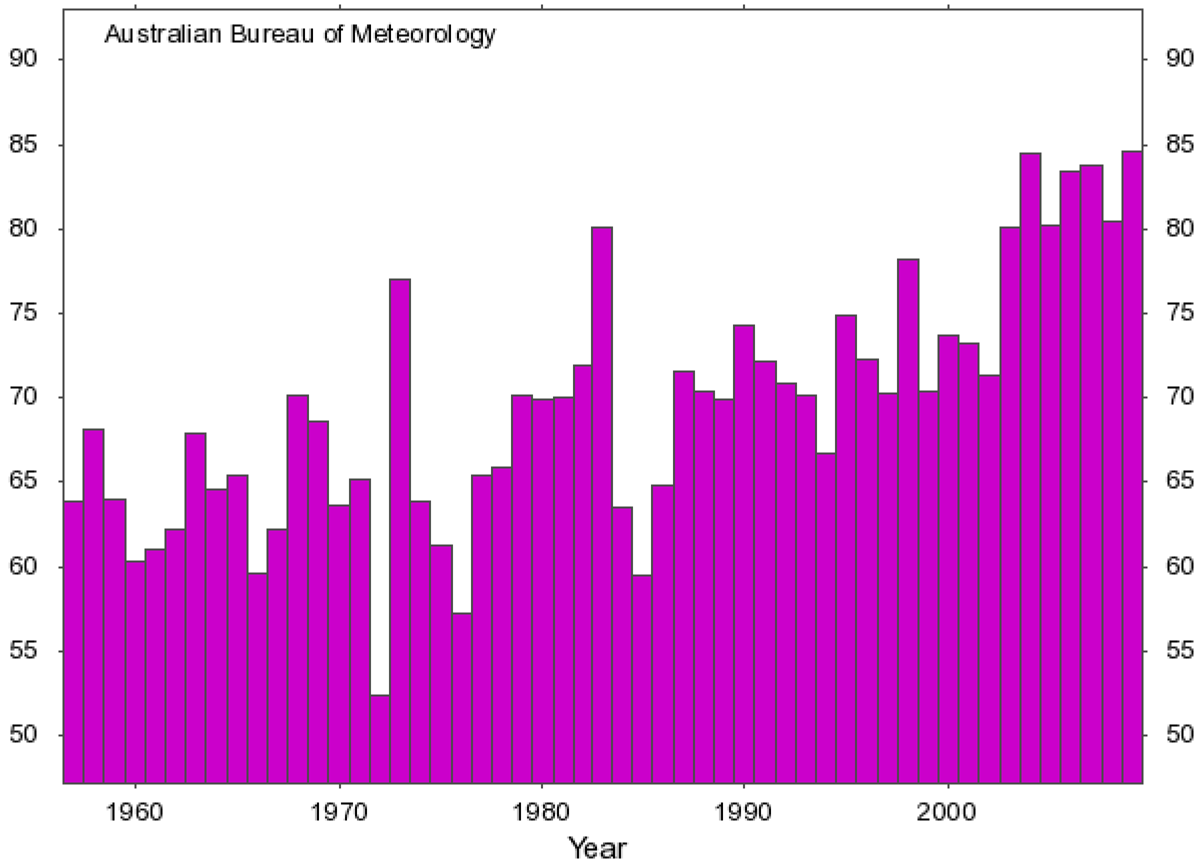
The average temperature for the Australian continent has increased by around 0.8˚C since 1910 (Figure 2.5), with most of this increase occurring after 1950. The warmest year was 1998, while the 1980s and 1990s were the warmest decades, although the 2000s will probably prove (with recent statistics) to be the warmest of all.



(Figure 2.5) Annual Mean Temperature Anomaly in Australia

(Source: www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi)

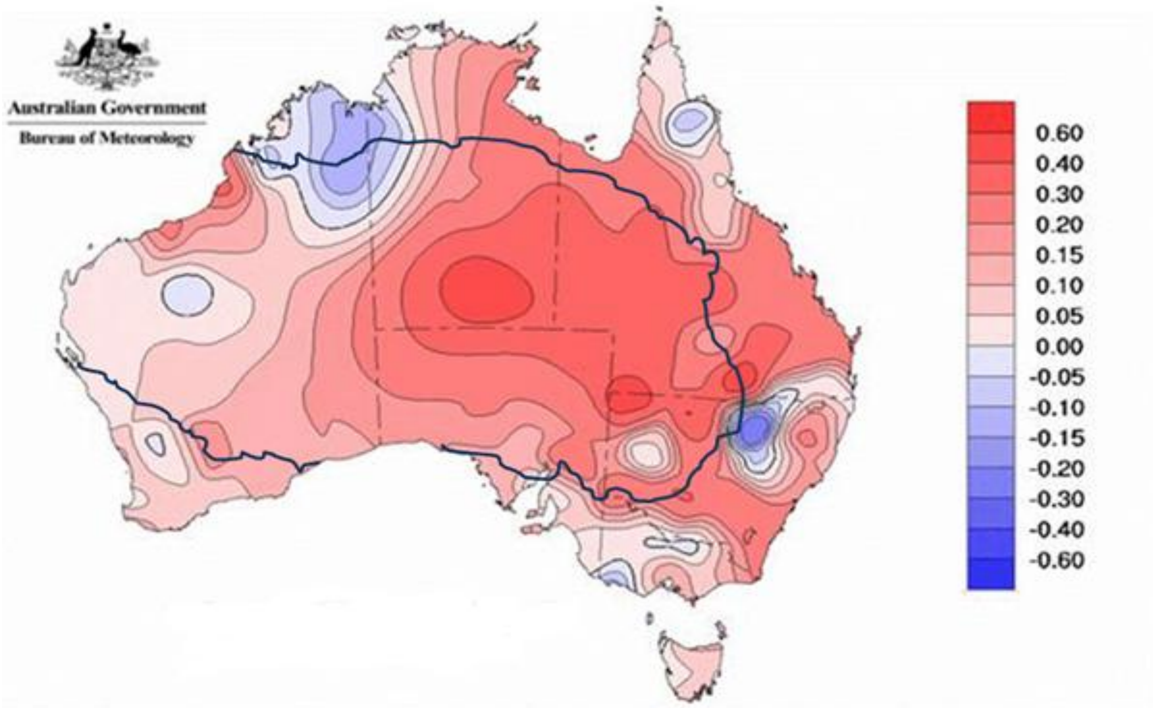
Throughout most of Australia, mean temperatures have increased between 0.1˚C and 0.2˚C per decade since 1951. Queensland and the southern half of Western Australia have experienced the greatest warming. However, southern Queensland and New South Wales have experienced some cooling. The night-time temperatures have increased more than the daytime temperatures (Figure 2.6), particularly in the northern half of the continent and, as a consequence, the diurnal temperature range has decreased (Hughes, 2003, p 424).



(Figure 2.6) Average Number of Hot Nights in Australia

(Source: www.bom.gov.au/cgi-bin/climate/change/extremes/timeseries.cgi)

There have been differences in the characteristics of temperature changes between western and eastern Australian arid and semi-arid locations. Between 1970 and 2007, annual average minimum temperatures in central and north-eastern Australia rose by 0.35˚C to 0.50˚C per decade (Figure 2.7), whereas average maximum temperatures rose slightly less (from 0.25˚C to 0.35˚C per decade) (Figure 2.8). Western Australian arid and semi-arid areas experienced fewer changes in temperatures. North Western Australia experienced an average decrease in annual lowest temperatures of 0.125˚C per decade whereas south-western Australian arid and semi-arid regions saw an increase of 0.125˚C per decade (Figure 2.7).

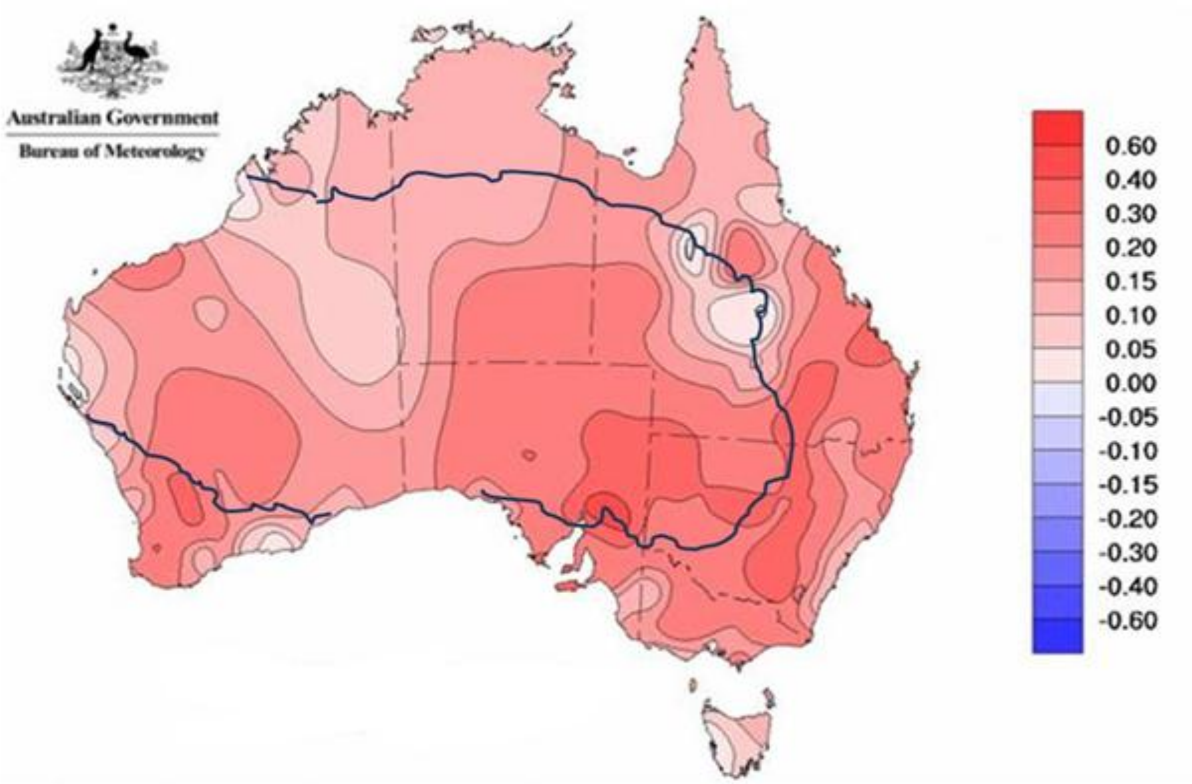


(Outer boundary of arid and semi-arid areas)

(Figure 2.7) Trend in Annual Average Minimum Temperature 1970-2010 (˚C /10yrs)

(Source: www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

Further, the increase in maximum temperatures was 0.075˚C per decade for north-western regions and 0.25˚C per decade in south-western Australian arid and semi-arid lands (Figure 2.8).

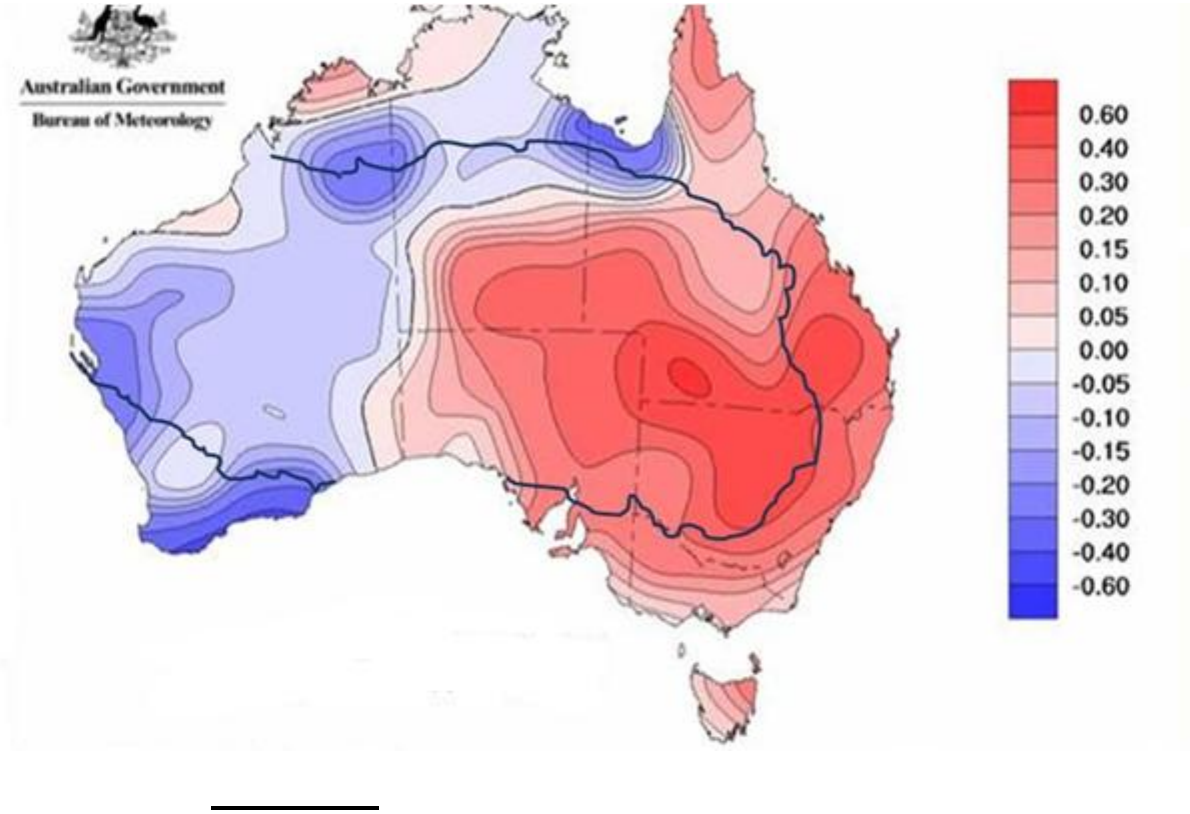


(Outer boundary of arid and semi-arid areas)

(Figure 2.8) Trend in Annual Average Maximum Temperature 1970-2010 (˚C /10yrs)

(Source: www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

Seasonal temperature trends in Australia have shown substantial changes since 1970. The highest temperatures in summer decreased in western arid and semi-arid regions and in the southern Gulf of Carpentaria, and increased in eastern regions (Figure 2.9).

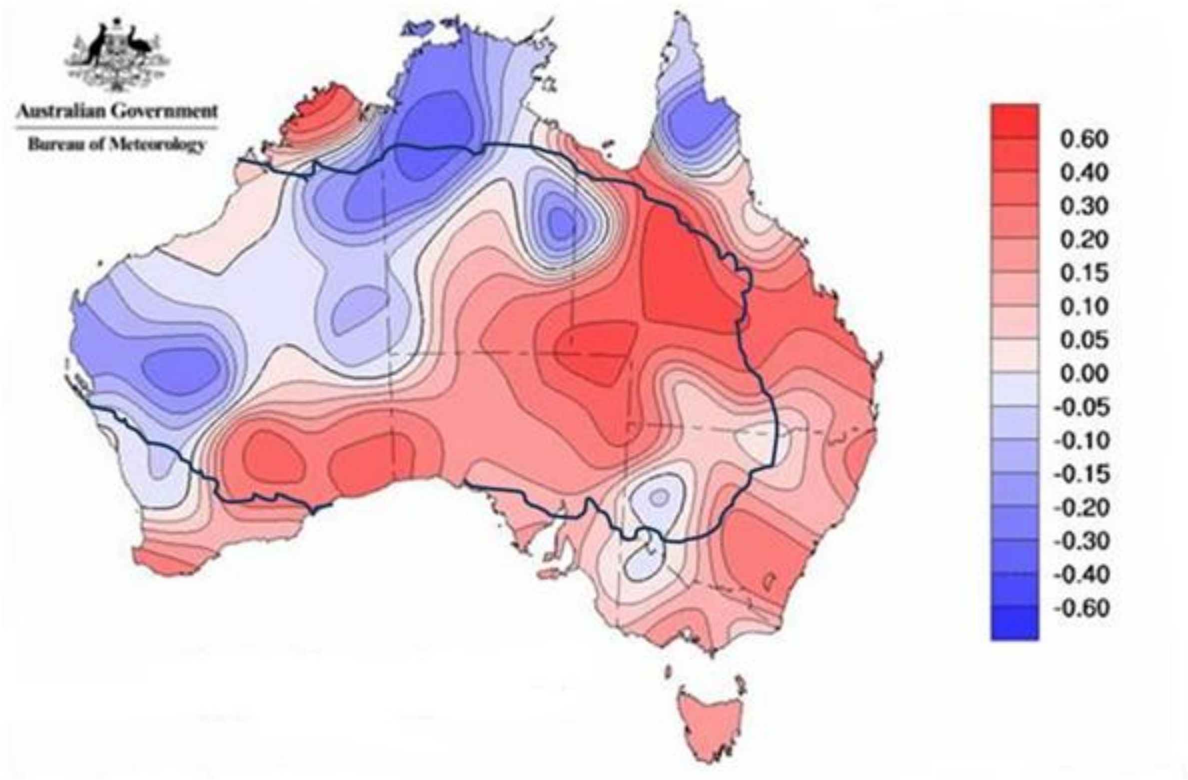


(Outer boundary of arid and semi-arid areas)

(Figure 2.9) Trend in Average Maximum summer Temperature / 1970-2009 (°C/10yrs)

(Source: www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

The lowest temperatures in winter increased (0.10˚C to 0.40˚C per decade) over most of the eastern and southern arid and semi-arid regions but dropped (-0.30˚C to -0.025˚C per decade) in central Western Australia, much of northern Australia and in western New South Wales (Figure 2.10).



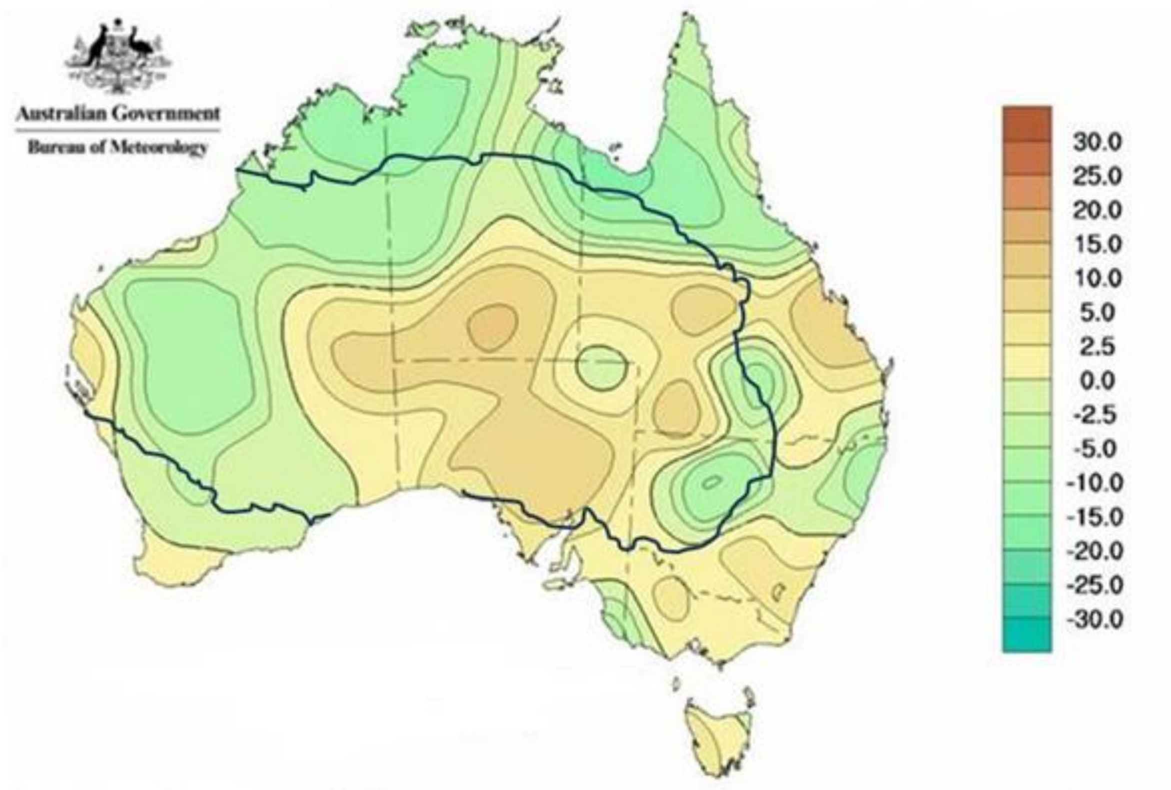
(Outer boundary of arid and semi-arid areas)

(Figure 2.10) Trend in Average Minimum Winter Temperature/ 1970-2009 (^{o}C/10yrs)

(Source: www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi)

2.2.3 Trends in Evapotranspiration

Annual pan evaporation has increased by up to 10 mm per year in central Australia and central Queensland since 1970, whereas the trend in pan evaporation was stable or decreased by as much as 10 mm per year across most of the Western Australian arid and semi-arid regions, western New South Wales and northern Australia (Figure 2.11). It seems clear that in historical climate trends, the desert areas do not all experience the same trends. This is because the arid and semi-arid areas have considerable internal variability in temperature and rainfall.



(Outer boundary of arid and semi-arid areas)

(Figure 2.11) Trend in Annual Pan Evaporation 1970-2009 (mm/yr)

(Source: CSIRO and Australian Bureau of Meteorology, 2007)

2.3 Climate Change Projections and Related Environmental Changes for Australian Arid and Semi-arid Lands

Following on from the above, changes in the temperature, annual rainfall and evaporation have occurred over the whole of Australia's arid and semi-arid lands. In order to assess the climate condition for Australian arid and semi-arid areas, this thesis describes the climate projections for these areas, including rainfall, temperature and evaporation projections. Because of the divergence in the level of possible greenhouse gas emissions in the future, this thesis provides climate projections for low, mid and high emission scenarios.

2.3.1 Rainfall Projections

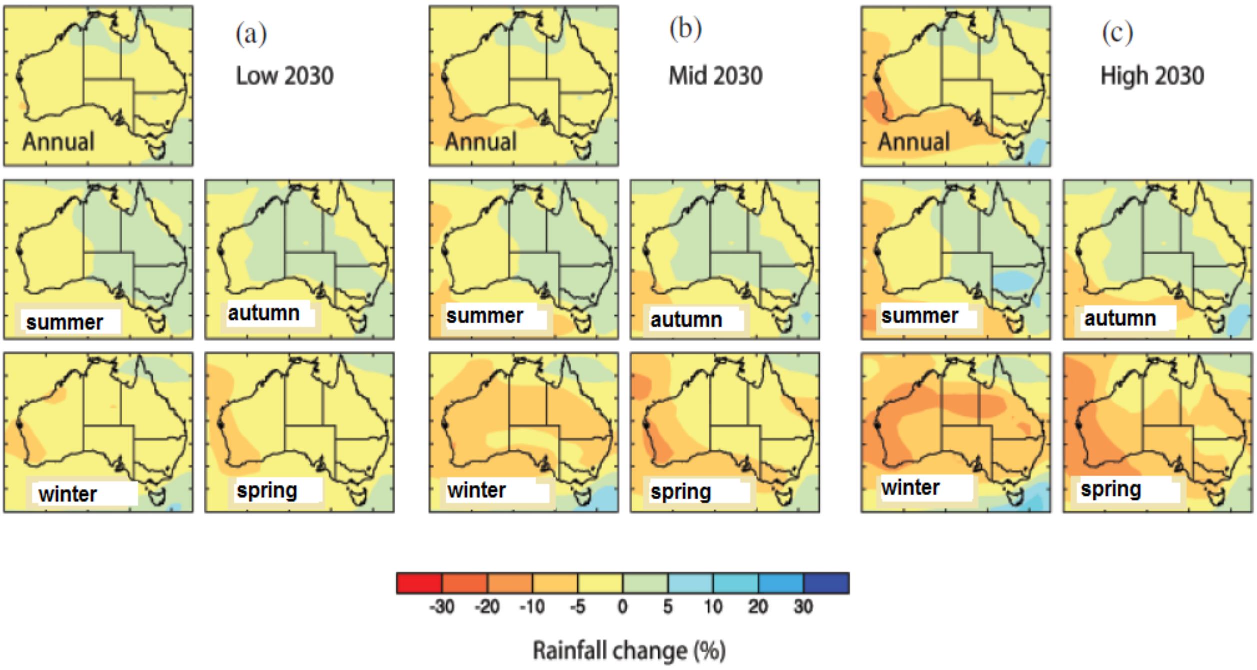
In general terms, Pearson (2008, p 39) predicts that climate change in the interior of Australia will lead to a decline in rainfall, increased frequency of droughts, increased wind speed and an increase in soil loss.

Pearson's (2008) argument that climate change in the interior of Australia will lead to a decline in rainfall needs to be treated with caution. This is because climate change can also cause an increase in the amount of rainfall through an increase in the phenomenon of heavy rainfall. In addition, climate change may cause different climate conditions, such as drought, floods, and storms, within the same region. Therefore, it is difficult to predict specific climate events through climate change. The northern Australian arid and semi-arid lands are the only parts of the country where median rainfall is not expected to decrease as a consequence of climate change, whereas it is projected that eastern arid and semi-arid regions will be drier and there will be a rise in the frequency of droughts (Stokes et al., 2008, p 42).

Interpreting from Figure 2.12, Suppiah et al (2007) indicated that for a low emission scenario in 2030, annual average rainfall is likely to decline by 0% to 5% across most Australian arid and semi-arid lands. However, I argue that an increase in annual average rainfall is also possible in arid and semi-arid regions of Australia. For example, when comparing annual rainfall in Mildura (Figure 4.7) between 1950 and 2010, the annual average rainfall for 2010 was the highest in all those years after the period of drought. This could indicate, therefore, that there is a possibility of annual average rainfall over Australian arid and semi-arid regions increasing in the future. In summer, increases of 0% to 5% are projected over the eastern half of Australian arid and semi-arid lands. In autumn, increases of 0% to 5% would occur through a band from the north west of Australian arid and semi-arid lands to New South Wales. In winter and spring, declines of 5% to 10% are projected over the south-west of Australia and declines of 0% to 5% elsewhere.

For a high emission scenario in 2030, annual average declines of 0% to 5% are projected over most Australian arid and semi-arid lands. In summer and autumn, the averages of variation are very similar to those for a low emission scenario. However, increases in rainfall are higher in New South Wales's arid and semi-arid regions. In winter, most western Australian arid and semi-arid lands and inland parts of the Northern Territory and Queensland would experience declines of 10% to 20%, and in spring, declines of 5% to 10% over most Australian arid and semi-arid lands. The average of the low and high emission scenarios is represented by the mid-emission scenario (Figure 2.12). In addition, based on the report by the CSIRO and the Bureau of Meteorology (2007) for the medium global warming scenario, the best estimate of expected variations in Australian rainfall for 2030 depends on the average change that has been calculated for the period 1961 to 1990, which would be from -7.5% to +2.5% for summer and autumn across the continent; this is smaller than for winter and spring where the expected change is -10% to +1%.

The average rainfall change for the period 1961 to 1990 does not in itself predict what will happen over the next 30 years (CSIRO and BOM, 2007). This is especially the case since the rainfall trend since the 1970s has been characterised by increasing rainfall in western Australian arid and semi-arid regions and a drop in the magnitude of rainfall in central and eastern Australian arid and semi-arid regions. For example, in comparison with other decades during the previous 100 years, the 1950s and 1970s were wetter decades (as has previously been mentioned in this Chapter).

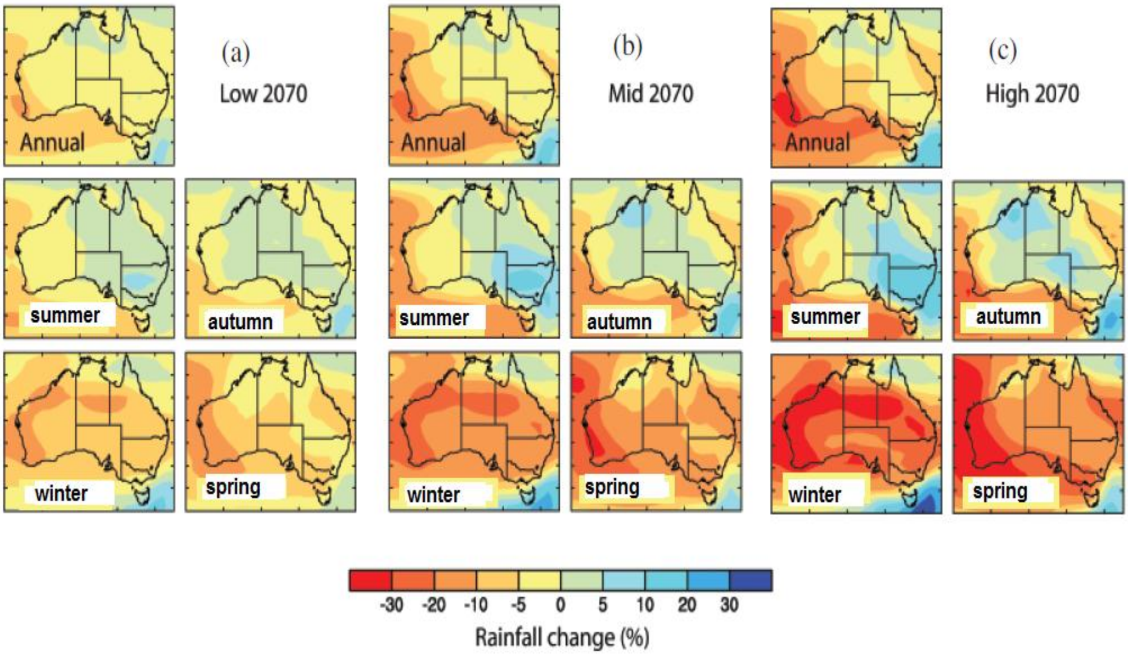


(Figure 2.12) Average Percentage Rainfall Changes for 2030, Relative to 1990, from 15 Models using (a) Low, (b) Mid and (c) High Global Warming Scenarios- CSIRO Via Suppiah et al

(Source: Suppiah et al., 2007, p 141)

For a low emission scenario for 2070, the ranges of rainfall change are very similar to the high emission 2030 scenario. For the high emission 2070 scenario, annual average declines in the amount of rainfall of 0% to 5% would occur in a band from the northern Australian arid and semi-arid lands to New South Wales. The arid and semi-arid lands within northern Victoria, and the southern Northern Territory would experience declines of 5% to 10% (Figure 2.13). In summer, and for the high emission 2070 scenario, the arid and semi-arid lands within New South Wales would experience increases in rainfall of 0% to 5%. In winter, most of Western Australia's arid and semi-arid lands and inland parts of the Northern Territory and Queensland would experience a decline in the amount of rainfall of 30% to 40%, with declines of 20% to 30% elsewhere. In spring, most Australian arid and semi-arid lands would experience decreases of 10% to 20% (Figure 2.13). In addition, the average annual rainfall variations in 2070 for inland Western Australia, the Northern Territory and coastal Queensland are projected to be between -45% and +23%. Moreover, areas within 200 km of the northern coast will experience a change in the amount of annual rainfall of between

-23% and +23% extending to between -45% and +45% over inland Queensland. For northern New South Wales, southern central Queensland and the central Northern Territory, the amount of rainfall will change by -23% to +45% (Suppiah et al., 2007, p 146).



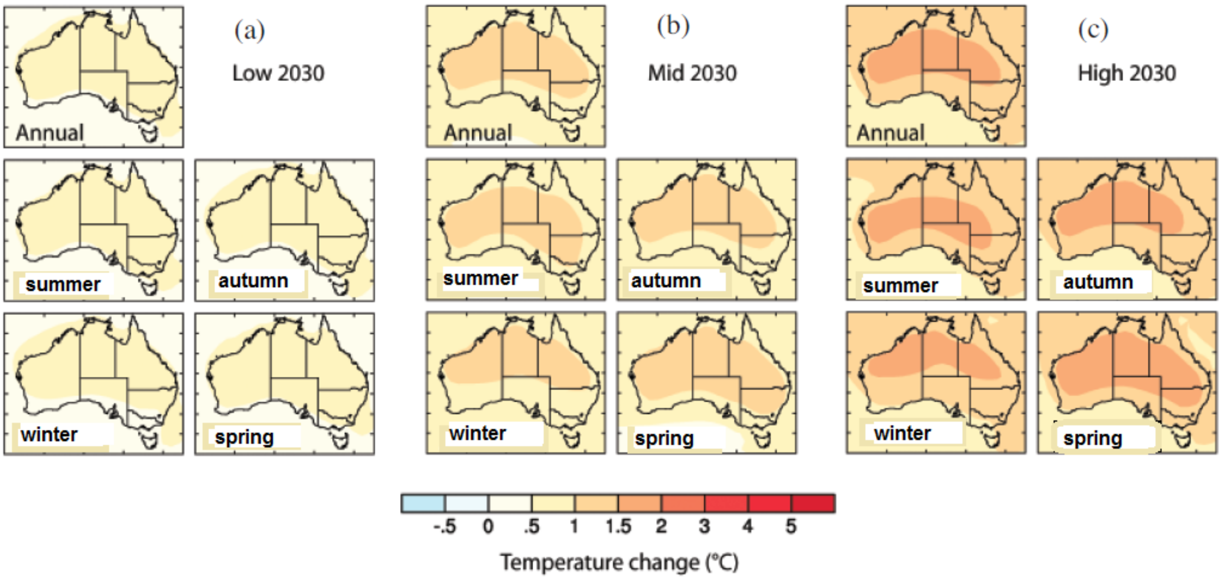
(Figure 2.13) Average Percentage Rainfall Changes for 2070, Relative to 1990, from 15 Models using (a) Low, (b) Mid and (c) High Global Warming Scenarios- CSIRO Via Suppiah et al

(Source: Suppiah et al., 2007, p 141)

2.3.2 Temperature Projections

The best estimate based on 2030 projections of annual warming across Australia is ~ 1.0˚C. The expected degree of warming is dependent on greenhouse gas emissions. In the interior of the continent, higher temperatures are expected, particularly towards the north-west of the continent, and an increase in the frequency of hot days and warm nights will be related to these temperatures. Interpreting from Figure 2.14 provided by Suppiah et al (2007), for the 2030 scenario, the temperature for a low global warming scenario will increase between 0.5˚C and 1.0˚C in inland regions of Australia.

For medium global warming for the 2030 scenario, the temperature increases will be between 1.0˚C and 1.5˚C over inland regions of Australia, whereas for high global warming for the 2030 scenario, the temperature will increase between 1.5˚C and 2.0˚C over central regions of Western Australia, the Northern Territory and Queensland (Suppiah et al., 2007, pp 139-140) (Figure 2.14).

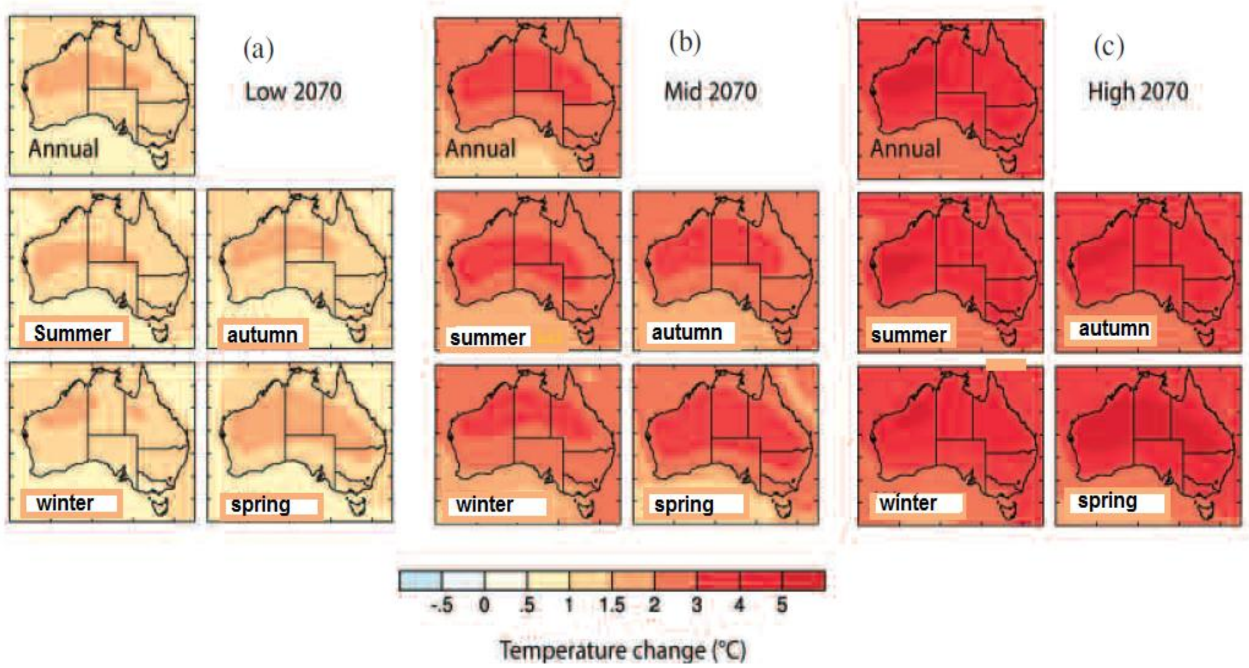


(Figure 2.14) Average Temperature Changes for 2030 Relative to 1990, from 15 Models using (a) Low, (b) Mid and (c) High Global Warming Scenarios- CSIRO Via Suppiah et al

(Source: Suppiah et al., 2007, p 139)

Furthermore, based on research by Suppiah et al (2007) for the 2070 scenario, the temperature for a low global warming scenario will result in a widespread increase of between 1.0˚C and 1.5˚C, with an increasing 1.5˚C to 2.0˚C in parts of the north to latitude 30˚S and more than 200 km inland. Suppiah et al's prediction, that temperature increases will be between 1.0 ˚C and 1.5 ˚C over inland regions of Australia for medium global warming for the 2030 scenario needs to be treated with caution. This is because, in a comparison between the actual trend of temperature increases in Australia since 1910 (0.8 ˚C) and the expectations of temperature increases by Suppiah et al for 2030, the increases in temperature which have occurred during the previous 100 years would be doubled in the next 30 years. In addition, the gap between temperature increases for a low global warming scenario (0.5 and 1.0 ˚C) and high global warming (1.5 and 2.0 ˚C) compared with the actual trend since 1910 (0.8˚C) is very large. Therefore, expectations of temperature increases might be inaccurate.qeX
.

For medium global warming for the 2070 scenario, the temperature will increase between 2.0˚C and 3.0˚C over most parts of Australia, rising to 3.0˚C to 4.0˚C in areas north of latitude 30˚S and more than 200 km inland. As for high global warming for the 2070 scenario, the temperature will increase between 4.0˚C and 5.0˚C across most Australian arid and semi-arid lands and by more than 5.0˚C in the north- west (Suppiah et al., 2007, pp 139-140) (Figure 2.15).



(Figure 2.15) Average Temperature Changes for 2070 Relative to 1990, from 15 Models using (a) Low, (b) Mid and (c) High Global Warming Scenarios- CSIRO Via Suppiah et al

(Source: Suppiah et al., 2007, p 140)

2.3.3 Evapotraspiration Projections

The CSIRO (2001) has reported that potential evapotranspiration for high emissions 2030 scenario will increase in northern and eastern arid and semi-arid parts of Australia by between 8% and 12%. As for the remainder of the continent, potential evapotranspiration will increase by between 4% and 8%.

2.4 Summary of Past and Probable Future Climate Trends in Australian Arid and Semi-arid regions

Over the past century, annual total rainfall in Australia has increased by around 15% in New South Wales, South Australia, Victoria and the Northern Territory. In contrast, south-west Australia has become 25% drier in winter. The wet days have increased by around 10% and heavy rainfall events have increased in summer, particularly in the east and north of Australia. Since 1970, rainfall trends have been characterised by increasing rainfall in Western Australia's arid and semi-arid regions (inland Western Australia and the Northern Territory) and a drop in the magnitude of rainfall in the central and eastern Australian arid and semi-arid regions. In most of Australia, the mean temperatures have increased between by 0.1˚C and 0.2˚C per decade since 1951. During the last century, the warmest year was 1998, while the 1980s and 1990s were the warmest decades. Queensland and the southern half of Western Australia have experienced the greatest warming. Annual pan evaporation has increased by up to 75 mm per decade in central Australia and central Queensland since 1970,

whereas the trend in pan evaporation has been stable or has decreased by as much as 75 mm per decade across most of the Western Australian arid and semi-arid regions. As for probable future climate trends in Australian arid and semi-arid regions, annual average rainfall is likely to decline by 0% to 5% across most of Australia's arid and semi-arid lands. In addition, temperature increases will be between 1.0˚C and 1.5˚C over inland regions of Australia for medium global warming for a 2030 scenario. Potential evapotranspiration for a high emissions scenario will increase in northern and eastern arid and semi-arid parts of Australia by between 8% and 12% by 2070. As for the remainder of the continent, potential evapotranspiration will rise between 4% and 8% based on the CSIRO report.

2.5 Desertification Phenomenon in Arid and Semi-arid Regions

2.5.1 Relationship between Climate Change and Desertification

Although some researchers have tried to attribute all desertification globally to human activity, it seems clear that the combination of human activities and climatic changes are the main causes of the desertification phenomenon. According to the United Nations Convention to Combat Desertification (UNCCD), desertification is 'land degradation in the arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variation and human activities' (Sivakumar, 2007, p 144). In addition, drought as a consequence of climate change represents the driving force of desertification. Climate change, drought and desertification are therefore strongly interlinked. Desertification represents a serious threat to arid and semi-arid lands which cover 40% of the earth's surface. Arid lands consist of about 29.7% from drylands around the world, whereas semi-arid lands consist of 44.3%. The large drylands regions are located in Asia (34.4%), Africa (24.1%), the Americas (24%), Australia (15%) and Europe (2.5%) (Sivakumar, 2007, p 144). It is difficult to assess desertification at a regional or national level. Based on research by Veron et al (2006, p 752), the UNCCD indicated that 'to date, although a great deal of data on land resources are available, it has not been possible to get a clear picture of the status of land degradation at regional and national levels'. However, the first assessment of desertification at the international level was undertaken from 1987 to 1990. This assessment indicated that 20% of the drylands were affected by degradation. More comprehensive research that employed regional data by using field assessment, literature reviews and remote sensing, has indicated that 10% of the drylands around the world are affected by desertification (Seely et al., 2008, p 237). According to UNCCD, up to 250 million people globally are seriously affected by desertification. Because of the relationship between land degradation and rainfall, desertification and climate change remain interlinked. Desertification can be exacerbated by changing the location and characteristics of climate elements, such as rainfall, temperature, winds and solar isolation (Sivakumar, 2007, p 144).

Climate change will lead to increases in the extent of land degradation in semi-arid areas. There is a projection that desert areas around the world will expand by 17% and this is associated with the level of atmospheric CO_2 doubling in the future (Sivakumar, 2007, p 144). In desert regions, greater impacts on natural vegetation which depends on surface roots to get

rainfall moisture can be caused by increasing temperatures. This is because moisture will decrease in desert regions as a result of evaporation increases. Moreover, wind erosion is likely to increase in arid lands around the world in response to climatic changes. Desertification is likely to aggravate the negative impacts of temperature increases on crop yields. In addition, changes in agricultural practices represent a driving force for desertification (Sivakumar, 2007, p 144). Therefore, 'the phenomenon of desertification is a highly dynamic process that includes both biophysical and socioeconomic factors' (Veron et al., 2006, p 754).

2.5.2 Impacts of Climate Change on Desertification in Australia

Arid and semi-arid lands in Australia have experienced rainfall variability greater than that of comparable climates around the world. Greater runoff can cause greater risk of flooding and erosion. However, the enhancement of revegetation and reduced erosion of land surface can occur during wet periods. The pattern of plant growth has altered through changes in rainfall. For example, in central Australia, the herbage cover has changed over the last 120 years. As a result of dry periods which occurred in the late 1890s, 'the late 1920s and the early 1960s and 2 exceptional growth pulses, one during 1920-21 and the other during 1973-75' (Pickup, 1998, p 59). The herbage growth experienced three long periods below the average (Pickup, 1998, p 59). Frequent and smaller rainfall events are responsible for major vegetation cover changes, especially when 50 to 150% of annual average rainfall falls in periods of a few days to several months. 'Periods in which these events are closely spaced in time or lacking create a series of minor growth periods and droughts which are superimposed on the longer term changes' (Pickup, 1998, p 59). In addition, climatic changes in Australia have affected the hydrological regimes that cause the erosion of floodplains. This is because annual variations in the frequency and magnitude of precipitation are very large.

2.6 Conclusion

Year to year changes in temperature, annual rainfall and evaporation have occurred over the whole of Australia's arid and semi-arid lands. Although the average temperature for Australia has increased by around 0.8˚C since 1910, there were differences in the characteristics of temperature changes between western and eastern Australian arid and semi-arid regions. In addition, over the past century, summer rainfall has risen in eastern Australia, whereas winter rainfall has declined in the south west. Changes in heavy rainfall intensity have occurred over different areas of Australia. Moreover, Australian arid and semi-arid lands have been exposed to frequent droughts over time. Therefore, climate change has affected Australian arid and semi-arid areas. This thesis studies the implications of climate change and the adaptive capacity of desert areas in Australia, by comparing the impacts of climate change and the adaptive capacity between two desert cities in desert regions of Australia.

Chapter 3

Adaptation and Adaptive Capacity to Climate Change

3.1 Introduction

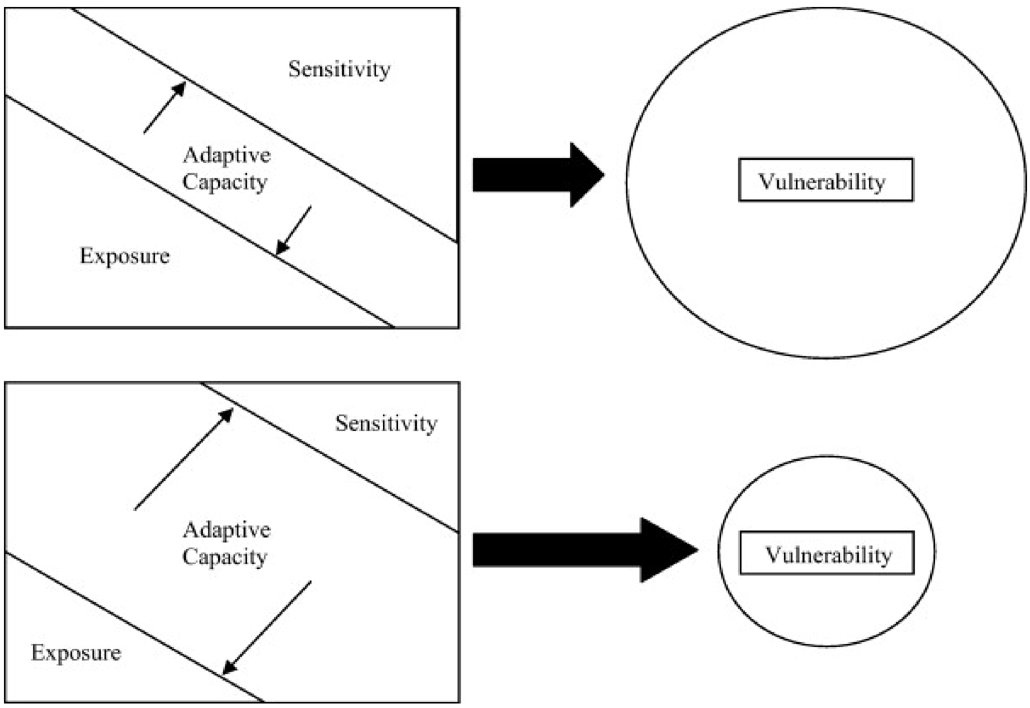
The terms adaptation, adaptive capacity, vulnerability and resilience are strongly interlinked and have broad applications in studies of global change (Yohe and Tol, 2002, p 27). Adaptation to climate change refers to the action, response or adjustment in a system to moderate or decrease the harmful effects of climate change, to avoid risk. Adaptation is represented as the manifestation of adaptive capacity and it refers to changes in the systems that are made in order to cope with outcomes of the interaction between exposure and sensitivity to climate change. There are three functions for adaptation to climate change: decrease the system's sensitivity to climate change; modify the exposure of the system to climate change; and enhance the resilience of the system to deal with the impacts of climate change (Adger et al., 2005, p 79).

The IPCC Third Assessment Report defined adaptive capacity as 'the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences' (IPCC, 2001, p 982). Measuring the adaptive capacity of a system (e.g. household, community, region or country) enables decision-makers to adopt suitable strategies in order to enhance the adaptive capacity or resilience of this system to climate change. Bardsley and Sweeney (2010) indicated that as a result of the significant uncertainties associated with climate change hazard, suitable adaptation actions will require to be framed more broadly than focusing on specific hazards. Actions related to building adaptive capacity may include using climate change knowledge, 'building awareness of potential impacts, maintaining well-being, protecting property or land, maintaining economic growth' (Adger et al., 2005, p 79). This chapter provides a review of the literature on vulnerability and resilience to climate change. In addition, it provides a review of the literature covering indicators of adaptive capacity in different contexts. In order to explain the reasons for the selection of the three indicators (the demographic, socioeconomic and government policy indicators) of adaptive capacity to climate change as research methods within this study, it also presents the importance of these indicators and the feasibility of the application of these indicators to the desert context of Australia. Moreover, it provides a review of the literature on strategies of adaptation in Australian arid and semi-arid lands.

3.2 Vulnerability and Climate Change

Vulnerability to climate change is the inability of social-ecological systems to cope, adapt and recover from the harmful effects of climate change. There are many factors (e.g. social,

economic, ecological and political factors) that affect the relationship between exposure to the impacts of climate change, the sensitivity of social-ecological systems to these impacts and the ability of systems to adapt to hazardous conditions (Smit and Wandel, 2006, p 286) (Figure 3.1). This vulnerability is unlikely to be the same for all climate stimuli (e.g. sea level rise, flood and drought). Therefore, the relationship between the exposure and sensitivity of a system (e.g. a community) to climate change is different from one system to another and depends on the interactions between the attributes of the system and the nature of climate stimuli. In addition, the determinants (drivers) of vulnerability are various and they are dependent on the attributes of systems, geographic location and climate stimuli. However, 'many of the determinants of occupance or sensitivity are similar to those that influence or constrain a system's adaptive capacity' (Smit and Wandel, 2006, p 286). There are several purposes for vulnerability assessments, ranging from the mitigation of global climate change to identifying a suitable way of measuring local adaptation. Raising awareness of climate change and monitoring of adaptation to climate change can be achieved by assessing vulnerability to the impacts of climate change (Hinkel, 2011, p 198). However, identification of adaptation strategies that are practical in communities is the main objective of vulnerability assessment (Smit and Wandel, 2006, p 282). 'All levels of vulnerability are highly dependent upon the capacity of human action to support adaptation in the long term' (Bardsley and Rogers, 2011, p 11). Vulnerability is symbolized by a set of socioeconomic, political and environmental variables that symbolize the sensitivity and exposure of national populations to climate risks (Brooks et al., 2005, p 152). Vincent (2007, p 20) indicated that the elderly, children and the infirm are the most vulnerable to the impacts of climate change.



(Figure 3.1) Adaptive Capacity Affects a System's Vulnerability through Modulating Exposure and Sensitivity (Source: Engle, 2011, p 4)

3.3 Resilience and Climate Change

Resilience to climate change is the ability of social-ecological systems to absorb the harmful effects of climate change. Other researchers have tried to define resilience as the speed of recovery from a stress. Adger (2000, p 349) indicated that there are three dimensions to social resilience: the economic, spatial and social dimensions. Vulnerability can be understood by assessing the interaction between social dynamics that occur within social-ecological systems and determine social resilience. For instance, 'livelihood specialization and diversity have been shown to be important elements in vulnerability to drought in Kenya and Tanzania' (Adger, 2000, p 273). Designing strategies that enable social-ecological systems to cope with the impacts of climate change can be achieved by managing climate resilience (Marshall, 2010, p 37). Tompkins and Adger (2005, p 567) indicated that 'response capacity can exist within institutions, individuals and groups, and it can be influenced by the institutional environment as well as individual choice and behaviour'. Hobson and Niemeyer (2011, p 12) indicated that deliberation can enhance the adaptive capacity of communities to climate change. The variety of social, political, economic, technological and institutional factors can determine the level of adaptive capacity to climate change (Vincent, 2007, p 12). Building adaptive capacity to climate change depends on the communication of climate change information, economic growth and builds awareness on likely impacts of climate change (Simoes et al., 2010, p 804). Garcia-Lopez and Allue (2011, pp 1436-1437) indicated that 'maintaining and restoring the resilience and adaptive capacity of forest ecosystems is therefore an essential 'insurance policy' and safeguard against expected climate change impacts'.

3.4 Indicators of Adaptive Capacity in Different Contexts

Different authors have suggested different indicators in various contexts which can be used to assess adaptive capacity to climate change. These include:

1. Demographic indicators: the number of people (population size) within a society and their distribution (density, urbanization and land per household), and the rate of population growth are indicators for adaptive capacity. Therefore, the greater the number of people in the population, which is not overcrowded, the greater the adaptive capacity (Malone, 2009, p 16). Machlis et al (1990) indicated that demographic factors represent one of the elements of social resilience to hazards. 'The percentage rural population is used as an indicator of dependence on natural resources sensitive to water stress and water availability' (Vincent, 2007, p 19). In addition, the migration of population as part of the demographic aspects can be considered as an indicator of social resilience. Adger (2000, p 355) indicated that migration represents an important indicator of social resilience. Moreover, 'the risk of non-linear increases in migration due to climate change is real and considerable' (Bardsley and Hugo, 2010, p 254).

2. Socioeconomic indicators: greater economic resources enhance adaptive capacity to climate change. Income level, job diversity, home ownership and local business ownership

are indicators for adaptive capacity (Swanson et al., 2007, p 16). ‘A resilient society offers at least moderate diversity in economic activity, so that switches from one livelihood (e.g. farming) to another (e.g. shop-keeping) are possible’ (Malone, 2009, p 16). In addition, wealth generally offers access to markets, technology and equipment that can be utilized to adapt to the impacts of climate change (Brenkert and Malone, 2005, p 65). Moreover, economic growth and income distribution play a vital role in building adaptive capacity for a society. Adger (2000, p 354) indicated that economic growth and the level of income for the population determine the adaptive capacity to climate change for societies. In addition, health and education are indicators of adaptive capacity to climate change - the higher the level of education and health in a society, the higher the level of adaptive capacity (Swanson et al., 2007, p 17).

3. Governance and policy: government policies play a vital role in adaptive capacity to the impacts of climate change. Relief programs (including unemployment income) regulate markets for the good of producers and consumers; job training, insurance and crop supports can be provided by government (including all levels of government and organizational influence) (Malone, 2009, p 17). ‘Haddad (2005) has shown empirically that the ranking of adaptive capacity of nations is significantly altered when governmental aspirations are taken into account’ (Vincent, 2007, p 14).

4. Information and skills: the lack of informed, skilled and trained personnel causes a reduction in adaptive capacity (Swanson et al., 2007, p 15). Increasing the likelihood of timely and appropriate adaptation can be achieved by access to information and improvement of skills.

5. Infrastructure: the provision of infrastructure can help a society to adapt to the impacts of climate change; for example, ‘access of population to basic services to buffer against climate variability and change’ (Brenkert and Malone, 2005, p 66).

6. Natural resources: the quality/quantity of surface water (water availability) and frequency of water shortages have a significant effect on adaptive capacity. Better quality and quantity of water provide greater ability to cope with the impacts of climate change (Swanson et al., 2007, p 17). Moreover, economic resources can affect the adaptive capacity and the vulnerability of societies to hazards. For example, Machlis et al (1990) indicated that there is a relationship between social vulnerability and the productivity of resources, such as forestry and mining resources.

7. Participation: the role of village committees in the decision-making process, membership of organizations and sharing of responsibility are social indicators for adaptive capacity (Elasha et al., 2005, p 13). Therefore, adaptive capacity to climate change will increase with more connectivity between stakeholders who participate in the management process (Swanson et al, 2007, p 16).

8. Culture: cultural factors can affect adaptive capacity to the impacts of climate change. 'A resilient society reflects the social and cultural values that contribute towards social, human and natural capital' (Malone, 2009, p 17).

3.5 Scale and Adaptive Capacity

As can be seen from the above indicators, much discussion of adaptive capacity has been in developing country contexts, or at very broad (national) scales. The suggested indicators are also very general. This thesis takes on the challenge of applying specific indicators at the local (Local Government Area) scale in a developed country. In so doing it provides a critical assessment of the indicators.

Time and geographical scale are important in the assessment of adaptive capacity to climate change (Alberini et al., 2006, p 124). Adger and Vincent (2005, p 399) have indicated that health, governance, political rights, literacy and economic wellbeing represent the indexes of adaptive capacity to climate change at the national level. Posey (2009, p 482) indicated that 'at the municipal level, adaptive capacity may be influenced by characteristics of the governing regime, fiscal capacity and the professionalism of the municipal workforce'. In addition, Adger et al (2005, p78) indicated that the ability to adapt to climate change at the municipalities, cities and markets scales depends on the availability of technologies, projections of climate hazards and regulatory systems. 'The scope and scale of the required adaptation responses will challenge local and regional capacities' (Bardsley, 2010, p 3).

Furthermore, some researchers have tried to discuss the ability of communities to adapt to the impacts of climate change by examining the social and cultural aspects that are associated with adaptation to climate change in a particular area. For example, research by Head et al. (2011) has examined the ability of wheat farming households in New South Wales to adapt to the impacts of climatic changes (drought). Coleman (2011, p 10) indicated that communities in forest regions that have property rights already have a higher adaptive capacity to climate change. Adger et al (2005) indicated that the ability to adapt to climate change at the individual scale depends on 'institutional processes such as regulatory structures, property rights and social norms associated with rules in use' (Adger et al., 2005, p 78).

Vincent (2007, pp 17-19) indicated that economic wellbeing, demographic structure, global interconnectivity, institutional stability and natural resources are indicators of adaptive capacity to climate change at the national level, whereas economic wellbeing, demographic structure, interconnectivity, natural resources and housing quality represent the indicators of adaptive capacity at the household level. At a local scale, 'the questions of whether adaptation and mitigation strategies for addressing climate change be addressed simultaneously have been raised' (Saavedra and Budd, 2009, p 246). Based on research by Eriksen and Kelly (2007), Adger and Kelly used income levels, inequality of income and job diversity as key indicators to assess vulnerability in the Red River delta of Vietnam. 'Strength of belief in climate change and adaptive capacities were found to be crucial factors for explaining

observed differences in adaptation among Swedish forest owners' (Blennow and Persson, 2009, p 100).

As for the context of drought, several studies have focused on using demographic, socioeconomic and government policy indicators in order to assess adaptive capacity to climate change in the context of drought. For example, Engle (2011, p 3) indicated that the assessment of vulnerability to drought depends on examining the stress (the drought assessment), the demographic aspects (which are related to surface water), the socioeconomic aspects, and the political and biophysical factors. In addition, income levels determine the ability of households and communities to adapt to drought. Some researchers have argued that people who have higher levels of income have higher levels of adaptive capacity to the impacts of drought. For example, 'Watts (1993) found substantial differences in the way that households at different income levels cope with drought' (Eriksen and Kelly, 2007, p 508).

Engle and Lemos (2010, p 5) indicated that, at broader scales, policy action and financial resources are important in order to build adaptive capacity to climate change. Williamson et al (2010) indicated that the scale, diversity, and relationships between the private and public sectors can affect the adaptive capacity of economic systems to climate change. Therefore, it is important to identify the scale in the assessment of adaptive capacity to climate change. Posey (2009, p 482) indicated that in order to achieve accurate analyses of adaptive capacity to climate change, the scale at which adaptation happens should be considered. It seems clear that researchers have tried to use several indicators of adaptive capacity to climate change in different scales. However, there is no specific indicator for a particular scale. Therefore, the identification of an appropriate indicator for a particular scale and the differences of scales has remained a challenge for the accurate assessment of adaptive capacity to climate change. As a result, an inaccurate assessment of adaptive capacity to climate change can occur with each single indicator in different scales. However, 'Whilst the exposure and sensitivity elements have a history of research, adaptive capacity has only recently begun to be explored' (Vincent, 2007, p 13).

3.6 Selection of Appropriate Adaptive Capacity Indicators (the Research Methods)

Following on from the above, this research applies demographic, socioeconomic and government policy indicators of adaptive capacity in order to assess and compare the adaptive capacity to climate change of two desert towns in Australia (Mildura and Broken Hill). Although these indicators are usually used in the contexts of developing countries to assess adaptive capacity or resilience to climate change, assessing the adaptive capacity for the Australian desert towns of Mildura and Broken Hill can also be achieved by using these indicators. In general, many studies have tried to examine the resilience of society to dangers and these studies have focused on the demographic and socioeconomic aspects of population. For example, Adger (2000, p 357) indicated that it is necessary to consider economic, demographic and institutional variables in assessing the resilience of society. 'Specifically, political ecology and geography have focused on 'social vulnerability' by emphasizing socio-

economic, demographic, cultural, and political characteristics' (Engle, 2011, p 3). However, I argue that the selection of the best possible indices of adaptive capacity to climate change in order to assess adaptive capacity in a specific region requires the identification of the climate stimuli and driving forces of social vulnerability within this region. Therefore, based on the climate meteorological statistics, the Australian desert towns of Mildura and Broken Hill have experienced a decline in rainfall and increases in temperature over the past decade. These climate stimuli have caused the reduction of water for irrigation and water supply in the towns of Mildura and Broken Hill respectively. Whilst low water allocation for irrigation and temperature increases have affected the agricultural sector which is the most important economic source for the town of Mildura, the shortage of water supply, and temperature increases in the town of Broken Hill will affect the socioeconomic aspects of that population as the cost of water is expected to increase over the coming years.

The consideration of socioeconomic aspects such as employment, income and productivity within the two case studies of Mildura and Broken Hill is therefore effective in determining the level of adaptive capacity to climate change for a number of reasons. First, socioeconomic aspects such as employment opportunities and income are greatly affected by drought and low water allocation in Mildura. Similarly, these aspects represent the capability of the population to cope with the impacts of climate change in Broken Hill, such as low water supply and heat stress.

Second, changes in other aspects of society, such as cultural aspects, health and skills, which in turn affect adaptation to climate change, are associated with changes in the socioeconomic aspects. Third, the provision of equipment and new technologies to deal with the impacts of climate change is dependent on the socioeconomic aspects of societies.

As for the selection of the demographic indicator, demographic aspects have been affected by drought within both desert towns and by other factors, such as the overproduction of wine grapes in the Mildura LGA and a decline in the mining industry in Broken Hill. The Mildura LGA is growing as a result of its vital role as a regional centre and its strong agricultural base. Therefore, when drought has caused a decline in the agricultural sector resulting in the abandonment of agriculture, the demographic aspects have been affected as a result of changing socioeconomic aspects.

For example, when the drought has affected employment and income, smaller farmers in the Mildura LGA have been forced to close their farms and move elsewhere to find alternative jobs as a result of increasing costs of production and less profitable crops (Mildura Rural City Council, 2009, p x). This could cause the demographic aspects of the Mildura LGA to be altered. Similarly, the rural areas of Broken Hill have experienced declining populations as a result of the impacts of drought on the pastoral industry. Demographic aspects can therefore indicate the level of adaptive capacity to climate change. The 'rural communities have at their disposal to resist or adapt to processes of demographic, economic and technological change' (Argent, 2008, p 245).

As for the selection of the government policy indicator, government policy regarding water allocation for irrigation in the town of Mildura and water supply in the town of Broken Hill has played an important role in enhancing adaptive capacity to climate change. This has resulted from the enhancement of water management by the three levels of government (Federal, State and Local governments). It is therefore important to consider the role of government in helping society to adapt to the impacts of climate change, especially when government determines the program of water allocation for irrigation in view of the shortage of water for irrigation in the Murray-Darling Basin as a result of drought. Accordingly, the assessment of government policy provides an insight into the level of adaptive capacity to the impacts of climate change.

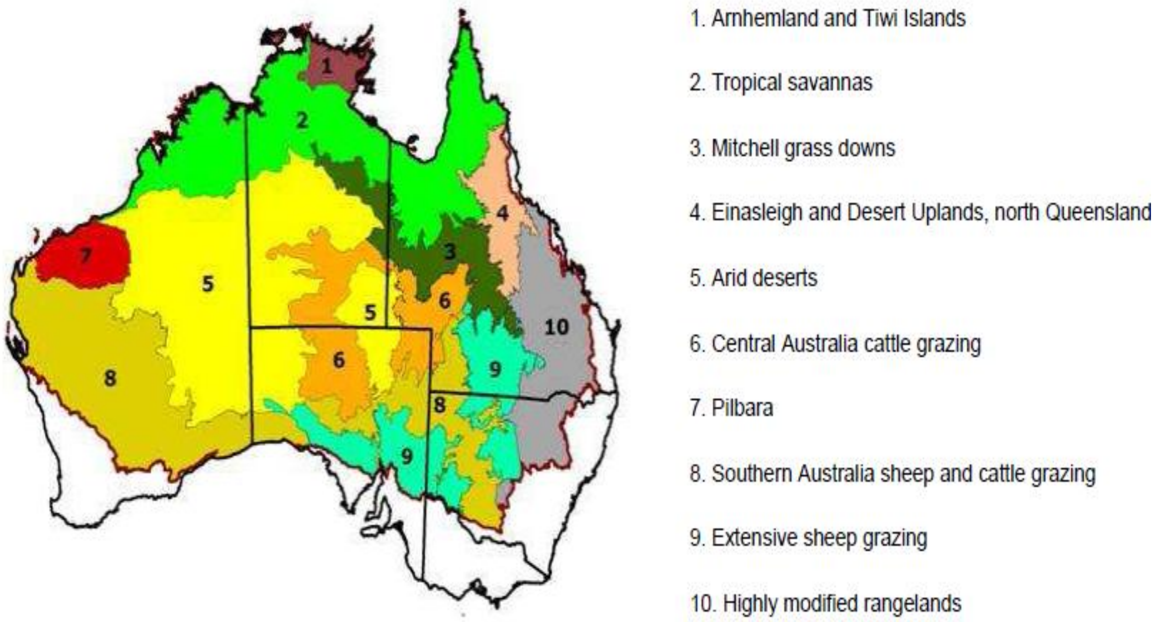
It is, therefore, the selection of three indicators (the demographic, socioeconomic and government policy indicators) of adaptive capacity is suitable in order to assess and compare adaptive capacity to climate change in the two desert towns of Mildura and Broken Hill. This enables comparison with indicators that have been used in developing countries contexts. However, I will also provide a critical assessment of these three indicators in order to advance discussions of adaptive capacity to climate change.

3.7 Adaptation Strategies to Climate Change in Australian Arid and Semi-arid Lands

This section reviews strategies which can be adopted in order to enhance adaptation in the agriculture, irrigation and health sectors. Because climate change has caused low water for irrigation (severe drought) and temperature increases in Australian arid and semi-arid regions, these sectors and socioeconomic aspects have been suggested to be most affected by the impacts of climate change.

3.7.1 Agricultural and Pastoral Adaptation Strategies

Some climate variations might have positive effects, whereas others will be negative. To take advantage of these opportunities and to reduce the negative impacts will require the use of a variety of means (Glover et al., 2008, p 3). Variation in rainfall and temperature is expected to have its greatest effect in the Australian arid and semi-arid regions. The southwest of the arid and semi-arid areas that comprise mixed sheep and cattle grazing (Figure 3.2) are expected to be adversely affected by decreasing rainfall, while the northern and eastern rangelands are expected to be the least adversely affected by decreasing rainfall (Stokes and Howden, 2008, p 237).



(Figure 3.2) Grazing Land Zones

(Source: Stokes and Howden, 2008, p 231)

Helping an agricultural system to adapt to a longer term overlay of climatic change can be achieved by tactical reactive adaptive responses to short-term climatic variability (Stokes and Howden, 2008, pp 238-239). Strategies to adapt to climate change in Australian arid and semi-arid areas should focus on the greatest impact of higher temperatures and decreased rainfall. Adaptations can take advantage of increased carbon dioxide and temperature. Changing from monocultural systems to diversified agricultural production systems can permit farmers to cope better with climate variation from year to year. In addition, stubble retention and decreased tillage may be important alternatives to strategies that increase water supply in arid and semi-arid areas. Using seasonal climate projections could also play an important role in decreasing the risk associated with climate variations.

Howden and Jones (2001) indicated 'that improved production of wheat crops (up to an 8% increase in mean production) is possible if growers respond with suitable adaptation strategies' (Anwar et al., 2007, p 146) such as the development of new wheat that is adapted to higher temperatures and less water availability.

Raising community awareness and understanding of the effects of climate change, and fostering the development of adaptation strategies for the agricultural sector in Australian arid and semi-arid lands can be encouraged by monitoring trends in pasture production and quality, woody vegetation, animal production and pest weed densities.

Other adaptation strategies can be adopted to improve current forage production and may include:

1. Development and sowing of new pasture that is adapted to higher temperatures, higher carbon dioxide concentration and less water availability.
2. Improvement of pasture and crop management decision support systems by using satellite imagery technology and advisory services drawing on expert systems.
3. Improvements in planting rules and planting decisions, such as time of sowing, row spacing and tactical applications of nitrogenous fertilizers.
4. Developing crops characterized by improved drought tolerance, heat shock tolerance and resistance to flower abortion in hot conditions.
5. Adapting to extreme heat through re-design of farm housing, machinery and outdoor clothing (Kingwell, 2006, p 16).

It is also important to adopt effective climate data collection, distribution and analysis systems to connect into ongoing evolution and adaptation. In Australia, 'for the wheat industry alone, relatively simple adaptations to future climate change may be worth between $100 million to $500 million per year at the farm gate' (Stokes and Howden, 2010, p 21).The development of new crop varieties using alternative crops or pastures and changing farm management practices are the main factors which can help farmers adapt to climate change.

Many options to adapt to climate change in Australian arid and semi-arid regions can be created by using modern biotechnology. These include:

1. Using genetic mapping technologies to enhance molecular markers, plant breeding and development of genetically modified variations.

2. Using modern biotechnology to develop new crops and pasture varieties that resist the stress of climate change.
3. Using modern biotechnology to develop plant varieties which can help in the adoption of farm management practices.

4. Using modern biotechnology to decrease greenhouse gas emissions generated by agriculture (Glover et al., 2008, pp vi-vii).

The local growers in Mildura LGA have made changes in crop types (grapevines and vegetables were the new essential plantings) to deal with the impacts of climatic changes (temperature increases and the reduction of water for irrigation). This is an indication of resilience or adaptive capacity to climate change in the agricultural sector of Mildura LGA.

3.7.2 Irrigation Adaptation Strategies

Water resources are increasingly a vital issue for both developed and developing countries due to limited resources and an increasing global population, and climate change offers a powerful additional challenge to water management in many dryland regions. Extreme droughts and rainfall events are challenges for water resources management. Because the current precipitation, runoff and stream flow have decreased in some regions to a level well below the long-term average, Australia currently experiences widespread water resources challenges (Preston and Jones, 2006, p 25). Therefore, climate change will affect water demand for irrigation and other water uses in Australia. For example, 'Inflows to reservoirs in New South Wales have been projected to decrease by up to 15% for just a 1˚C increase in temperature' (Preston and Jones, 2006, p 25). A reduction in the main river flows and higher flow variability within Australian arid and semi-arid regions is expected in the future. Accordingly, irrigators have several options to reduce the impact of decreased and more variable water supplies on their farm business as outlined below:

1. Agricultural producers are likely to adapt to the variability of water supply by developing better delivery systems or enhanced irrigation management practices. Agricultural producers can increase their water use efficiency. Generation of significant reductions in the agricultural costs of climate change can be achieved by developing efficient water use systems. In dry land areas, an increased awareness of the efficiency required in the future has led to efficient watering systems in irrigation and farms and farming techniques that use soil moisture retention. Using irrigation systems such as micro sprinklers and drippers can help to maximize water use efficiency (Milne et al., 2008, p 57).

2. Agricultural producers can obtain more flexibility in adapting to the effects of climate change by water trading in either the temporary or permanent market. For short-term variability in water supply, irrigators can trade yearly allocations of water (temporary water trade). Temporary water trade that 'allows irrigators with high value uses to source water from irrigators with lower value uses can lead to better water management' (Sanders et al., 2010, p 7). As for permanent water trade, this involves the sale or acquisition of water entitlements that yield water every year. This is a more permanent means of adaptation to a decreased or more variable water supply. This trade permits water to transfer to higher value activities. The price of seasonal allocations can expose large variations, while the price of entitlements is approximately constant (Sanders et al., 2010, p 7).

3. A decrease in rainfall and inflows causes reduction in surface water allocation, whereas ground water allocations are usually not related to inflows or surface water. Therefore, irrigators are more likely to use ground water when surface water becomes scarce and the price of water increases. Although ground water is usually more expensive than surface water because of the extra pumping costs, these costs may be acceptable to irrigators as water becomes scarce (Sanders et al., 2010, p 7).

4. Another option that irrigators may use to adapt to reduced and more variable water supply is to change their mix and level of production. By changing their mix of production, irrigators can transfer from water-intensive crops toward crops that require less water during periods of low water supply. Irrigators may also decrease production. This option may be suitable to some in dairy and perennial horticulture irrigation (Sanders et al., 2010, p 7).

5. Farm dams enhance access to water and lead to promotion of adaptive capacity by increasing the productivity of agricultural areas (Nelson et al., 2007, p 27).

4. Develop systematic updating of health risks based on climate change scenarios for the future (McMichael, 2009, p 15).

Although climate change has affected the agricultural sector in Mildura LGA, the irrigated agriculture sector has remained the most important economic source for Mildura. This is because the local farmers have undertaken technological change, and invested in more efficient infrastructure to deal with climate change impacts.

3.7.3 Health Adaptation Strategies

The major effect of climate change in the Australian desert is projected to be toward higher average temperatures, a reduction in effective rainfall and a rising occurrence of extreme climate events. Increasing heat stroke, cramps, heat exhaustion and death are caused by temperature increases (Campbell et al., 2008, p 3). Across the north of Australia, climate change is projected to create warmer summers and milder winters with higher frequency and intensity of heat waves. In southern central arid areas fewer winter respiratory infections and deaths will occur, because of temperature increases. However, most effects of rising temperatures are likely to be negative. Changing temperatures, the length of heat waves and rising night-time temperatures are responsible for physiological heat stress. The heat waves are of highest risk for elderly people and those who have low physical fitness and poor cardiovascular health. The incidence of communicable diseases such as bacterial diarrhea can also increase in hot and dry conditions (Green, 2006, p 6).

More severe droughts and long-term dry conditions in rural communities are responsible for a serious range of adverse health impacts. Therefore, a foundation for dealing with the health impacts of climate change could be provided by the health care and public health systems that already exist. These systems could:

1. Monitor health conditions to address and resolve health problems. For example, tracking of illness and trends associated with climate change.
2. Enhance policies and plans, such as heat wave preparedness plans, that enable communities and individuals to deal with climate change (McMichael, 2009, p 14).

3. Identify new methods and effective solutions to health problems. For example, ‘Research on health effects of climate change, including innovative techniques, such as modeling and research on optimal adaptation strategies’ (McMichael, 2009, p 15).

It is important to develop adaptation plans to the health impacts in Mildura and Broken in order to minimize these impacts on the community.

3.7.4 Socioeconomic Adaptation Strategies

Adaptation practices or processes (e.g. resource management, livelihood enhancement and disaster preparedness) appear through all of the following scales: individual, community, industry, regional, national and international. Adaptive capacity to climate change can be improved by enhancing the socioeconomic aspects, which are considered to be the driving forces of social vulnerability to the impacts of climate change.

Reduction of the impact on farm viability of climate change variability and long-term climate change can be achieved by using strategies that diversify the business or farming operation. Diversification within the farm operation involves changes to the types of production. Another strategy to deal with the socioeconomic impact of climate change in arid and semi-arid land is the diversification of off-farm strategies, such as taking on a part-time job or participating in a different business or market. Off-farm strategies are usually in evidence when family members participate in a job outside the farm. There is the view that off-farm diversification is a method to deal with long-term climate risk. For example, ‘when water was scarce and production was affected, the other less agriculturally dependent business supported the family’ (Milne et al., 2008, p 58).

Social capital can be promoted through systems that support community development and communication facilities, such as the Australian Landcare movement. Adaptive capacity can be created by providing input to the immediate policy development costs and benefits of different mitigation, policy adjustments and any trade-off implications in balancing adaptation and mitigation. ‘It means creating interdisciplinary forms of science that inform policy-relevant outcomes, and embedding these in science-policy engagement processes that support decision making’ (Nelson et al., 2010, pp 24-25).

The editors Stokes and Howden (2010) indicated that there are some options that individuals can apply to improve their adaptive capacity. They include:

1. Improving adaptation options and existing strategies can be occurred by increasing educational opportunities.

2. Searching for alternative and additional opportunities to create income and increasing the range of transferrable skills.

3. Increasing profitability over the longer term can be achieved by enhancing strategic business skills.

4. Planning for more financial flexibility.

5. Accessing climate information which helps to increase awareness about adaptation to climate change.
6. Tracking and implementing adaptation options in reaction to changes in local climate, environment and the economy.
7. Enhancing adaptation to climate change can be achieved by learning networks within the community

Mildura LGA has already adapted to the socioeconomic impacts of drought. The growth of the retail trade and manufacturing sectors in the Mildura LGA is resulting in more resilience to the impacts of climate change. For example, the share of employment in the retail trade increased from 16.1% to 16.8% and compensated the jobs that were lost as a result of drought from the sectors of agriculture, forestry and fishing (Mildura Rural City Council, 2009, p 65).

3.8 Conclusion

There have been numerous studies which have attempted to analyse the relationship between the level of climate change impacts (vulnerability) and the level of adaptive capacity (resilience) that need to be addressed. Some researchers have tried to develop new methods or indicators to enhance the assessment of adaptive capacity, whilst others have tried to analyse the relationship between exposure and sensitivity to the impacts of climate change. There is much discussion and debate, therefore, about the concept of adaptive capacity or resilience to the impacts of climate change and how different models can be developed in order to obtain an accurate assessment of adaptive capacity. However, the concept of resilience or adaptive capacity to climate change is not dissimilar to the concept of resilience to other stress changes (e.g. social, economic, drought, desertification and bushfire). Because the dangers of climate change for different groups of society are extensive, societies around the world need more active resilience to climate change in order to minimize their vulnerability to its consequences. It seems clear that the implications of climate change and the adaptive capacity to climate change for desert areas have not been studied in Australia. My research considers three widely applied indicators of adaptive capacity (demographic, socioeconomic and government policy indicators) to these desert contexts. In addition, this research provides

critical assessment of the three indicators of adaptive capacity to climate change. Therefore, the outcomes of this research will add new knowledge to the discipline.

Chapter 4

The Town of Mildura and Its Adaptive Capacity to Climate Change

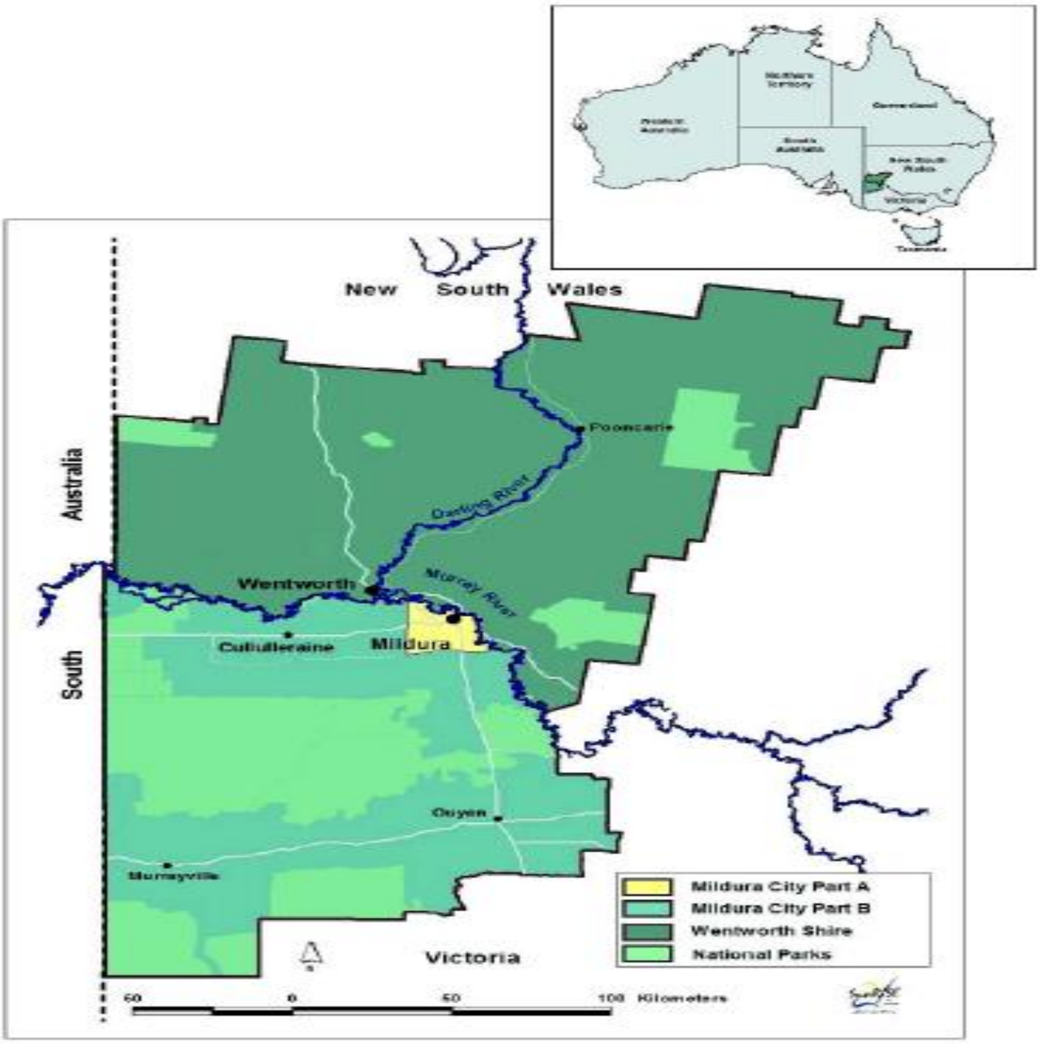
4.1 Introduction and Chapter Structure

The general aim for this chapter is to discuss the implications of and recent adaptation to climate change in the town of Mildura, while the specific aim is to assess the adaptive capacity of the town by applying demographic, socioeconomic and government policy indicators. The influence of the recent drought provides an analogy for possible adaptation scenarios under enhanced climate change. After an introduction to the study area in section 2, section 3 provides information about Mildura's climate (recent climate and climate projections). Because most of the impacts of climate change have occurred within the irrigation sector, Section 4 focuses on the impacts of climate change on this sector. Section 5 provides information about the population of Mildura (historical change and population projections) in order to apply the demographic indicators of adaptive capacity to climate change. Section 6 provides information about economic aspects (employment and income, agriculture, manufacturing, retail trade and tourism). Section 7 provides information about the recent adaptation to climate change in the town. In order to assess government policy indicators of adaptive capacity to climate change for Mildura, Section 8 in this chapter provides information about the government policy. Finally, Section 9 provides a discussion about the likely implications of, and adaptive capacity to, climate change in the Mildura LGA. As discussed in chapter 1.6 (methodology), this chapter draws on a range of sources, mostly reports from different parts of government. For example, the Victorian Government's Mallee Catchment Management Authority commissioned the community organisation SunRISE 21 to undertake its Irrigation Status Report for the Pumped Irrigation Districts (SunRISE 21 Incorporated 2010). This provides an important source for the discussion of changing areas under irrigation.

4.2 Mildura Location

The Mildura LGA (study area) is located in Victoria's north-west on the Murray River. It is 400 kms north east of Adelaide and 550 kms northwest of Melbourne. It is recognized as one of the fastest growing towns in Australia. The Mildura LGA covers around 22,214 square kilometres and this includes two statistical local areas; part A of Mildura consists of the town and a small part of the agricultural region that is generally irrigated, whereas Mildura part B includes the hinterland of irrigated and dryland agriculture which is located to the south of Mildura part A. The Mildura region includes Mildura LGA and Wentworth Shire in New South Wales (Mildura Development Corporation, 2006, p 5) (Figure 4.1). It is considered the

largest centre within the Mallee region, which comprises around 39,000 square kilometres of semi-arid areas. 'The Mallee region is bordered in the north by the River Murray, and includes the Mallee basin and sections of Wimmera, Avoca and Millicent coastal basin in the south and east' (The Victorian Government Department of Sustainability and Environment, 2008, p 1).



(Figure 4.1) The Mildura Region

(Source: Mildura Development Corporation, 2006, p 6)

The Murray River and the South Australian border are the northern and western borders of the council area of Mildura which covers 10% of the area of Victoria. The landscape varies from Mallee vegetation to grain fields, concentrated horticulture and a range of urban centres, towns and villages including Mildura, Redcliffs, Merbein, and Irymple near the Murray River, and Ouyen and Murrayville further inland (Stubbs et al., 2010, p 20). Grain fields comprise around 98% of private land and the 2% remaining is private land for intensive irrigated horticulture. European settlement has been established in Mildura since the 1840s when grazing by pastoralists became the main economic activity along the Murray River

because of the availability of grasslands and water. Agricultural settlement came 40 years later.

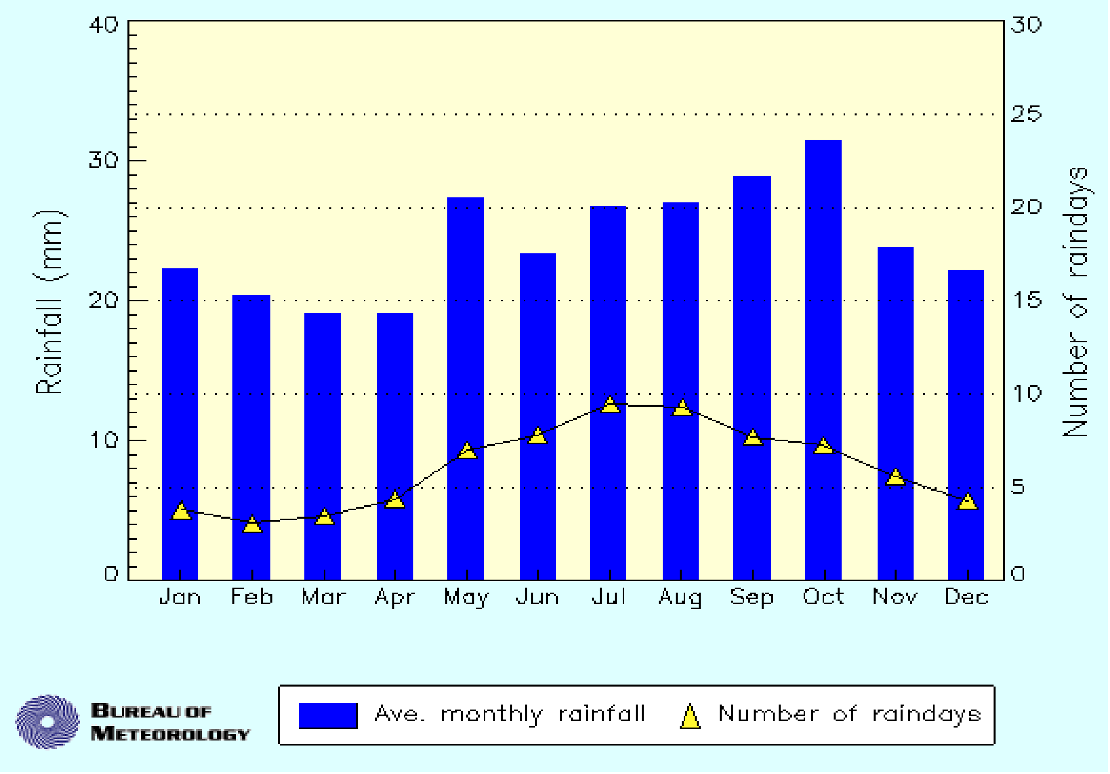
In the 1880s, it was established 'when Canadian brothers, George and William Chaffey, were invited by then Victorian Minister for water supply, Alfred Deakin, to establish a Victorian irrigation colony' (Mildura Development Corporation, 2006, p 5). The strategic location at the junction of Victoria, New South Wales and South Australia has enabled Mildura to become a regional service centre. As a result, Mildura has experienced increases in its population and size over time.

4.3 Mildura Climate

4.3.1 Recent Climate

The Mildura LGA is located within the Mallee which is considered the driest and hottest region in Victoria (Mildura Planning Taskforce, 2009, p 21). The climate is recognized as warm and dry. The average annual rainfall of 292 mm can be seven times less than the potential annual evaporation within the Mallee which is a semi-arid area (Mildura Development Corporation, 2006, p 113). 'Low rainfall combined with high evaporation and highly permeable soil means that the dryland area of the Mallee is primarily a wind-formed landscape' (Mildura Development Corporation, 2006, p 113).

The wettest month is October and Mildura receives around 31 mm on average, whereas March and April are classified as the driest months and receive only 19 mm on average (Figure 4.2).

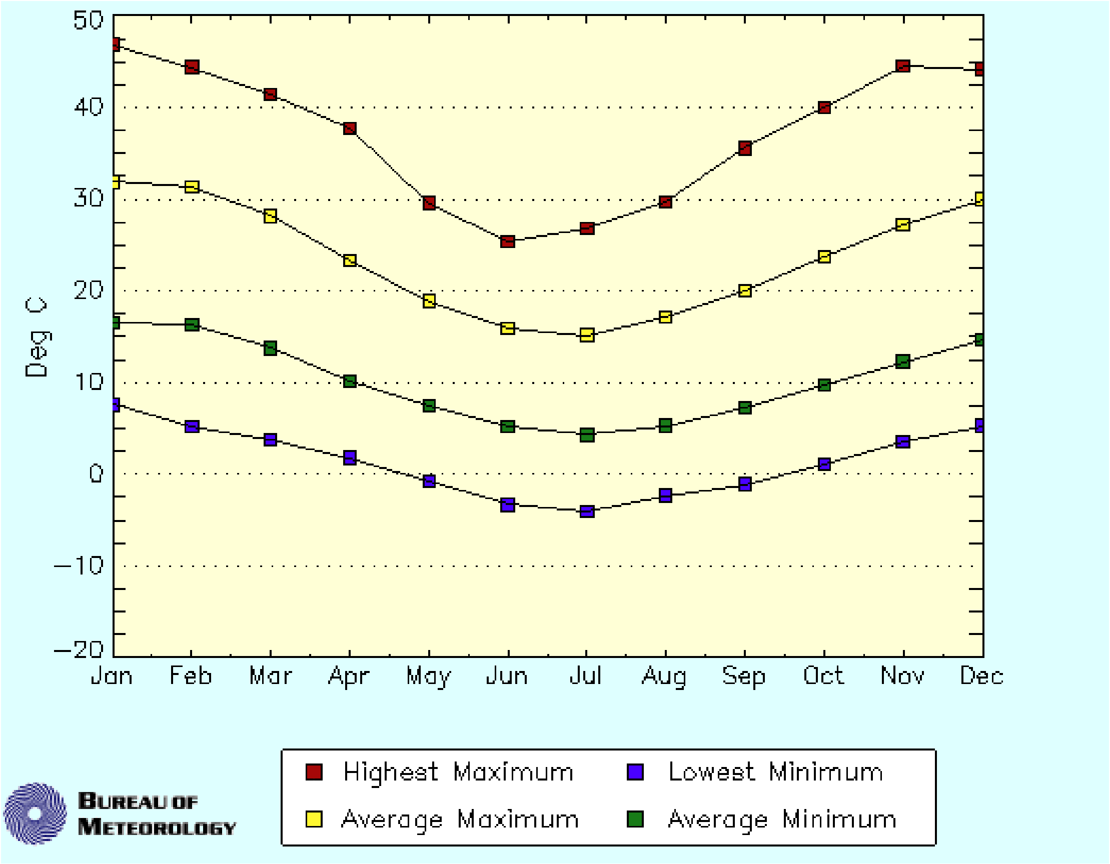


(Figure 4.2) Average Monthly Rainfall (mm) for Mildura LGA

(Source: reg.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/map_script_new.cgi?76031)

The average maximum temperatures are experienced in January and February (Figure 4.3). The average temperature in winter is about 16˚C but the average minimum in winter is 4˚C. The yearly average highest temperature is 23.6˚C. The monthly average daily temperature varies from 15.2˚C in July to 31.9˚C in January (Figure 4.3).

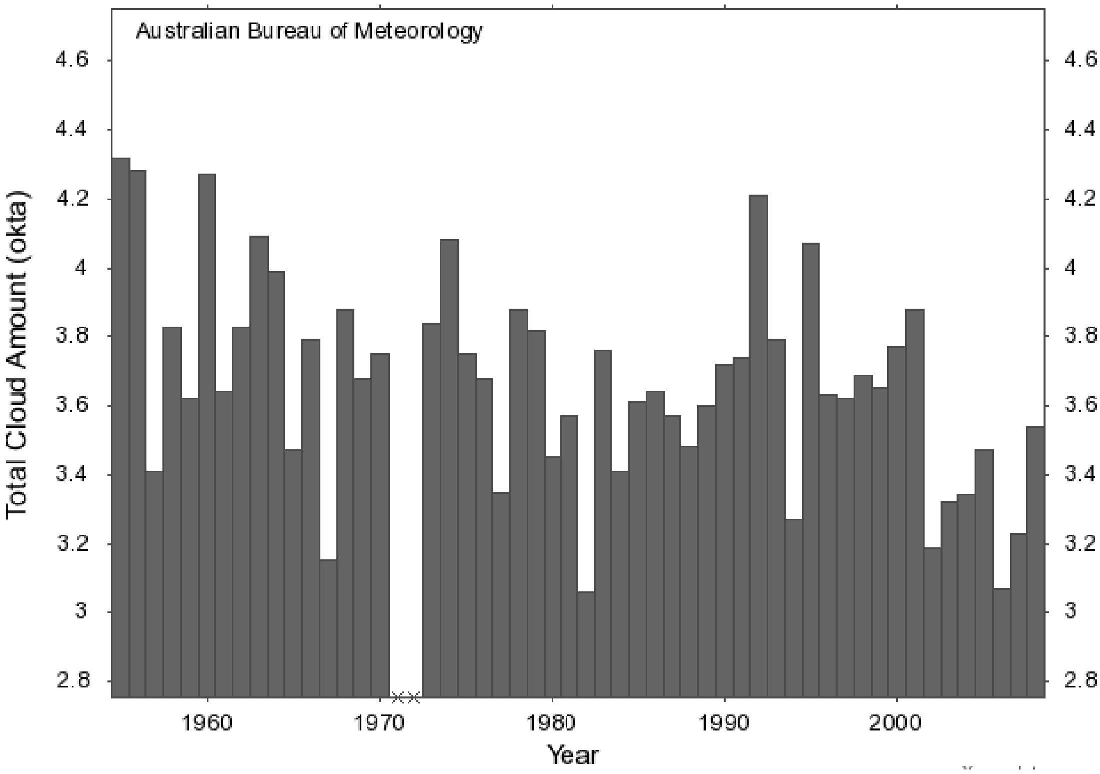
The temperature is higher than 30˚C on an average 77 days per annum including 30 days when the temperature is higher than 35˚C (Mildura Development Corporation, 2006, p 123). The yearly average daily lowest temperature is 10.3˚C, ranging from 4˚C in July to 16.5˚C in January. 'There are an average 4 nights per annum when the temperature falls below zero' (Mildura Development Corporation, 2006, p 123).



(Figure 4.3) Average Monthly Temperature for Mildura LGA

(Source: reg.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/map_script_new.cgi?76031)

On average, 122 days per annum are clear whereas there are 63 cloudy days per annum. The most cloudy months are May, June and July with an average of 7 cloudy days each (Mildura Development Corporation, 2006, p 123). The amount of annual total cloud has decreased during this decade and has decreased since 1955 (Figure 4.4).

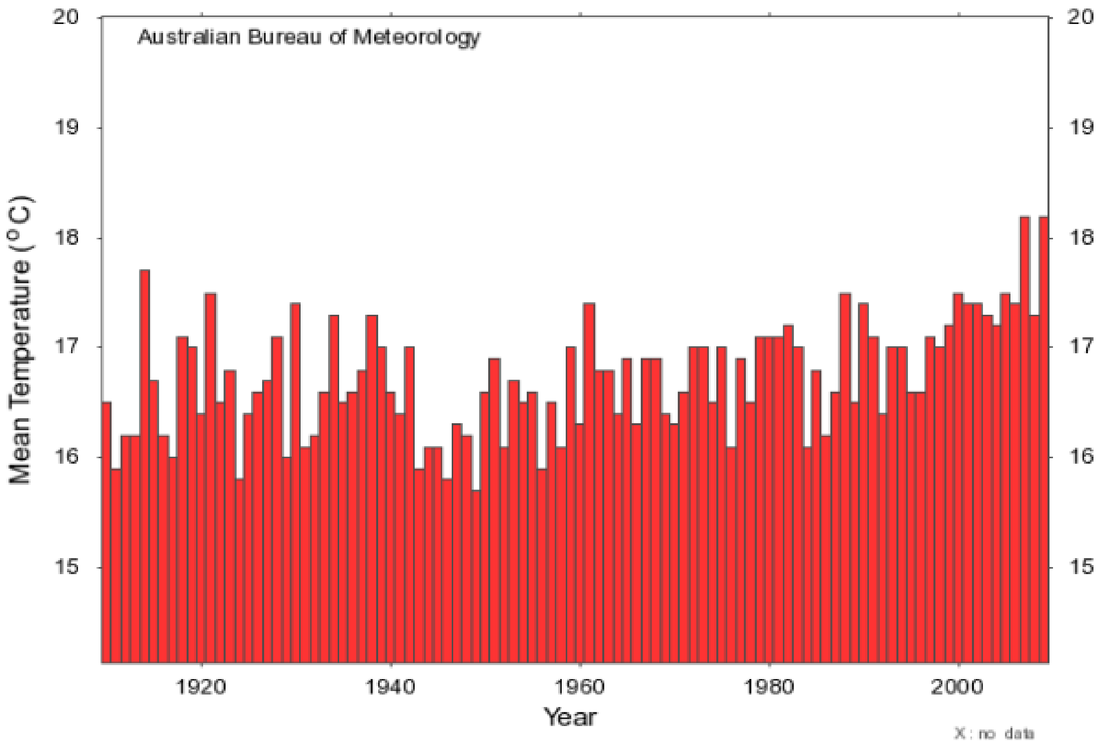


(Figure 4.4) Annual Total Cloud Amount (okta) for Mildura LGA

(Source: www.bom.gov.au/climate/data/)

Thunderstorms happen regularly in the spring and summer; winter thunderstorms happen occasionally. The wind in summer takes almost a southerly direction, whereas in winter it takes almost a northerly direction. During dry years the generation of occasional dust storms, particularly in spring and summer, can be caused by strong winds associated with cold fronts (Mildura Development Corporation, 2006, p 123).

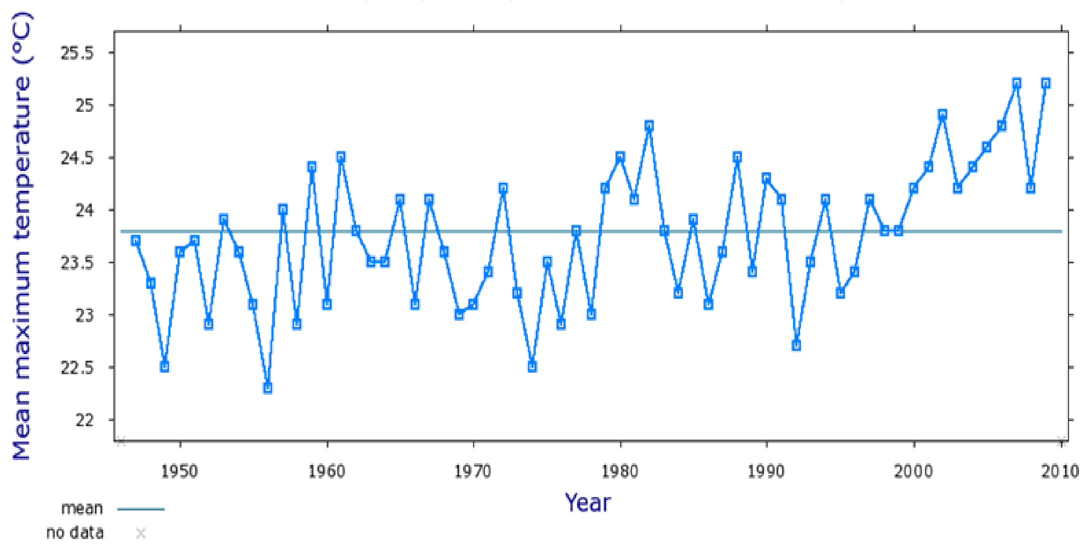
During the last decade (1998-2007), the average annual temperature in the Mallee region (where Mildura LGA is located) rose 0.4˚C compared with the 30 year (1961 to 1990) average (Figures 4.5 and 4.6).



(Figure 4.5) Annual Mean Temperature (˚C) for Mildura LGA

(Source: www.bom.gov.au/climate/data/)

Also, average maximum temperatures have risen since 1998 (Figure 4.6), whereas the average daily minimum temperature has not changed (The Victorian Government Department of Sustainability and Environment, 2008, p 3).



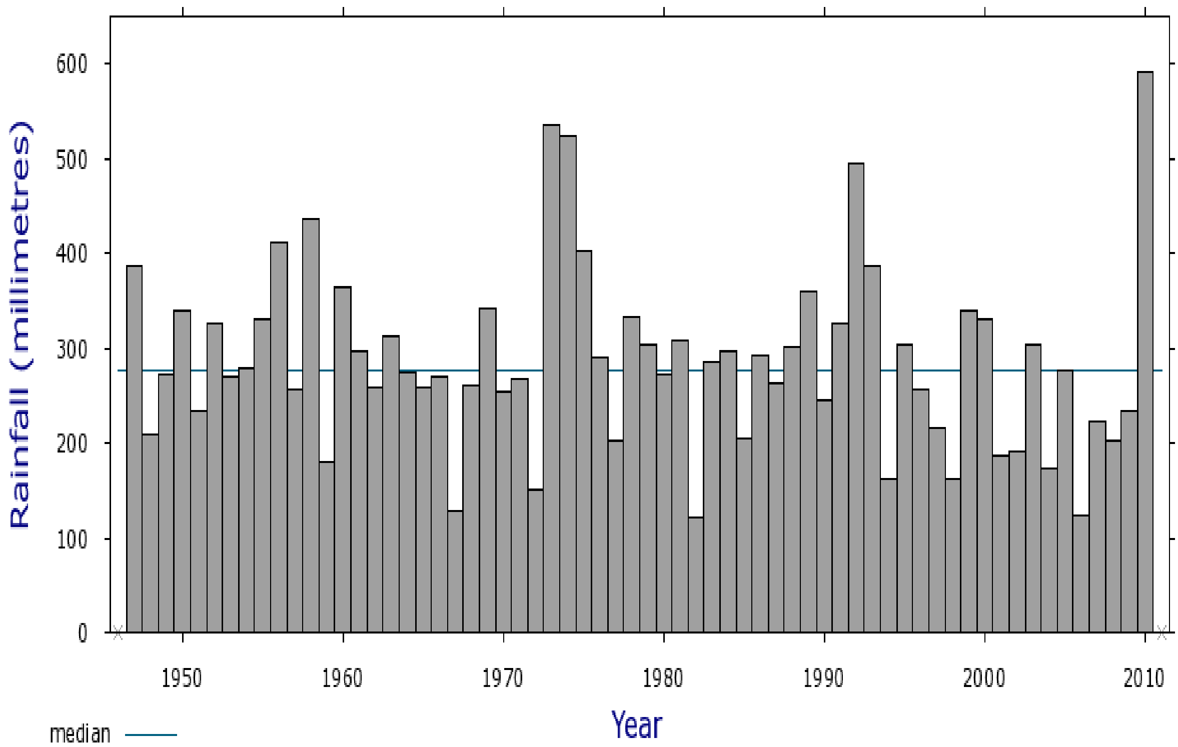
(Figure 4.6) Annual Maximum Temperature (˚C) for Mildura LGA

(Source: www.bom.gov.au/climate/data/)

Between 1998 and 2007, the greatest increase in temperature happened in summer (0.6˚C), whereas the maximum temperature increased the most in summer and spring; 0.9˚C and 0.8˚C respectively. Minimum temperatures rose the most in summer (0.3˚C), whereas a large decrease happened in autumn (0.6˚C).

Between 1998 and 2007, the average annual number of days above 30˚C rose by 8 days whereas the number of days above 35˚C increased by 6 days. In addition, there were 3 extra days above 40˚C (The Victorian Government Department of Sustainability and Environment, 2008, p 3).

Mildura LGA has experienced a decline in rainfall over the past decade (Figure 4.7). Since 1998 Mildura has experienced drought. For example, 'between 1998 and 2007 the region's average rainfall was 13% below the 1961 to 1991 average' (The Victorian Government Department of Sustainability and Environment, 2008, p 3). Rainfall has decreased by approximately 10 mm per decade (CSIRO, 2008, p 5). The greatest decreases in the region's rainfall were in autumn and winter, whereas average summer rainfall rose by 18%.



(Figure 4.7) Annual Rainfall (mm) for Mildura LGA

(Source: www.bom.gov.au/climate/data/)

4.3.2 Climate Projections for Mildura

As discussed in chapter 2, because of the divergence in the range of possible greenhouse gas emissions trajectories, projections of future climate are uncertain. The median climate is projected to become gradually drier into the future and by 2070 the median climate under high global warming is expected to be largely similar to the extreme 2030 climate (CSIRO, 2008, p 8). Therefore, this requires greatest flexibility and adaptive capacity in water resources management in the Murray Darling Basin.

In the Victorian Mallee region, 'climate conditions in 2030 are likely to be hotter and drier as a result of increases in annual average temperature and decreases in annual average rainfall' (Mildura Rural City Council, 2010, p 3). By 2030, the average annual temperature is projected to be higher by 0.9˚C than it is today, whereas the biggest temperature increases will be happening in summer (1˚C). The number of hot days is expected to rise. Decreases in the average annual rainfall by around 4% are expected, with the highest decreases in the amount of rainfall happening in spring (7%). The drier conditions can be expected to increase the potential evaporation and to reduce relative humidity within the Mallee region (The Victorian Government Department of Sustainability and Environment, 2008, p 5).

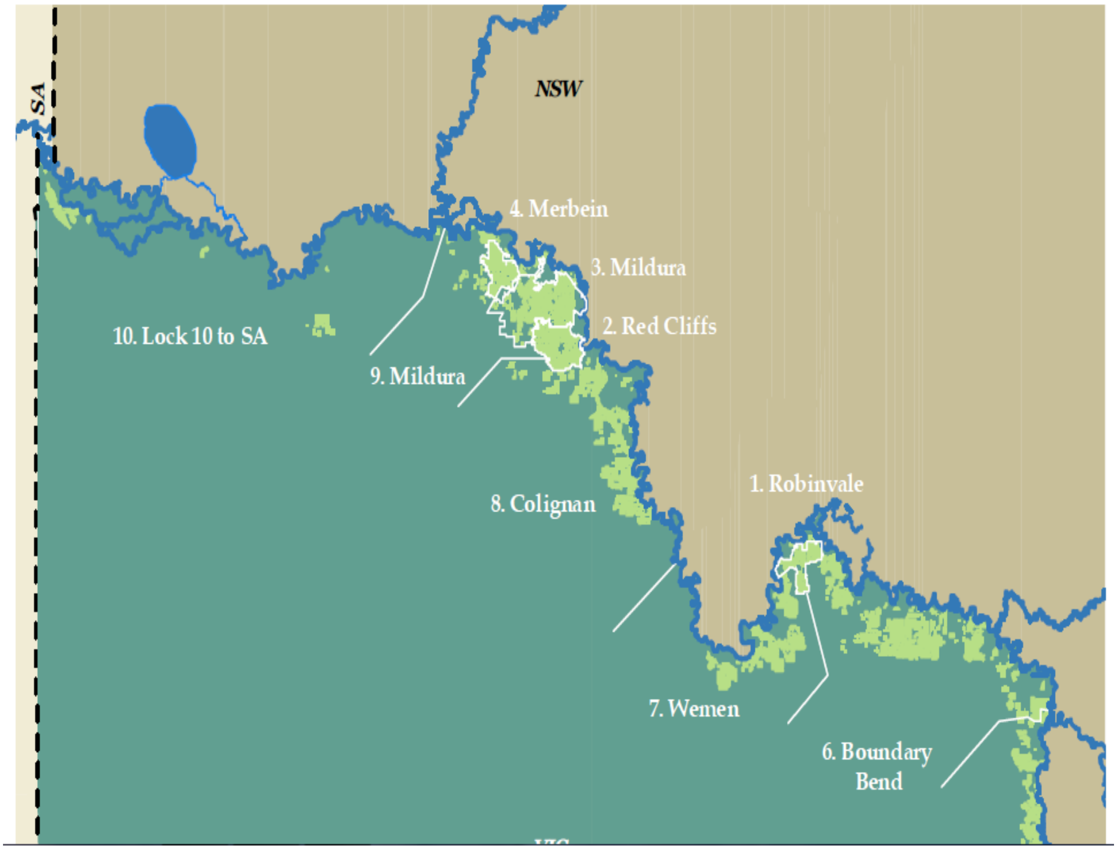
By 2070, because of global warming, the temperature and rainfall will be similar to those of current day Wilcannia in New South Wales (Mildura Rural City Council, 2010, p 4). In addition, solar radiation will increase a little (0.5%). The wind speed will change little in its average, and any reductions are likely to happen in autumn.

By 2070 and for a lower global warming scenario, an additional increase in mean temperature (1.4˚C) is expected, whereas for a higher global warming scenario, temperature increases will be double (2.8˚C). While hot days continue to rise, the amount of rainfall will continue to decrease (The Victorian Government Department of Sustainability and Environment, 2008, p 5). The warming is likely to be highest in the summer, whereas decreases in rainfall are likely to be in the spring. The projections for the average of annual and seasonal rainfall are expected to decrease, whereas the heaviest daily rainfall is likely to increase in its intensity in some seasons and drop in others. The average changes in temperature, rainfall and evaporation will have long term implications for the Mallee region. However, the effects of climate change are more likely to appear through extreme events, such as the number of hot days, a drop in the number of frosts and changes to the precipitation patterns.

Also, bushfire danger is likely to increase. For example, 'the number of extreme fire danger days is expected to increase by between 10% and 38% by 2020 and between 18% and 119% by 2050' (The Victorian Government Department of Sustainability and Environment, 2008, p 7).

4.4 Mildura Irrigation

In 1887, the first irrigation settlement created in the lower Murray Darling Basin was located in Mildura (the first Mildura Irrigation Trust). This was followed by Merbein in 1909 and Red Cliffs in the 1920s. Currently, Mildura LGA includes six irrigation districts. 'These are the pumped districts of Red Cliffs, first Mildura Irrigation Trust and Merbein; and the river reach of Colignan, Mildura and Lock 10 to the south Australian border' (Stubbs et al., 2010, p 28) (Figure 4.8). Because of the historic development of its irrigation districts, Mildura's older irrigation area is unique within Victoria. The irrigation districts depend on the design of irrigation settlements created by the Chaffey brothers in California. In this design, the form of a block was large enough to be used to help a family to live off. Then, a living area was designated to be 4 ha whereas a living area was designated to be 6.5 ha during the institution of Red Cliffs.



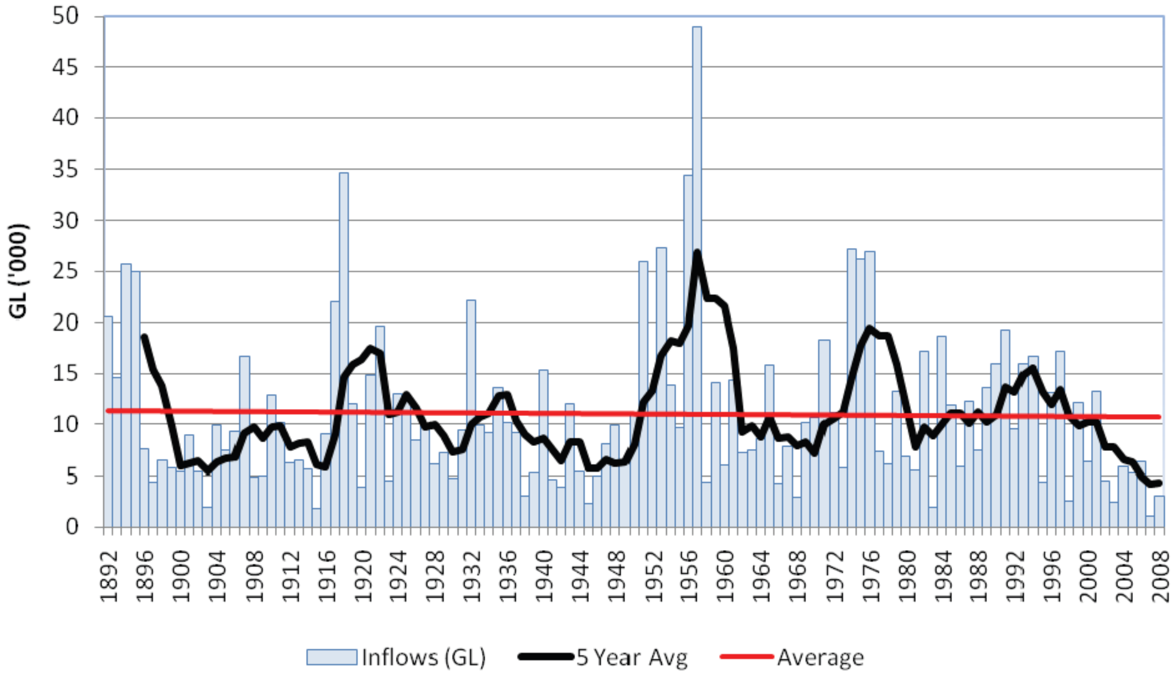
(Figure 4.8) Mildura Irrigation Districts

(Source: SunRISE 21 Incorporated, 2010, p 7)

Between 1997 and 2006, the areas which depended on irrigation in the Victorian Mallee (where Mildura LGA is located) increased by 17000 hectares (42%), with the large growth of new irrigation development happening in Boundary Bend, Wemen and Colignan; whereas the older irrigation areas, or pump areas, remained constant (SGS Economic and Planning, 2008, p 20).

The availability of surface water across most of the Murray Darling Basin is projected to drop as a result of climate change. Based on CSIRO projections for the median global warming, the average surface water availability across the MDB will experience reduction of 11% by 2030 due to climate change. Therefore, the future conditions will be generally drier in the Murray Darling Basin. However, the conditions in the south of the MDB will be less severe (CSIRO, 2008, p 8).

The low levels of water within the Murray Darling Basin have directly affected irrigation over the past few years. Australia over the recent years has experienced extreme climate conditions resulting in a prolonged drought. 'Between 1998 and 2007, the average rainfall in the northern Mallee was 13% below 1961 to 1990 average' (Mildura Rural City Council, 2009, p 4). This drought has led to a reduced water flow in Murray River system (Figure 4.9).



(Figure 4.9) Inflows to the Murray-Darling Basin 1892-2008

(Source: Quiggin et al., 2009, p 10)

As recognized by the Productivity Commission Report 2008 'this is the first time that Australia has experienced a widespread "irrigation drought" with severely reduced water allocations for many producers' (Mildura Rural City Council, 2009, p 11). As a result, the reduced water flow has imposed a reduction in water allocations for irrigation. Mildura LGA 'is therefore suffering mostly from water allocation drought, as opposed to the typical drought elsewhere in Australia resulting from lower annual rainfall' (Mildura Rural City Council, 2009, p 4). The 2009-2010 season water allocation declarations were: 17 August 0% of entitlement, 1 September 2%, 15 October 37%, 16 November 55%, 15 December 60%, 15 January 63%, 1 February 63%, 15 March 78% and 1 April 100% (SunRISE 21 Incorporated, 2010, p 7). The hydrological effects of climate change in the Murray Darling Basin have

remained very uncertain. For example, ‘average surface water availability could reduce by as much as 34% percent by 2030 (more severe on average than the recent climate) or increase by up to 11 percent’ (CSIRO, 2008, p 8).

The total irrigated area in the Mildura LGA in 2009 was around 29,000 ha and about half (14,000 ha) of this land was in pumped districts. The combination of the reduction of water for irrigation, water prices and availability, and farm viability and personal circumstances, are responsible for the most dramatic decreases in land under irrigation in the Mildura LGA from 2006 (Stubbs et al, 2010, p 45). There are three pumped districts within the Mildura LGA which experienced the highest increases in the areas considered out of production (not irrigated lands). The highest non-irrigated area was in Merbein at 35%; there was also a major non-irrigated area in the Mildura Reach (33%) and in the private diversion areas (19%). Therefore, about one-quarter of irrigable land was out of production in 2009 as a total (Stubbs et al., 2010, p 29).

The Mildura irrigation district consists of 6,080 hectares of irrigated land; a 90 hectare decline since 2005-2006. In the 2009-2010 irrigation season, there were 2,055 hectares (34%) of irrigable area that was not irrigated. The area of land not irrigated rose from 640 hectares (10%) of the total in 2005-2006 to 2,055 hectares (34%) in 2009-2010 (Table 4.1).

Not Irrigated (NI)	2005-06 Not Irrigated		2007-08 Not Irrigated		2008-09 Not Irrigated		2009-10 Not Irrigated	
	(ha)	%	(ha)	%	(ha)	%	(ha)	%
Perennial	530	9%	1,215	20%	1,535	25%	1,760	29%
Seasonal	110	2%	220	4%	290	5%	295	5%
Total NI	**640**	**10%**	**1,435**	**23%**	**1,825**	**30%**	**2,055**	**34%**
Total irrigable	**6,170**		**6,170**		**6,080**		**6,080**	

(Table 4.1) Mildura Area not Irrigated

(Source: SunRISE 21 Incorporated, 2010, p 23)

As for the Mallee region, the four pumped districts consist of 16,110 hectares of irrigable land. In the year 2009-2010, around 5,180 hectares from the total of the irrigable land was not irrigated. The land not irrigated increased from 1,370 hectares (8%) in 2005-2006 to 5,180 hectares in 2009-2010 (SunRISE 21 Incorporated, 2010, p 11) (Table 4.2).

Not Irrigated (NI)	2005-06 Not Irrigated		2007-08 Not Irrigated		2008-09 Not Irrigated		2009-10 Not Irrigated	
	(ha)	%	(ha)	%	(ha)	%	(ha)	%
Perennial	1,185	7%	2,920	18%	3,860	24%	4,695	29%
Seasonal	185	1%	345	2%	450	3%	485	3%
Total NI	**1,370**	**8%**	**3,265**	**20%**	**4,310**	**27%**	**5,180**	**32%**
Total irrigable	**16,230**		**16,230**		**16,110**		**16,110**	

(Table 4.2) Mallee Region / Pumped Districts Total Area not Irrigated

(Source: SunRISE 21 Incorporated, 2010, p 11)

The Merbein district has experienced the greatest increase in rate of non-irrigated lands, whereas Robinvale has experienced the least effects (Table 4.3).

Pumped irrigation district	2005-06 Not Irrigated		2007-08 Not Irrigated		2008-09 Not Irrigated		2009-10 Not Irrigated	
	(ha)	%	(ha)	%	(ha)	%	(ha)	%
Robinvale	115	5%	285	12%	310	13%	365	15%
Red Cliffs	315	7%	730	16%	1,095	24%	1,425	31%
Mildura	640	10%	1,435	23%	1,825	30%	2,055	34%
Merbein	300	10%	815	26%	1,080	35%	1,335	43%
Total NI	1,370	8%	3,265	20%	4,310	27%	5,180	32%

(Table 4.3) Area not Irrigated Per Pumped District / Mallee Region

(Source: SunRISE 21 Incorporated, 2010, p 11)

4.5 Mildura Population

4.5.1 Recent Population

Mildura LGA is growing as a result of its vital role as a regional centre and its strong agricultural base. While the agricultural sector has declined in Mildura as a result of drought, the population has increased in the town. Between 1976 and 2006 the population increase was 14,183 (40%) (Stubbs et al., 2010, p 35). Moreover, the total population within the Mildura LGA increased from 38,344 in 1981 to 53,122 in 2008 (Mildura Planning Taskforce, 2009, p 22). The population of the Mildura LGA is expected to continue growing into the future, reaching around 55,523 by 2026 (Mildura Development Corporation, 2009, p 18). In 2007-2008, the rate of population growth was 1.1% , whereas in the same period the population of Wentworth Shire Council (which is located across the Murray river from Mildura on the northern side of the river) has remained comparatively steady with a total 7,159 in 2008 (Mildura Planning Taskforce, 2009, p 22) (Table 4.4).

Region	Year	Population	Period	% Change	Annual %Change
Wentworth Shire Council	1981	7,100			
Wentworth Shire Council	1986	7,374	1981-1986	3.9%	0.8%
Wentworth Shire Council	1991	7,270	1986-1991	-1.4%	-0.3%
Wentworth Shire Council	1996	7,197	1991-1996	-1.0%	-0.2%
Wentworth Shire Council	2001	7,214	1996-2001	0.2%	0.1%
Wentworth Shire Council	2006	7,058	2001-2006	-2.2%	-0.4%
Wentworth Shire Council	2008	7,159	2006-2008	1.4%	0.7%

(Table 4.4) Population Changes-Wentworth Shire Council 1981-2008

(Source: Mildura Development Corporation, 2009, p 15)

Although Mildura has experienced an increasing population, the rate of population increase between 1996 and 2001 (8.3%) was higher than the rate of population increase between 2001 and 2006 (4.0%) (Table 4.5). More severe drought in recent years in Mildura might be the main reason for the decline in the rate of population increase in the Mildura LGA. This is

because the drought has caused a decline in the agricultural sector resulting in agriculture abandonment, low employment opportunities and low incomes.

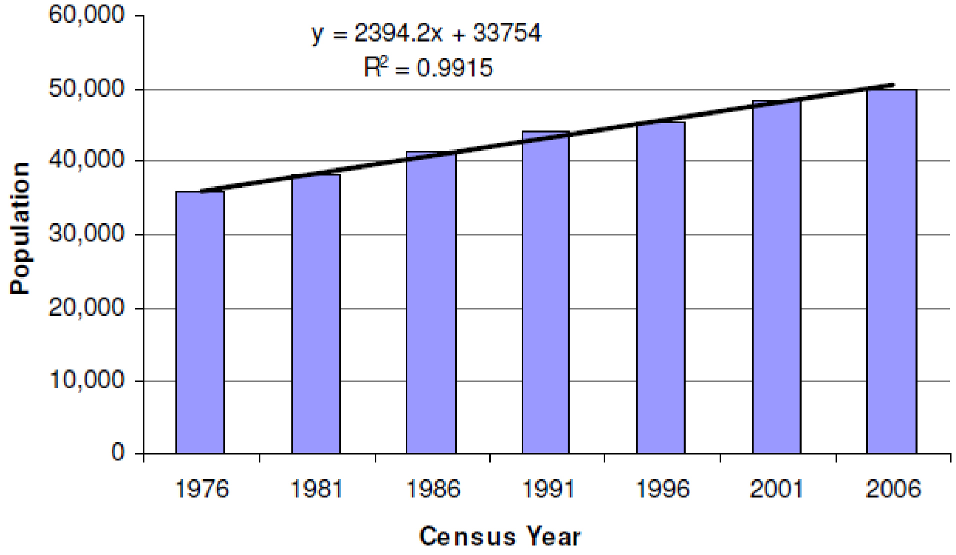
Region	Year	Population	Period	% Change	Annual %Change
Mildura City & Shire, Walpeup	1981	38,344			
Mildura City & Shire, Walpeup	1986	41,506	1981-1986	8.3%	1.6%
Mildura Rural City Council , Pt A & Pt B	1991	44,537	1986-1991	7.3%	1.4%
Mildura Rural City Council , Pt A & Pt B	1996	45,811	1991-1996	2.9%	0.6%
Mildura Rural City Council , Pt A & Pt B	2001	49,616	1996-2001	8.3%	1.6%
Mildura Rural City Council , Pt A & Pt B	2006	51,590	2001-2006	4.0%	0.8%
Mildura Rural City Council , Pt A & Pt B	2008	53,122	2006-2008	3.0%	1.5%

(Table 4.5) Population Changes-Mildura LGA, 1981-2008

(Source: Mildura Development Corporation, 2009, p 15)

Therefore, 'a complex of environmental, historical, economic and social factors are usually at play in creating the particular density range and type of any given rural community' (Argent, 2008, p 246). The increasing of population by 2,000 people from 1976-2006 indicated that more than one-third of the population growth within Mildura's urban centre arrived from its hinterland. 'Nonetheless, a fairly stable hinterland population is also evident in these trends' (Stubbs et al., 2010, p 35). The drought might be the main reason for migration from Mildura's hinterland. This is because the drought has affected the agricultural sector in Mildura. As a result, people in the rural areas have left agriculture because of the shortage water for irrigation. In addition, this refers to increase in the impacts of drought in recent years as a result of climatic changes. 'Mildura has provided some security for those farming families affected by declines in local agricultural industries, with many families from farms moving to Mildura' (Kiem et al., 2010, p 39). It is therefore very important to consider the drought as one of the factors that has caused the population increases in the urban centre of Mildura. 'Overall there will be minimal overall short term population change in the region, however, this comprises a continuation of the inward migration of persons to Mildura city' as well as an increased outside migration as people look for jobs (Mildura Rural City Council, 2009, p ix).

Also, the people who arrived from overseas rose from 3% in 2001 to 8% in 2006. Around 84.4% of those who migrated to become residents in Mildura were under 55 years. From 2001 to 2006, the percentage of the new arrivals 55 years and older was 15.6% compared with 32.7% of longer term residents (Aarons and Glossop, 2008, p 4). Although the rate of population increase has declined in recent years as a result of drought, the Mildura township experienced a steadily increasing population (Figure 4.10) between 1976 and 2006 (an additional 16,050 people) as a result of powerful and continuing extension of its irrigated agricultural sector and 'its importance as a regional service centre and its attractiveness as a tree change location' (Stubbs et al., 2010, p 34).



(Figure 4.10) Population Change 1976-2006 for Mildura LGA

(Source: Stubbs et al., 2010, p 35)

4.5.2 Indigenous People

The Latje Latje people represent the traditional indigenous people in Mildura, whereas the broader area of the Mildura LGA includes the Latje Latje and Wergaia. In historical research, the Negintait, Ngardad and Jari Jari have lived in Mildura (Mildura Development Corporation, 2006, p 20)

Today, the land in Mildura is documented as Latje Latje country and the land in Wentworth is documented as Barkindji country. The indigenous population in the Mildura region has been rising. For example, the indigenous population increased from 1,631 to 2,043 between 2001 and 2006 (Table 4.6) (Mildura Development Corporation, 2009, p 20) and in 2006 this represented 3.1% of the total population (Australian Bureau of Statistics). In addition, (based on the 2001 Census) Mildura LGA and Wentworth Shire have a higher proportion of indigenous people than does regional Victoria and regional NSW (Mildura Development Corporation, 2006, p 23).

Region	2001		2006	
	Males	Females	Males	Females
Mildura Rural City Council	516	574	645	787
Wentworth Shire Council	262	279	299	312
Mildura Region	778	853	944	1,099
Total	1,631		2,043	

(Table 4.6) Indigenous Population in Mildura Region

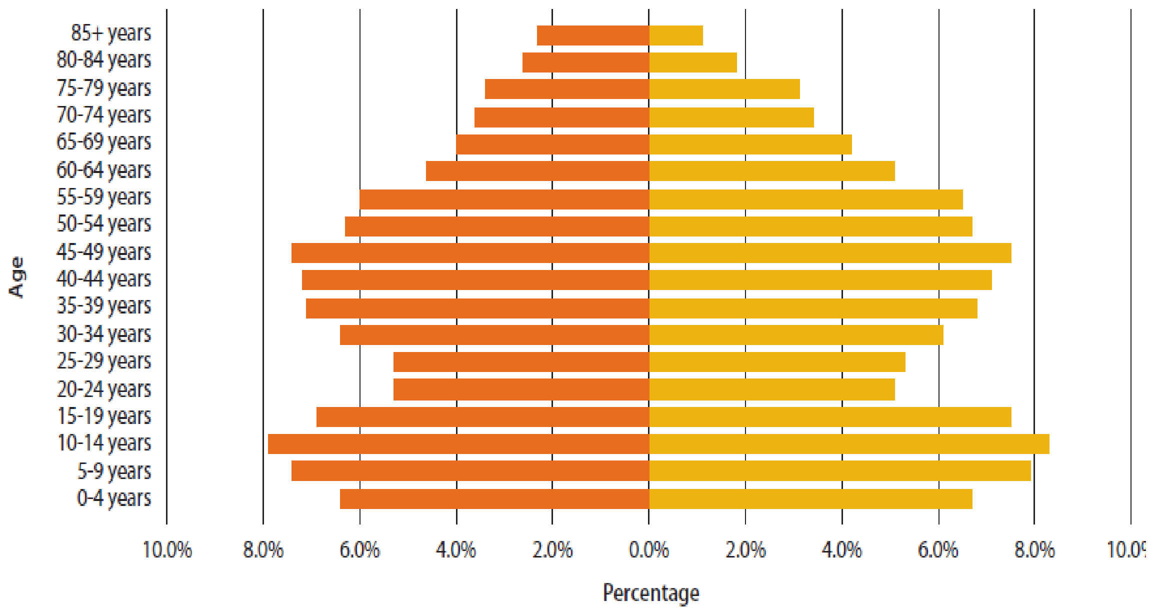
(Source: Mildura Development Corporation, 2006, p 20)

4.5.3 Population Structure

People aged between 5 and 9 years in the Mildura region were the highest proportion of the population (4,621 persons or 8.1%) in 2001, whereas people aged between 10 and 14 years were the highest proportion of the population (4,748 persons or 8.1%) in 2006 (Figure 4.11).

The shift in the highest proportion of the population from people aged between 5 and 9 years in 2001 to people aged between 10 and 14 years in 2006 could indicate that the drought has caused the population increase in the Mildura LGA to slow down. Whilst a decline in births might be the reason as a result of the impacts of drought on the socioeconomic aspects of families, such as employment and income, the migration of some younger families out of the Mildura LGA could be another reason, or both factors might be the cause. In a comparison between the proportions of the population in Mildura, the population aged between 15 and 24 years was the lowest proportion compared to the other proportions between 0 and 59 years. This could indicate that some young people aged between 15 and 24 have migrated out of Mildura.

'The drought has resulted in an accelerated aging regional population throughout the rural villages and townships across the Mildura Service Area' (Mildura Rural City Council, 2009, p ix). The proportion of elderly people who are between 80 and 84 years has risen by 30% between 2001 and 2006 (Kiem et al., 2010, p 39).



(Figure 4.11) Resident Population Structure / Mildura Region for 2006

(Source: Mildura Development Corporation, 2009, p 19)

4.5.4 Population Projections

The Victorian Government Department of Sustainability and Environment (DSE) projections for Mildura suggest that the population of Mildura will increase to about 67000 people by 2031 (Mildura Development Corporation, 2006, p 17). The proportion of population growth exceeds the projections by the DSE for regional Victoria as a whole (0.79% from 2001 to 2030). It is important to note that there are three scenarios for population growth by 2031 which are considered by The Mildura and Irymple Residential Land Strategies. These include 'a 'conservative' estimate of 65,800, a 'likely' estimate of 74,300, or the ambitious estimate of 86,000' when comparing the projections of population to 2031 (Mildura Planning Taskforce, 2009, p 22). The majority of this increase will occur due to migration from within regional Victoria, including people who move to or from nearby municipalities. In addition, the total number of households within Mildura is expected to rise from 19,142 households in 2001 to 30,370 households in 2031.

4.6 Mildura Socioeconomic Status

4.6.1 Employment and Income

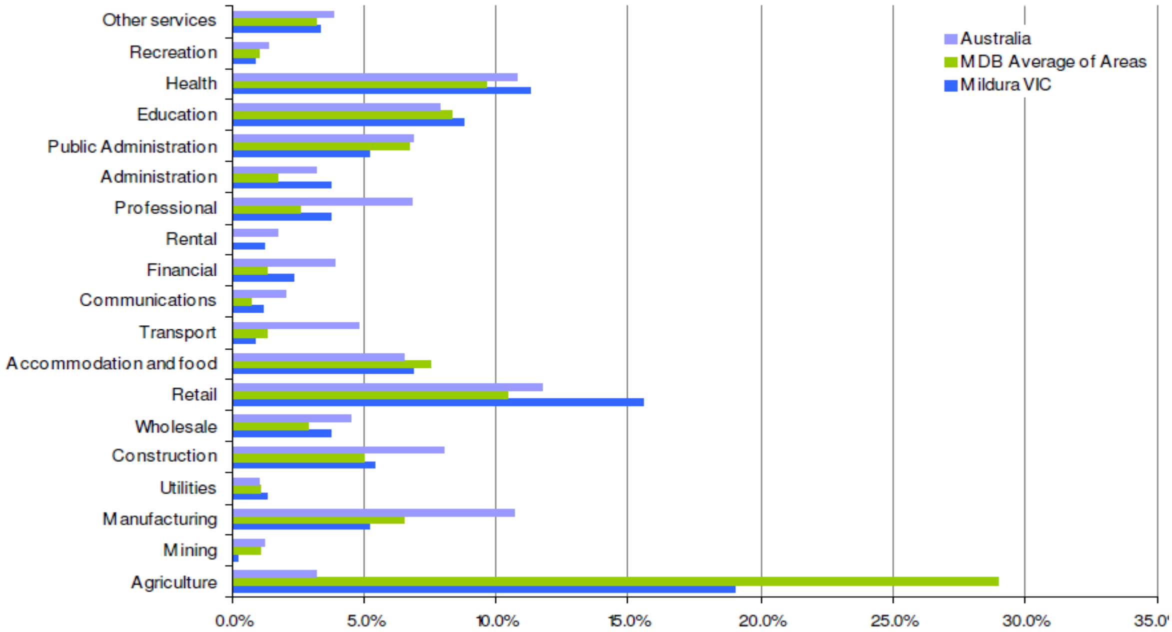
The drought has affected the employment opportunities and incomes within many economic sectors in Mildura LGA (Table 4.7). The sectors that were most adversely affected were the agriculture, forestry and fishing. Increased expenditure and employment occurred in retail trade and services.

Industry	Output ($M)	Value Add ($M)	Income ($M)	Employment (FTE)
Direct Impacts				
Irrigated Agriculture	-$97.3	-$59.8	-$12.2	-234
Dryland Farming	-$152.6	-$74.3	-$7.8	-181
Services to Agriculture	$3.3	$2.2	$2.0	33
Wine Manufacturing	-$115.9	-$40.5	-$13.5	-245
Dried Vine Fruit Manufacturing	-$10.1	-$2.9	-$1.5	-20
Olive Oil Manufacturing	-$0.9	-$0.2	-$0.1	-1
Tourism Retail Trade	-$11.8	-$5.7	-$3.7	-95
Tourism Accommodation, Cafés and Restaurants	-$12.2	-$4.6	-$3.0	-78
Employment Services	$9.5	$3.8	$3.0	42
Community Support Services	$0.9	$0.5	$0.4	14
Total Direct Impacts	*-$387.0*	*-$181.4*	*-$36.4*	*-767*

(Table 4.7) Economic Impacts of the Drought in the Mildura LGA

(Source: Mildura Rural City Council, 2009, p 32)

Around 19.5% of 18, 613 people who are employed in the Mildura LGA were employed in agriculture (based on the 2006 census) (Stubbs et al., 2010, p 36) (Figure 4.12).



(Figure 4.12) Employment Profile 2006/ Mildura

(Source: Stubbs et al., 2010, p 37)

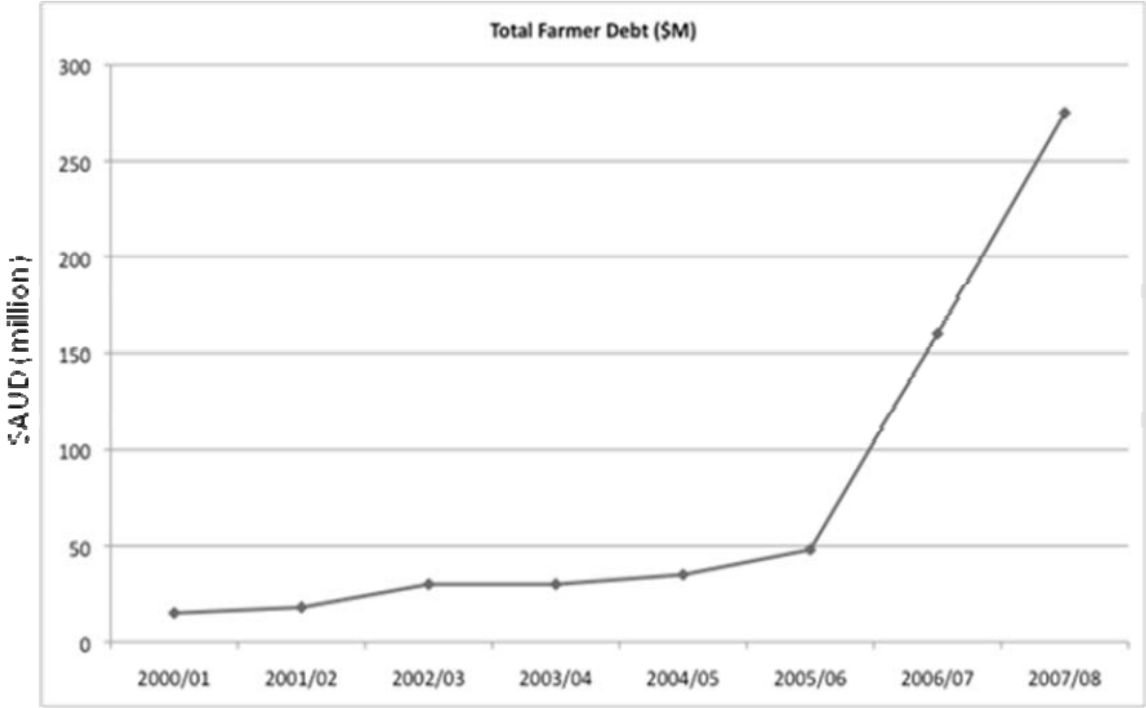
In 2005/2006, over half of all agricultural employment was in grape growing, whereas cereals, fruit and vegetation growing represented over 11% of agricultural employment. In addition, grazing had an important role in land use within the Mildura LGA but the people who were employed in this sector were only 4% of agricultural employment. Mildura has provided alternative job opportunities for its population and for new people who migrated from its hinterland. Unemployment rates in Mildura LGA decreased from 8.5% in 2001 to 7.4% in 2008 and from 8.7% in 2001 to 7.5% in 2008 for the Mildura region (Mildura Development Corporation, 2009, p 24). However, between 2001 and 2006, the share of employment decreased from 18.4% to 13.8% (Table 4.8) within the sectors of agriculture, forestry and fishing in Mildura LGA, as a result of the ongoing drought (Mildura Rural City Council, 2009, p 65).

Industry	Mildura LGA			Mildura Service Area		
	2001	2006	% Pt. Change	2001	2006	% Pt. Change
Agriculture, Forestry and Fishing	18.4%	13.8%	-4.6%	21.8%	16.9%	-4.9%
Mining	0.5%	0.4%	-0.1%	0.5%	0.5%	0.0%
Manufacturing	9.9%	11.2%	1.4%	9.2%	10.6%	1.4%
Electricity, Gas and Water Supply	1.2%	1.1%	-0.1%	1.2%	1.1%	0.0%
Construction	5.8%	6.8%	1.0%	5.6%	6.7%	1.1%
Wholesale Trade	6.3%	5.4%	-1.0%	6.1%	5.3%	-0.8%
Retail Trade	16.1%	16.8%	0.7%	15.2%	15.8%	0.6%
Accommodation, Cafes and Restaurants	4.8%	4.6%	-0.2%	4.8%	4.7%	-0.1%
Transport and Storage	3.8%	4.5%	0.6%	3.8%	4.3%	0.5%
Communication Services	0.9%	0.8%	-0.1%	0.9%	0.8%	-0.1%
Finance and Insurance	1.8%	1.9%	0.1%	1.7%	1.8%	0.2%
Property and Business Services	6.5%	6.4%	0.0%	6.1%	6.1%	0.1%
Government Administration and Defence	2.5%	4.1%	1.6%	2.6%	3.9%	1.4%
Education	7.4%	7.7%	0.3%	7.2%	7.5%	0.3%
Health and Community Services	9.6%	10.3%	0.7%	9.2%	9.8%	0.6%
Cultural and Recreational Services	1.5%	1.3%	-0.2%	1.4%	1.2%	-0.2%
Personal and Other Services	3.0%	2.9%	-0.1%	2.9%	2.9%	0.0%
Total	**100.0%**	**100.0%**	-	**100.0%**	**100.0%**	-

(Table 4.8) Employment by Industry for Mildura LGA in 2006

(Source: Mildura Rural City Council, 2009, p 65)

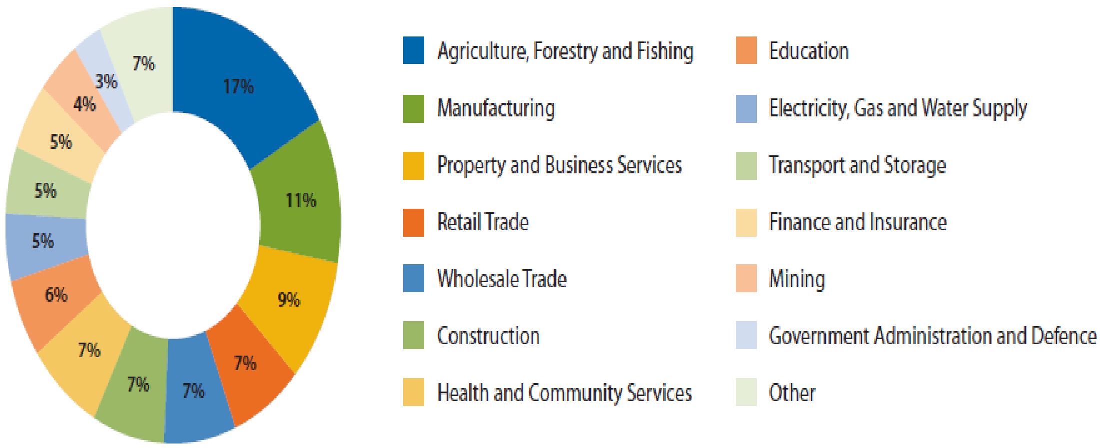
Further, the ongoing drought has caused farmer debts to increase, especially in recent years as a result of low water allocation for irrigation, and increasing the cost of cultivation. For example, the Rural Financial Counselling Service (RFCE) 'has noted a steady rise in aggregated farmer debts from $ 15 million in 2000-01 to 48.2 million 2005-06, with a surge in debt to $ 257 million in 2007-08' (Kiem et al., 2010, p 38) (Figure 4.13).



(Figure 4.13) Farmer Debt ($million) in Mildura Region

(Source: Kiem et al., 2010, p 39)

In 2007-2008, agriculture, forestry and fishing represented the highest proportion of production in the Mildura region (17%), whereas manufacturing represented 11% of the region's production (Figure 4.14).

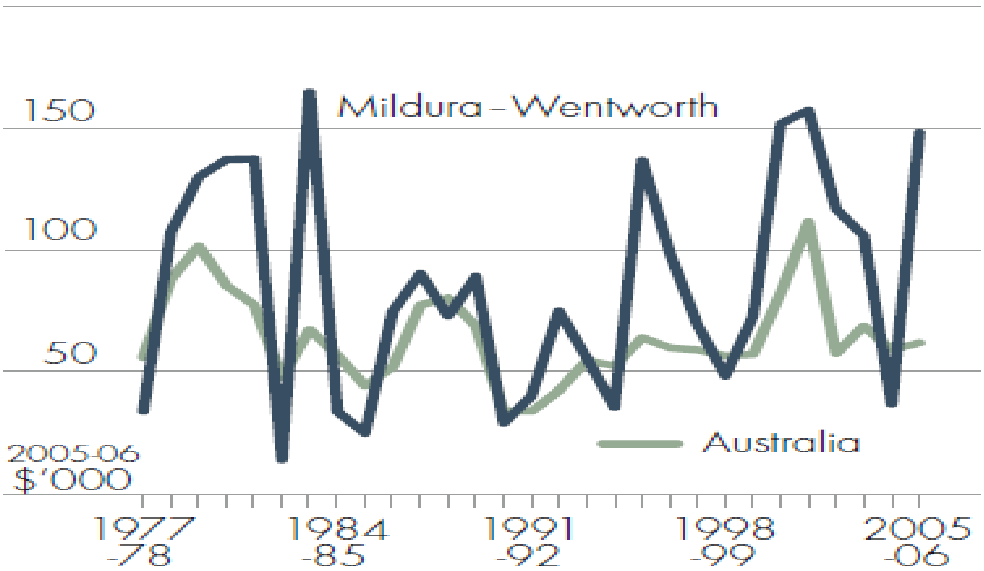


(Figure 4.14) Mildura Region Gross Regional Product % Contribution, 2007-2008

(Source: Mildura Development Corporation, 2009, p 9)

ABARE has argued that, historically, the incomes of farms in the Mildura region have been sensitive to climatic change. Crop yields and pasture growth in the Mildura region have been very variable.

Based on analysis of farm income for the Victorian Mallee which includes Mildura, the Mildura region is experienced more fluctuation than the Australian average (ABARE, 2006, p 5) (Figure 4.15).



(Figure 4.15) Farm Cash Income for Mildura Region

(Source: ABARE, 2006, p 5)

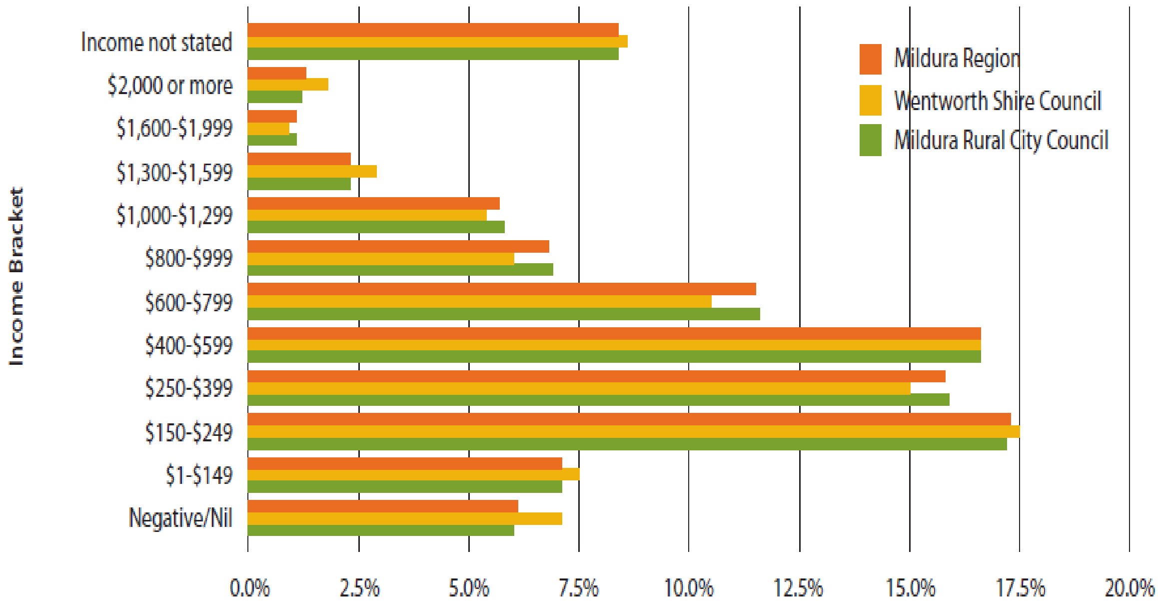
The total proportion of people who have incomes under $600 per week dropped from of 73.8% in 2001 to 65.7% in 2006. Conversely, the total proportion of people who have incomes over $1000 per week rose from 7.4% in 2001 to 12.8% in 2006 (Aarons and Glossop, 2008, p 4). In 2006, the weekly income of households in the Mildura LGA was between $500 and $649 for 13% of the population. This includes 2,403 households, whereas 203 households had income between $1 and $149 (Table 4.9).

Income	Mildura Rural City Council		Wentworth Shire Council		Mildura Region		VIC		NSW	
	No.	%	No.	%	No.	%	No.	%	No.	%
Negative/Nil	203	1.1%	38	1.5%	241	1.2%	22,685	1.3%	28,841	1.2%
$1-$149	320	1.7%	53	2.2%	373	1.8%	26,714	1.5%	34,454	1.5%
$150-$249	1,168	6.3%	145	5.9%	1,313	6.3%	87,245	4.9%	121,575	5.2%
$250-$349	1,655	9.0%	194	7.9%	1,849	8.8%	121,844	6.8%	162,152	7.0%
$350-$499	1,202	6.5%	174	7.1%	1,376	6.6%	88,966	5.0%	120,360	5.2%
$500-$649	2,403	13.0%	315	12.8%	2,718	13.0%	181,209	10.2%	233,507	10.0%
$650-$799	1,332	7.2%	162	6.6%	1,494	7.1%	114,574	6.4%	139,260	6.0%
$800-$999	1,362	7.4%	191	7.7%	1,553	7.4%	127,076	7.1%	151,853	6.5%
$1,000-$1,199	2,203	11.9%	295	12.0%	2,498	11.9%	192,733	10.8%	231,371	9.9%
$1,200-$1,399	1,134	6.1%	127	5.2%	1,261	6.0%	99,036	5.6%	118,009	5.1%
$1,400-$1,699	1,146	6.2%	148	6.0%	1,294	6.2%	132,682	7.4%	166,841	7.2%
$1,700-$1,999	849	4.6%	89	3.6%	938	4.5%	106,961	6.0%	138,083	5.9%
$2,000-$2,499	674	3.6%	100	4.1%	774	3.7%	106,265	6.0%	140,562	6.0%
$2,500 -$2,999	388	2.1%	52	2.1%	440	2.1%	92,251	5.2%	140,184	6.0%
$3,000 or more	283	1.5%	60	2.4%	343	1.6%	82,885	4.7%	139,990	6.0%
Partial income stated	1,392	7.5%	205	8.3%	1,597	7.6%	144,802	8.1%	193,198	8.3%
All incomes not stated	770	4.2%	117	4.7%	887	4.2%	53,737	3.0%	67,978	2.9%
Total	18,484	100.0%	2,465	100.0%	20,949	100.0%	1,781,665	100.0%	2,328,218	100.0%

(Table 4.9) Weekly Household Income in 2006 / Mildura Region

(Source: Mildura Development Corporation, 2009, p 27)

In 2006, the proportion of people who had weekly individual income between $400 and $900 was about % 16.5 in the Mildura LGA and this was the same proportion of weekly individual income in Wentworth and Mildura region, whereas the proportion of people who had weekly individual income between $150 and $249 was about 17% and this was lower than the proportion of Wentworth or Mildura region (Figure 4.16).



(Figure 4.16) Weekly Individual Income in 2006/ Mildura Region

(Source: Mildura Development Corporation, 2009, p 27)

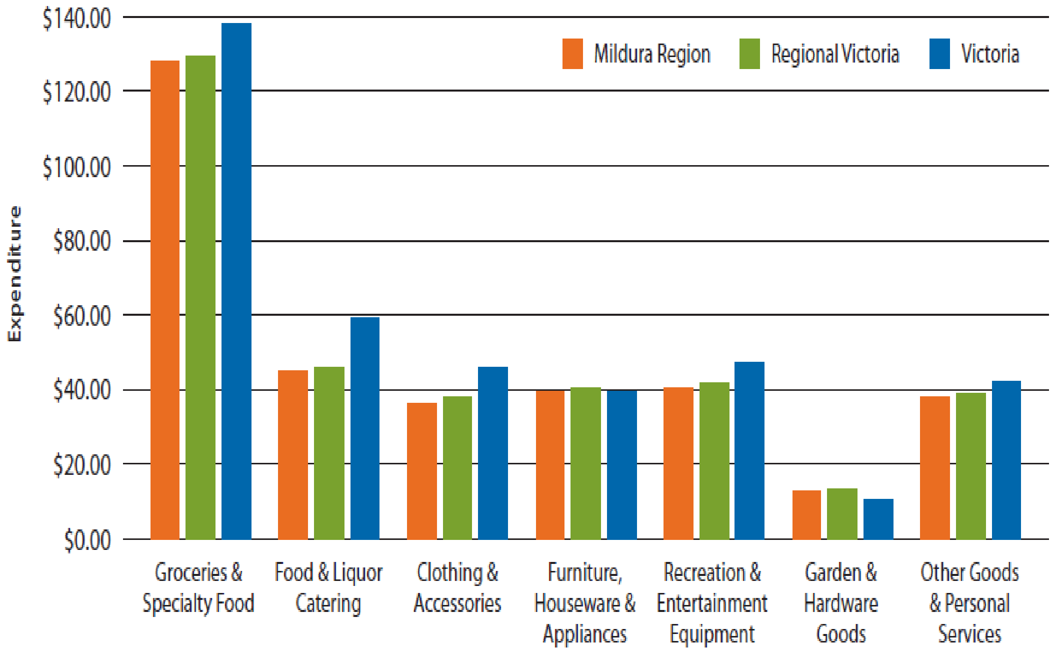
Around 19.5% of the 18,613 people employed in the Mildura LGA were employed in agriculture, based on the 2006 census (Stubbs et al., 2010, p 36) (Figure 4.12). However, when the agriculture sector has been affected by drought and low water allocation, job opportunities have declined, especially in the rural areas of Mildura. 'Between 2001 and 2006 in the Mildura LGA, retail trade displaced agriculture, forestry and fishing as the largest employing industry' (Mildura Rural City Council, 2009, p 65).

Based on research by Stubbs et al, 2010, a permanent reduction in irrigation water of 10%, 25% and 50% was expected to lead to the loss of 664, 1,513 and 2,927 job opportunities respectively, based on the 2005/ 2006 season. Searching for another job has thus become more difficult for families living in rural areas. In these cases, small farms have been exposed to pressure from ceasing or changing the type of the crop they grow as a result of their diminishing ability to meet the extra costs of irrigation water and production. As a result, demand has increased for off-farm employment as a replacement for the jobs and income that have been lost from agriculture.

Furthermore, increases in debt levels, the selling of water allocations and less profit for growers has forced many farms to go out of production. This has resulted in more employment opportunities being lost. Although the drought and low water allocation have affected the agriculture sector since 2001, other reasons have contributed to this decline in the profitability of farms, which has in turn affected employment opportunities and industries related to agriculture. For example, the wine grape sector has also been affected by low prices as a result of overproduction. Similarly, the cost of wine grape production has increased because of the extra cost of irrigation water.

Although the wine industry has attracted investments that are generating job opportunities, 'large quantities of wine in storage and an over production of wine grapes are currently impacting on grower returns' (Mildura Development Corporation, 2006, p 59). Therefore, there was a 43% increase in wine grape planting between 1997 and 2006, whereas between 2006 and 2009 grape planting experienced a decrease of 15% (SunRISE 21 Incorporated, 2010, p 8). This has resulted in an increase in the proportion of unemployed people in the agriculture sector around Mildura.

Even though the drought might be one reason for people moving to regional centres from surrounding areas, for a number of reasons this research does not support the 'sponge city' argument, which indicates that the growth in some larger regional centres has resulted from the relocation of people from surrounding areas, especially in the case of Mildura. First, the Mildura LGA is growing as a result of its strong agricultural base. Second, the population of Mildura has steadily increased over time, whether or not there was drought. For example, between 1976 and 2006 the population increase was 14,183 (40%) (Stubbs et al., 2010, p 35). Third, most of the new arrivals to the urban centre of Mildura have come from overseas and other parts of Australia. For example, the percentage of people who arrived in Mildura from overseas rose from 3% in 2001 to 8% in 2006 (Aarons and Glossop, 2008, p 4). Fourth, the cost of living in Mildura is lower than in many other parts of Australia, including the capital cities. This factor has therefore encouraged people to migrate to Mildura (Figure 4.17).

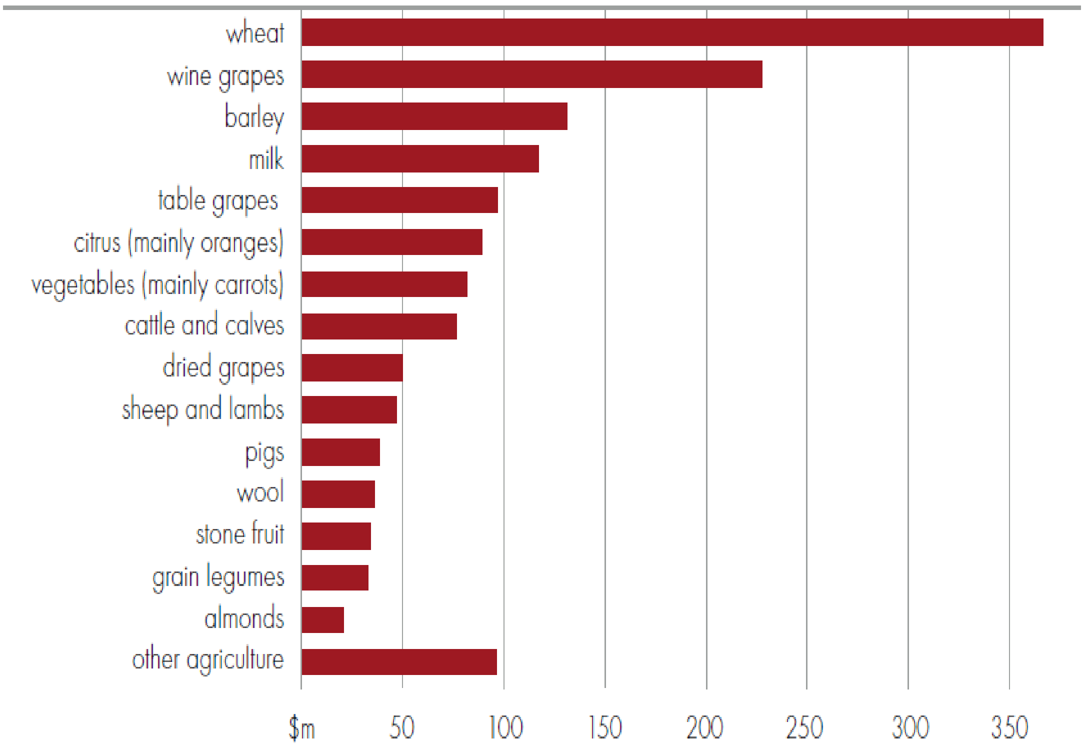


(Figure 4.17) Cost of Living in Mildura Region

(Source: Mildura Development Corporation, 2009, p 87)

4.6.2 Mildura Agriculture

The Mildura region is considered to be one of the major areas for agribusiness, and horticultural production is the main activity. The Mildura region is dominated by grain and grapes. In 2003-2004, the value of agricultural production for wheat and barley was over $1.5 billion and this represented about 24% of the region's total value of agricultural production. In addition, grapes represented 24% of the gross value of production, with wine grapes represented around 15% of the total value of production. Moreover, table grapes represented 5%, and milk production 9% (ABARE, 2006, p 1) (Figure 4.18).



(Figure 4.18) The Value of Agricultural Production in Mildura Region 2003-2004

(Source: ABARE, 2006, p 2)

Dryland farming in the grain industry in the Mildura region has become the agricultural tradition of the area and this industry is well established. Wheat, barley, oats and canola are the major dryland crops in the Mildura LGA and involve around 500 dryland farms (Mildura Planning Taskforce, 2009, p 36). Dryland farming in Mildura is dependent on water from rainfall events; which is highly variable. Dryland farming in Mildura, and in the whole Murray Darling Basin, experienced drought events to some degree early in the 1990s and severe droughts between 1994 and 1995 and drought during 2000s, particularly 2003-03 and 2006-08.

Dryland farming has adapted to deal with (and survive) low water availability. In addition, dryland farming operations are generally more flexible or resilient than farming which is more dependent on water allocation. However, the drought has caused a decrease in the

production and value of grain crops in the Mildura region. The continuing drought between 2006 and 2008 caused an increase in farmer debt as a result of buying seed for planting. As a result, dryland farming experienced a decline in its production. Therefore, the production of grain crops experienced a decline between 2006 and 2008 (Mildura Rural City Council, 2009, p 24) (Table 4.10).

Grain Crop	2008 Production (Tonnes)	Change from Drought	
		(%)	(Tonnes)
Wheat	574,000	-50.0%	-574,000
Barley	300,000	-50.0%	-300,000
Oats	30,000	-50.0%	-30,000
Canola	3,000	-50.0%	-3,000
Total	**907,000**	**-50.0%**	**-907,000**

(Table 4.10) 2008 Grain Production and Change as a Result of Drought in Mildura Region

(Source: Mildura Rural City Council, 2009, p 24)

In addition, the drought was the main reason for a loss of around $223.3 million in grain production in the Mildura region in 2008 (Table 4.11).

Vegetable Crop	Value / Tonne ($/t)	Change in Value ($M)
Wheat	$238	-$136.6
Barley	$255	-$76.5
Oats	$292	-$8.8
Canola	$464	-$1.4
Total	-	**-$223.3**

(Table 4.11) Change in Value of Grains from Drought / 2006-2008 / Mildura Region

(Source: Mildura Rural City Council, 2009, p 24)

Therefore, climate change has affected the dryland farming in Mildura. However, 'where the horticulture industry fails, dryland farming may benefit in the long term. Given the lower cost of returning land to dryland uses than irrigated crops' (Mildura Rural City Council, 2009, p vi). If reduction of water for irrigation continues for the next few years, over the long term some areas that recently utilised irrigated agriculture may transfer to dryland farming.

As for the irrigated farms in the Mallee region (where Mildura LGA is located), grapevines remain the dominant crop type with wine grapes remaining the dominant produce. In 2009, the area covered by grapevines was 21,720 hectares, whereas around 19,905 hectares was covered by almond trees. The highest proportion of agricultural production was in wine grape plantings, while significant growth occurred between 2003 and 2009 in the planting of almond trees. Between 2003 and 2009, a 3,995 hectare increase in fruit trees was experienced; whereas there was a 5,855 hectares decrease in field crops. In addition, there was a 43% increase in wine grape planting between 1997 and 2006; whereas the grape planting experienced a decrease of 15% between 2006 and 2009. Table grape plantings experienced an increase of 44% between 2006 and 2009. A 53% decrease in dried grape plantings happened between 1997 and 2009 (SunRISE 21 Incorporated, 2010, p 8).

The drought in Mildura has affected the agriculture sector by reducing the production and value of crops as a result of the reduction of water for irrigation. For example, between 2006 and 2008 the production of the citrus crop experienced a decline in the Mildura region (Mildura Rural City Council, 2009, p 20) (Table 4.12).

Citrus Crop	2008 Production (Tonnes)	Change from Drought	
		(%)	(Tonnes)
Oranges	117,470	-25.5%	-40,160
Mandarins	6,292	-23.5%	-1,928
Lemons/ Limes	1,500	-75.0%	-4,500
Grapefruits	5,100	-25.3%	-1,730
Tangellos	2,143	21.1%	373
Total	**132,505**	**-26.6%**	**-47,945**

(Table 4.12) 2008 Citrus Crop Production and Change as a Result of Drought in the Mildura Region (Source: Mildura Rural City Council, 2009, p 20)

Also, the value of citrus crops has experienced a decline as a result of changing production volumes (Table 4.13)

Citrus Crop	Value / Tonne ($/t)	Change in Value ($M)
Oranges	$770	-$30.9
Mandarins	$1,380	-$2.7
Lemons/ Limes	$933	-$4.2
Grapefruits	$843	-$1.5
Tangellos	$1,369	$0.5
Total	-	**-$38.7**

(Table 4.13) Change in Value of Citrus Crop / 2006-2008 / Mildura Region

(Source: Mildura Rural City Council, 2009, p 20)

Another example is that wine and table grapes have experienced a decline in production and value as a result of the reduction of water for irrigation. The drought in the Murray Valley has caused a decrease of around 200 wine grape growers between 2006 and 2008. Grape production declined by 69,525 tonnes in the Mildura region (Mildura Rural City Council, 2009, p 21). (Table 4.14)

Grape Type	2008 Production (Tonnes)	Change from Drought	
		(%)	(Tonnes)
Red Wine Grapes (Crushed)	144,504	-17.0%	-29,670
White Wine Grapes (Crushed)	220,707	-9.4%	-22,968
Table Grapes	46,174	-26.8%	-16,886
Total	**411,385**	**-14.5%**	**-69,525**

(Table 4.14) 2008 Grape Crop Production and Change as a Result of Drought in the Mildura Region (Source: Mildura Rural City Council, 2009, p 21)

In addition, the drought was the main reason for a loss of around $ 67.6 million in wine and table grape production in the Mildura region between 2006 and 2008 (Table 4.15). Therefore, there is a difference in the implications of climate change for irrigated and non irrigated agriculture.

Grape Type	Value / Tonne ($/t)	Change in Value ($M)
Red Wine Grapes	$547	-$16.2
White Wine Grapes	$582	-$13.4
Table Grapes	$2,250	-$38.0
Total	-	**-$67.6**

(Table 4.15) Change in Value of Wine and Table Grapes / 2006-2008 / Mildura Region

(Source: Mildura Rural City Council, 2009, p 21)

4.6.3 Manufacturing

In order to add value to its regional service centre, Mildura has adopted many manufacturing sectors. Manufacturing represents about 2.6% of businesses and around 10.8% of employment. Manufacturing consists of food, wine, fruit and vegetable processing which are mostly related to the agriculture sector (Mildura Development Corporation, 2006, p 78). Therefore, manufacturing has been affected by the drought as a result of agriculture declining.

4.6.4 Retail Trade in Mildura

Retail trade is considered a significant industry in Mildura LGA. Based on the 2001 census, this type of trade provided 16.3% of the workforce with a job, whereas the rate was 15.3% for regional Victoria (Mildura Development Corporation, 2006, p 76). This is because Mildura has become a regional service centre for regional Victoria, South Australia and New South Wales. In order to direct the continuing development of the retail sector in urban Mildura, the town of Mildura created a retail strategy. In June 2003, Mildura Rural City Council reviewed the Mildura Retail Strategy 2000. The review indicated that, according to population expectations presented in a Mildura Rural City Council report, by 2016 the Mildura trade area population may range from 104,000 to 107,000 persons and by 2021 from 106,000 to 112,000. Therefore, the projections indicated that by 2012 an amount of 35,280 to 58,070 square metres of additional retail floor space may be established in Mildura. ‘In 2005, Mildura Rural City Council adopted Amendment C29, based on Panel recommendations for rezoning of areas for retail development in the CBD’ (Mildura Development Corporation, 2006, p 78).

4.6.5 Tourism in Mildura

The tourism sector has become an important industry in the town of Mildura. Every year the town of Mildura gains $210 million from this sector. In addition, tourism in Mildura provides around 2100 full time jobs. For the whole of 2008, Mildura had 1.3 million visitor nights by

attracting some 500,000 visitors (domestic, international and day tripper) and the highest rate of visitors was the domestic overnight travellers. In 2008, Mildura received 392,000 domestic overnight visitors; 16% less than the previous year (Mildura Planning Taskforce, 2009, p 30). The tourism industry has been affected by drought in recent years. The number of visitors declined by 21% between 2006 and 2008. The drop in visitation is considered to have caused a reduction in contribution to Mildura LGA of $ 5.7 million (Mildura Rural City Council, 2009, p 7).

4.6.6 Mining Resources in Mildura

The Murray Basin has a great quantity of mineral sands resources and is the next large mineral producing region in Australia. The extraction of these minerals has been by the major mineral sands companies. The mining sector has participated in the expansion and diversity of the region's economy and this sector has expanded four times during the last few years as a result of increases in mineral sands and salt extraction (Mildura Planning Taskforce, 2009, p 30).

4.6.7 Educational Attainment in the Mildura LGA

Although the drought and low water allocation have had a socioeconomic impact which could affect the educational sector of the Mildura LGA, there was an improvement in educational attainment in the Mildura LGA between 2001 and 2006, including rural areas. For example, the proportion of people who completed Year 12 in the Mildura LGA increased by 2.5% between 2001 and 2006 (Mildura Rural City Council, 2009, p 69). This could indicate that the population of Mildura has focused on completing high school to improve their education. This has led to an increase in the proportion of the population who have high levels of education in the Mildura LGA. For example, people who have a postgraduate degree increased from 164 persons in 2001 to 241 persons in 2006 (47%). In addition, people who have a bachelor degree increased by 23.4% between 2001 and 2006. This could indicate that the population of Mildura has a high level of adaptive capacity to climate change based on the educational attainment indicator.

4.7 Recent Adaptation to Climate Change in Mildura LGA

Mildura LGA has experienced frequent droughts over the last decade, providing an analogy for conditions that will become more frequent under climate change. An adaptation or otherwise to the recent drought can provide insights as to how Mildura may deal with long term climate change, especially when the availability of surface water across most of the Murray Darling Basin is projected to drop as a result of climate change. Although there were declining inflows to the Murray-Darling Basin between 1997 and 2006, the areas which depended on irrigation in the Victorian Mallee (where Mildura LGA is located) rose by 17000 hectares (42%) for the same period. In addition, Mildura LGA has experienced an increasing population. There is a suggestion that more than one-third of the population growth within Mildura's urban centre arrived from its hinterland. The drought might be the

main reason for migration from Mildura's hinterland. This is because people in the rural areas have left agriculture because of the shortage water for irrigation.

4.7.1 Recent Adaptation in The Irrigation Sector

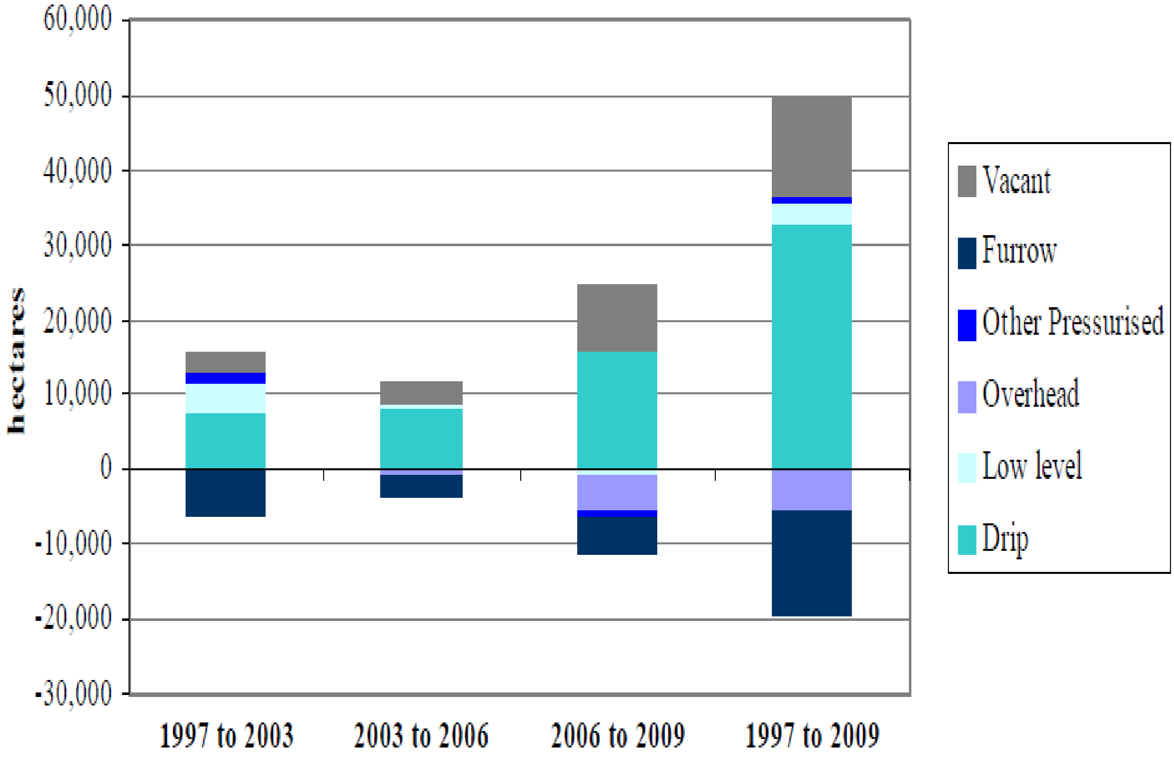
Although climate change has affected the agricultural sector in Mildura LGA, the irrigated agriculture sector has remained the most important economic source for Mildura. This is because the local farmers have adapted to the impacts of climate change by using efficient irrigation technology to deal with the reduction of water for irrigation, such as drip irrigation and low level sprinklers. In addition, the local farmers have used water trading and seasonal crops as replacements for permanent planting (SunRISE 21 Incorporated, 2010, p 7). Moreover, the policy of water allocations (e.g. Basin Plan) has succeeded to increase the water allocations for the most recent year 2009-2011. Furrow irrigation in the Mildura district decreased by 895 hectares from 24% (1,345 hectares) of irrigated crops in 2005-2006 to 11% (450 hectares) of irrigated crops in 2009-2010 as a result of drought that caused the reduction of water for irrigation, whereas drip irrigation rose by 275 hectares, from 18% (980 hectares) of irrigated crops in 2005-2006 to 31% (1,255 hectares) of irrigated crops in 2009-2010 as adaptation to the impacts of drought (Table 4.16). Therefore, the local farmers have undertaken technological change, and invested in more efficient infrastructure.

Irrigation Method	2005-06 Irrigated		2005-06 to 2009-10 change	2009-10 Irrigated	
	(ha)	%	(ha)	(ha)	%
Drip	980	18%	+275	1,255	31%
Low level	1,440	26%	-205	1,235	31%
Overhead	1,765	32%	-680	1,085	27%
Furrow/Flood	1,345	24%	-895	450	11%
Total irrigated	**5,530**	**100%**	**-1,505**	**4,025**	**100%**

(Table 4.16) Mildura Change in Irrigation Methods of Irrigation Crops

(Source: SunRISE 21 Incorporated, 2010, p 26)

Also, the Lower Murray Water indicated that the local growers within the Mallee region (where Mildura LGA is located) have changed the irrigation methods (Figure 4.19).



(Figure 4.19) Irrigation Method Change within the Mallee Region (Where Mildura LGA is located) (Source: SunRISE 21 Incorporated, 2010, p 11)

Furrow irrigation decreased by 2,345 hectares in the Mallee region. This reduction was from 22% (3,320 hectares) of irrigated crops in 2005-2006 to 9% (975 hectares) of irrigated crops in 2009-2010. On the other hand, drip irrigation rose by 1,080 hectares. This increase was from 17% (2,575 hectares) of irrigated crops in 2005-2006 to 33% (3,655 hectares) of irrigated crops in 2009-2010 (SunRISE 21 Incorporated, 2010, p 14) (Table 4.17).

Irrigation Method	2005-06 Irrigated		2005-06 to 2009-10 change	2009-10 Irrigated	
	(ha)	%	(ha)	(ha)	%
Drip	2,575	17%	+1,080	3,655	33%
Low level	4,895	33%	-850	4,045	37%
Overhead	4,070	27%	-1,815	2,255	21%
Furrow/Flood	3,320	22%	-2,345	975	9%
Total	**14,860**	**100%**	**-3,930**	**10,930**	**100%**

(Table 4.17) Pumped Districts Change in Irrigation Methods of Irrigated Crops

(Source: SunRISE 21 Incorporated, 2010, p 14)

4.7.2 Recent Adaptation in Agriculture Sector

The local growers in Mildura have made changes in crop types (grapevines and vegetables were the new essential plantings) to deal with the impacts of climatic changes (temperature

increases and the reduction of water for irrigation). This is an indication of resilience or adaptive capacity to climate change in the agricultural sector of Mildura. For example, the local growers made changes in crop types; between 2005-2006 and 2009-2010 a 480 hectares of Mildura districts irrigable land experienced replanting or reworking (Source: SunRISE 21 Incorporated, 2010, p 26) (Table 4.18).

Irrigated Crop		**2005-06 Irrigated**		**Change (ha)**			**2009-10 Irrigated**	
		(ha)	**%**	**new**	**removed**	**total**	**(ha)**	**%**
Perennial plantings	Grapevine	4,935	89%	+315	-1,665	-1,350	3,585	89%
	Citrus	115	2%	+15	-40	-25	90	2%
	Fruit tree	65	1%	+10	-15	-5	60	1%
	Nut tree	35	1%	+15	0	+15	50	1%
	Other	85	2%	+15	-60	-45	40	1%
Seasonal plantings	Field crop	210	4%	+60	-150	-90	120	3%
	Vegetable	85	2%	+50	-55	-5	80	2%
Total irrigated		**5,530**	**100%**	**+480**	**-1,985**	**-1,505**	**4,025**	**100%**
Total irrigable area		**6,170**					**6,080**	

(Table 4.18) Mildura Change in Irrigation Crops

(Source: SunRISE 21 Incorporated, 2010, p 26)

4.7.3 Recent Adaptation to the Socioeconomic Impacts

Mildura LGA has already adapted to the socioeconomic impacts of drought. The growth of the retail trade and manufacturing sectors in the Mildura LGA are resulting in more resilience to the impacts of climate change. For example, between 2001 and 2006, the share of employment decreased from 18.4% to 13.8% within the sectors of agriculture, forestry and fishing in Mildura LGA as a result of the ongoing drought, whereas the share of employment in the retail trade increased from 16.1% to 16.8% and compensated the jobs that lost from those sectors (Mildura Rural City Council, 2009, p 65).

4.8 Government Policy

4.8.1 Federal Government Water Policy

The Australian Government's national framework, Water for the Future, includes The Water Act 2007 and progresses the previous application of the National Water Initiative by the Council of Australian Governments (COAG) (Kiem et al., 2010, p 13). There are four key priorities that are identified by the framework. These priorities comprise reacting to climate change, using water efficiently, providing water supplies and enhancing healthy rivers. $12.9 billion will be invested in order to achieve these priorities over ten years (2010-2020) through the establishment of strategic programs and enhancement of water management and water policy in rural and urban regions (Kiem et al., 2010, p 13). Research by Kiem et al (2010) indicated that the national framework includes several policies and programs that have direct relevance to the Murray-Darling Basin (which is associated with Mildura). These are:

1. The Australian Government has committed to provide $5.8 billion to the Sustainable Rural Water Use and Infrastructure program in order to help irrigation communities to enhance irrigation systems.

2. $3.1 billion has been committed through the 'Restoring the Balance in the Basin' to purchase water allocations in order to protect the environment.

3. The Commonwealth Environmental Water Holder (CEWH) controls the water allocations acquired by the Commonwealth to be utilised for environmental irrigation.

4. The 'Driving Reform in the Basin' program supports contributions from the Australian Government to the operation and water reform functions of the Murray-Darling Basin Authority (MDBA)' (Kiem et al., 2010, p 13).

5. A $200 million has been allocated to the 'Strengthening Basin Communities' program to help local governments in the MDB to enhance their adaptation to less water in the future.

6. Using smart technologies and practices regarding water consumption across Australia has been accelerated by applying 'Water Smart Australia' programs.

7. The 'MDB Sustainable Yields' program, adopted by the CSIRO, provides projections regarding water availability.

8. 'The efficiency of water registers, transaction and market information functions will be improved by the development of a National Water Market System' (Kiem et al., 2010, p 13).

4.8.2 State Government Water Policy

The State Government of Victoria has the authority to control all surface water and groundwater through the Victorian Water Act 1989. In addition, the Victorian State Government provides a framework for water usage (Stubbs et al., 2010, p 22). There are four types of water allocation: bulk allocation, environmental allocation, water allocation and water licences. 'Water rights' in northern Victoria (where Mildura is located) were declared in July 2007 pertaining to the allocation of water, delivery share and the licences water usage. 'A water share is a legally recognized, secure share of the water available to be taken from a water system and may be 'high-reliability' or 'low-reliability' (Stubbs et al., 2010, p 22). Around 75% of the water allocations in the northern Victorian region are considered as high-reliability water allocations. A water share is the quantity of water that can be utilised through an entitlement to water every year and is dependent on water availability during the year (Stubbs et al., 2010, p 22).

In 2007, the State Government of Victoria adopted the regional Sustainable Water Strategies. These strategies include the engagement of regional stakeholders. The development of Sustainable Water Strategies achieved through cooperation between water corporations,

Catchment Management Authorities, stakeholders within the regions and the community. The main objectives for these strategies are to enhance policies regarding water use efficiency in order to protect agriculture and improve adaptive capacity for communities to shortages of water in the future as a result of climate change.

4.8.3 Local Government Water Policy

Mildura Rural City Council (2010) indicated that there are elementary principles and implications regarding water issues in the town. These have been identified by Mildura Rural City Council. These are:

1. Supplying 100% allocation of water entitlement each year.

2. In years where the allocations of water are lower than 100%, there is upgrading of rights to offer priority to use the permanent plantings.

3. The amount of water allocation which is withdrawn from farmers as a result of any Government Act or policy will be fully compensated.

4. 'For the total aggregate of water entitlement to be reduced significantly so that available resources and sustainable certain demand are more closely matched' (Mildura Rural City Council, 2010, p1).

5. Ensuring a higher likelihood of being capable to provide water to the permanent plantings which are characterised by high value.

6. Storing water in reserve for the next irrigation season when allocations are between 30% and 50% for high-reliability water shares.

7. If system losses and requirements happen in the regions, they should be allocated to the farmers within those regions.

8. 'That the ability to carry over water entitlements to the next season is maintained and the current cap on the entitlement percentage able to be carried over remains the same' (Mildura Rural City Council, 2010, p 1).

10. That the financial losses from purchasing carryover water entitlements will be compensated by the State Government.

Further, Mildura Rural City Council has recognised the social and economic impacts of climatic changes (drought) (Mildura Rural City Council, 2009, p iii).

4.8.4 Murray-Darling Basin Plan

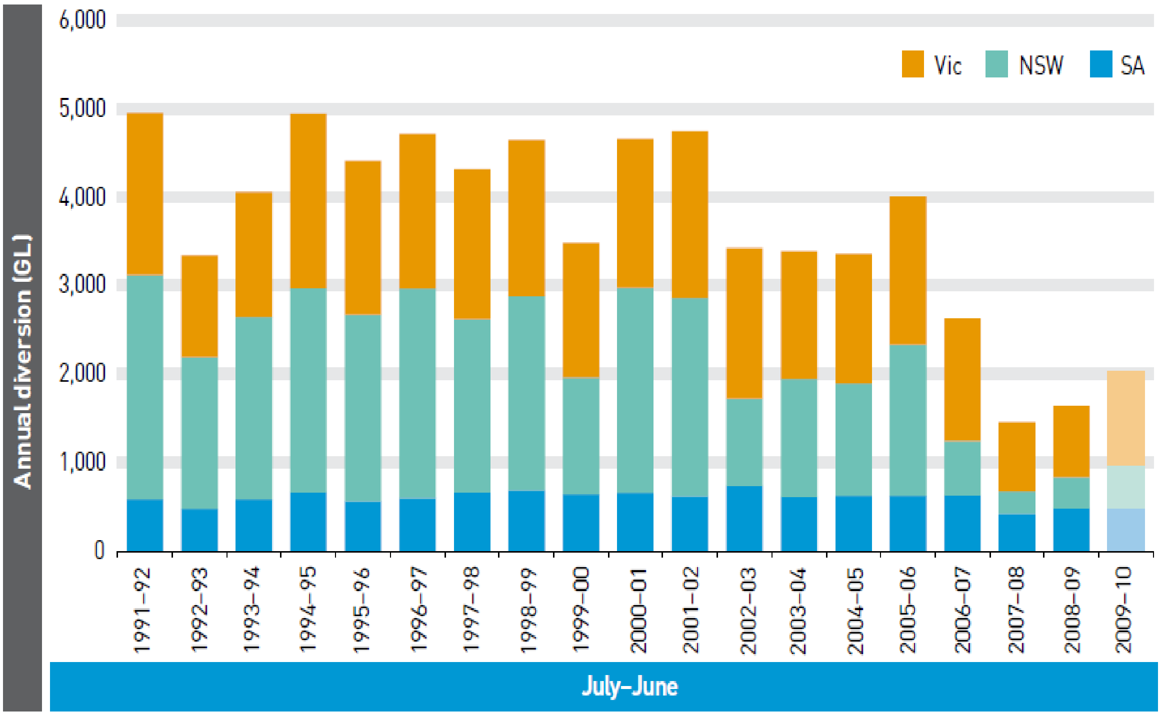
The Murray Darling Basin Authority has put a limitation of 3% of the current diversion limit (about 410 GL/y for the whole Basin and about 127 GL/y for the Murray region) as a suitable allowance to account for the impacts of climate change on surface water. Therefore, the Authority has determined the recent limits for all types of water extraction in the Murray

Darling Basin. The recent diversion limits for surface water comprise watercourse diversions for town and community water supplies, irrigation and industries, and floodplain harvesting and interception activities such as dam and forestry plantations. The surface water long term average diversion limit for the whole Basin had been expected to be about 13,700 GL/y and at 4,219 GL/y for the Murray region (Murray Darling Basin Authority, 2008, p 2). In order to restore and maintain the Basin's key environmental assets and key ecosystem functions, the Act and Basin plan searched to identify over-extraction of water from the Basin's rivers.

To achieve the sustainable diversion limit (SDL) proposal, it is important to find out how much water is required to maintain the health of the Basin's river systems, wetlands and floodplains. Therefore, the Authority has started an assessment of the environmental water necessities of key environmental assets and key ecosystem purposes for the whole of the Murray Darling Basin.

The environmental water necessary for the Murray region is expected to be between 3,945 GL/y and 5,722 GL/y (an increase of between 1,414 GL/y and 3,191 GL/y from the 2,531 GL/y at present obtainable for the environment). The SDL proposal would need a decrease in the recent long term average water diversion limit at the Basin from 13,700 GL/y (a decrease of between 3,000 GL/y and 4,000 GL/y or 22% to 29%).

As for the Murray region (where Mildura is located), this would equate to a decrease in the recent long term average surface water diversion limit of 4,219 GL/y to between 3,126 GL/y and 2,756 GL/y (a decrease of between 1,093 GL/y and 1,464 GL/y or 26% to 35%). While, final seasonal water allocation was 43% of entitlement in 2007/2008, it was 35% in 2008/2009. The final allocation of water was 100% in April 2010 for 2009/2010. Therefore, the allocations of water were different from one year to another (Figure 4.20). However, ‘the season commenced 1 July 2009 with 0% and then allocation increases announced as the season progressed did not meet crop water requirement’ (SunRISE 21 Incorporated, 2010, p 7).



(Figure 4.20) State Diversions / 1991-92 to 2009-10

(Source: Murray-Darling Basin Authority, 2010, p 67)

The development of the first Basin plan continued during 2009-2010. The *Guide to the proposed Basin Plan* focuses on several issues, such as the Murray-Darling Basin history and its water management, the issues that threaten the Basin and its habitats, the scientific research regarding the Basin, and the impacts of climate change (Murray-Darling Basin Authority, 2010, p 4). In order to develop the Basin plan (the proposed Basin plan), The Murray-Darling Basin Authority (MDBA) continued its work during 2009-10 through using the best scientific knowledge and available information from different sources, such as Basin states and federal government agencies (Murray-Darling Basin Authority, 2010, p 4). In addition, during 2009-10, MDBA has been committed to involve all stakeholders in the development of Basin plan, including those from the public, government and industry (Murray-Darling Basin Authority, 2010, p 5).

Between 2009 and 2010, a draft environmental watering plan was developed for the proposed Basin plan by MDBA in order to maximize the efficiency of water use for environmental purpose (Murray-Darling Basin Authority, 2010, p 17). Moreover, a draft monitoring and assessment program has been developed by MDBA. This program can be used to identify the short and long-term implications of elements of the Basin plan (Murray-Darling Basin Authority, 2010, p 17).

At the beginning of 2009-10 and due to the continued low water availability, a special arrangements for sharing water between the states (Victoria, NSW and South Australia) were adopted by state governments. There were four priorities for sharing water: ‘conveyance

water, critical human water needs, private carryover and an initial allocation of 25 GL for each state' (Murray-Darling Basin Authority, 2010, p 66). The contingency measures were utilized to underpin these necessities.

In August 2009, there was an improvement in water availability. At that time, the primary allocation of water was 25 GL for each state and without the need for any contingency measures (Murray-Darling Basin Authority, 2010, p 66).

The Murray Darling Basin Authority acknowledges that applying SDLs may include significant social and economic consequences for individual entitlement holders and communities in the whole Basin: 'However, the Australian Government has committed to recovering sufficient water access entitlements to fully offset the impacts of SDLs across the Basin' (Murray-Darling Basin Authority, 2008 , p 4).

4.9 Likely implications of, and Adaptive Capacity to, Climate Change in Mildura

Mildura LGA, like any location, is exposed to the impacts of climate change. The averages of climate elements such as temperature, rainfall and evaporation have experienced changes over time, especially in recent years. The drought, as a part of climate change, has affected the economy and society of the Mildura region. The low rainfall with high evaporation as a result of temperature increases has impacted on surface water in the Murray Darling Basin. Climate change and the water allocation policy have affected the water supply for the agricultural sector that is the most important economic source for Mildura. This has caused the reduction of water for irrigation in Mildura. Around 19.5% of people who were employed in Mildura LGA were working in the agriculture sector (based on 2006 census) (Stubbs et al., 2010, p 36). In addition, about one third of local jobs are associated with irrigated agriculture. Moreover, there are many economic sectors in the town of Mildura that are related directly or indirectly to the agricultural sector.

Climate projections indicate that conditions for Mildura are likely to be hotter and drier as a result of increases in annual average temperature and decreases in annual average rainfall. This indicates that frequent drought and climate uncertainty will continue in the long term. If the reduction of water for irrigation continues in the long term, the horticulture industry in Mildura LGA may experience failure in the future as a result of the most permanent crops being removed from production because of the decline in productivity and increased production costs.

Further, the permanent reduction of water for irrigation may cause an increase in the level of debts. This is because the reduction in incomes has imposed on many growers the need to borrow to cover extra operation costs of their farms. Moreover, the permanent reduction of water will leave large areas (non irrigated land) out of production for a long time. This may expose these areas to soil erosion and desertification. Therefore, dealing with the impacts of climate change may become a more complex issue year by year. Although the severe drought has affected Mildura LGA, especially in recent years, Mildura has had the experience to deal with the drought. This may assist the town of Mildura to deal with long term but less severe

drought in the future. In addition, more development of irrigation technology (e.g. drip irrigation) can be used to return non-irrigated areas to production in Mildura. Therefore, an increased adaptive capacity to climatic changes in Mildura can be achieved by using more developed irrigation technology in the future.

If severe drought continues in the future it may lead to a decrease in the population of Mildura. This is because people will migrate from the Mildura region to look for jobs. In addition, the population structure may change in the town of Mildura. More severe drought in the future is resulting in youth and younger families may move outside Mildura. Therefore, if drought continues for a long time in Mildura, the proportion of elderly people will increase as a result of the migration of younger people. This will result in low adaptive capacity to climate change in the future, because elderly people are generally thought to be less resilient or adaptable to the impact of climate change than younger people as they look for jobs. Vincent (2007, p 20) indicated that the elderly, children or the infirm are the most vulnerable to the impacts of climate change. However, if less severe drought continues, Mildura can adapt to its impacts and the migration of people from its hinterland may generate new economic activity in the town.

Further, as a result of climate change, the long term reduction in irrigation water is expected to have a greater effect on employment opportunities in the Mildura LGA. For example, with a ‘reduction in water ranging from 10% to 50% on the 2005/2006 baseline year, Mildura LGA could lose at least between 661 (3.2%) and 2,933 (14.2%) jobs in agriculture’ (Stubbs et al., 2010, p 5). In addition, the dryland farms are more resilient to the impacts of climate change than is irrigated agriculture. This is because dryland farms have the ability to cope with drought better than does irrigated agriculture. If drought continues for a long time (as a resulting of climate change), this may lead to transfer of irrigated agriculture to non irrigated agriculture (e.g. wheat crop). As a result, there will be an increase in unemployment because irrigated agriculture has a higher capacity to use large numbers of people than does dryland farming and this may cause people to leave the land and migrate from Mildura town.

There are many ways in which the town of Mildura has high adaptive capacity to the impacts of climate change. It has become a regional service centre as a result of its strategic location near the junction of Victoria, New South Wales and South Australia, growing its irrigated agriculture and its high quality services. In addition, living costs in Mildura LGA are much lower than many other parts of Australia. Therefore, Mildura has experienced increases in its population and then in its size. In addition, the town of Mildura has had the ability to retain its existing population and attract new people in recent years. This represents high adaptive capacity to the impacts of climate change based on the demographic indicators. However, if the severe drought continues for a long time in Mildura as a result of climate change, people migrating from its hinterland as a result of abandoning of agriculture will increase. This represents low adaptive capacity to climate change in rural area of Mildura based on demographic indicators.

In addition, because the town of Mildura has provided jobs and services such as education, health and recreation, most of the people who migrated from its hinterland and far towns are younger. This can be beneficial for economic growth and result in more adaptive capacity to climatic changes based on demographic indicators. However, if severe drought continues for the long term, the younger persons and households will migrate from the Mildura LGA as they look for jobs. This would decrease the adaptive capacity in the town of Mildura.

The town of Mildura has provided alternative employment opportunities that are not associated with the agricultural sector. More jobs for people who are in Mildura, and for new people, can be provided by different sectors (such as retail, education, tourism, health and transport). Moreover, the rate of unemployment in the Mildura LGA is lower than that of the Mildura region. This can play a vital role in adaptive capacity to climate change based on socioeconomic indicators, because more job opportunities from different sectors will compensate for the job losses in the irrigated agriculture sector in Mildura LGA as a result of a long term but less severe drought.

Similarly, the incomes (of households and individuals) have increased over time for the population of Mildura LGA and that is an indicator of more adaptive capacity to climate change based on socioeconomic indicators. However, if severe drought continues for a long time the incomes may decrease, especially in the rural areas of Mildura LGA, and result in a high rate of unemployment and migration. This would in turn reduce adaptive capacity.

The enhancement of policies regarding climate change and its impacts on water resources has occurred via partnerships between the three levels of government, the Federal, State (the Victorian Government) and Local government (Mildura Rural City Council). Adaptation strategies to climate change have been considered in government policies and programs. For example, the drought policies have focused on increasing water use efficiency, the water allocation and preparing all sectors of the society to live with shortage of water in the future. In addition, the Murray-Darling Basin Authority has started an assessment of the environmental water necessities of key environmental assets and key ecosystem purpose for the whole of the Murray-darling Basin. Furthermore, the Murray–Darling Basin Authority (MDBA) continued its work to develop the Basin plan during 2009-2010 through using the best scientific knowledge and available information. In addition, Mildura Rural City Council has recognised the social and economic impacts of climatic changes. This represents high adaptive capacity to climate change in the town of Mildura based on government policy indicators. However, Mildura Rural City Council should develop a suitable adaptation plan to the impacts of climate change in order to minimize these impacts on the different sectors, such as education, health and economic sectors. In addition, responding to the impacts of climate change requires a high level of collaboration among the three level of government.

In order to achieve the assessment of adaptive capacity accurately, it is important to adopt the suitable scale of analysis. This is because the complexity of the different scales of analysis still represents a challenge for the assessment of adaptive capacity to climate change. This

research adopts the local scale (Local Government Area) and discussion about this selection will be mentioned in the chapter 6.

Chapter 5

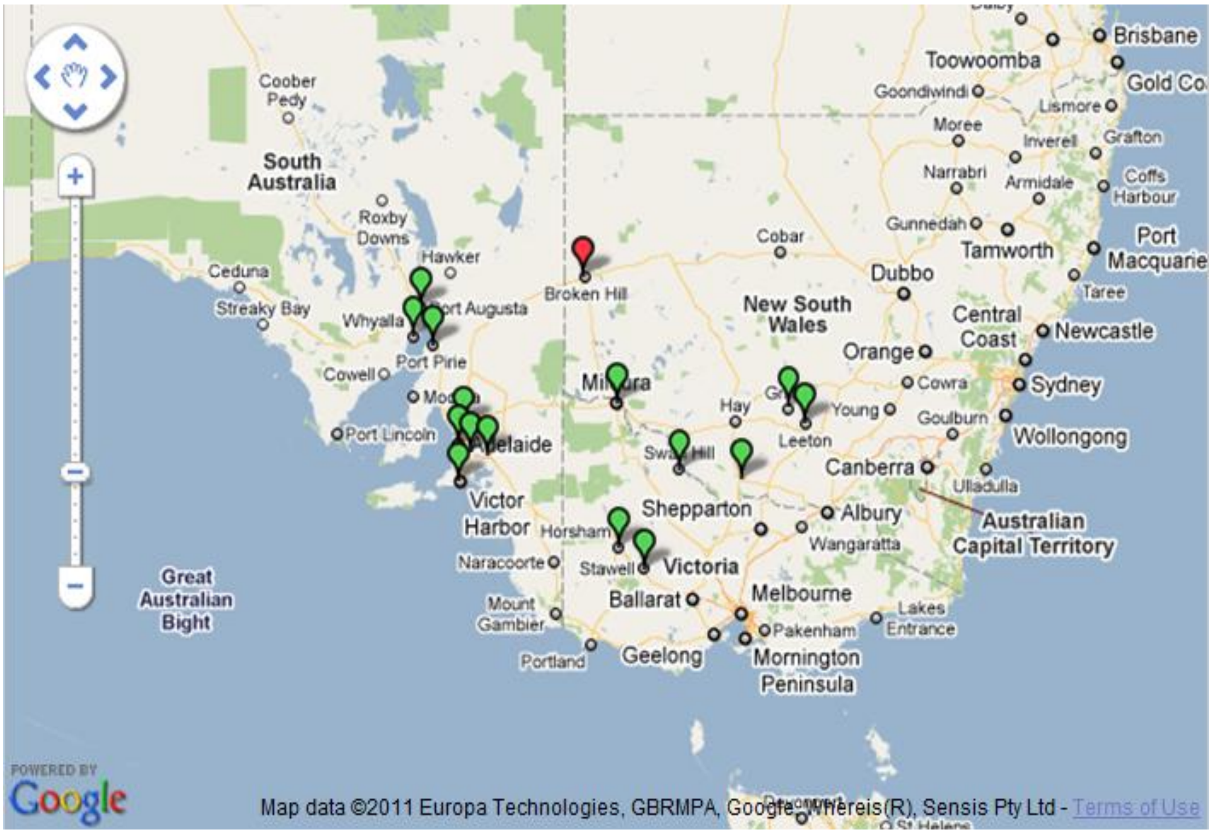
The Town of Broken Hill and Its Adaptive Capacity to Climate Change

5.1 Introduction and Chapter Structure

The general aim for this chapter is to discuss the implications of and recent adaptation to climate change in the town of Broken Hill, while the specific aim is to assess the adaptive capacity of the town by applying demographic, socioeconomic and government policy indicators. After an introduction to the study area in section 2, section 3 provides information about climate (recent climate and climate projections). Section 4 provides information about the population (historical change and population projections) in order to apply the demographic indicators of adaptive capacity to climate change. Section 5 provides information about economic aspects (employment and income, agriculture, manufacturing, retail trade and tourism). Because most of the impacts of climate change have occurred within the water supply sector, section 6 focuses on the impacts of climate change on this sector. Section 7 provides information about the Aboriginal people and water management in Broken Hill. In order to assess government policy indicators of adaptive capacity to climate change for Broken Hill, Section 8 provides information about the government policy and water supply in Broken Hill. Finally, Section 9 provides a discussion about the likely implications of, and assessment of adaptive capacity to, climate change in the town.

5.2 Broken Hill Location

The Far West Region comprises 18.4% of New South Wales, ranging across 147,142 square kilometres of the world famous Australian outback. The town of Broken Hill includes just fewer than 179 of those square kilometres and is located 1,160 kilometres west of Sydney, near to the South Australian border, and about 500 km north east of Adelaide (Figure 5.1).'Because of its proximity to South Australia, Broken Hill has strong cultural and economic links to this state' (A NSW Government Initiative, 2010, p 7). It was established in the late 1880s following the discovery of a huge ore body, including silver, lead and zinc.



(Figure 5.1) Map for Location of Broken Hill

(Source: http://www.travelmath.com/cities-near/Broken+Hill,+Australia)

5.3 Broken Hill Climate

5.3.1Trend in Temperature

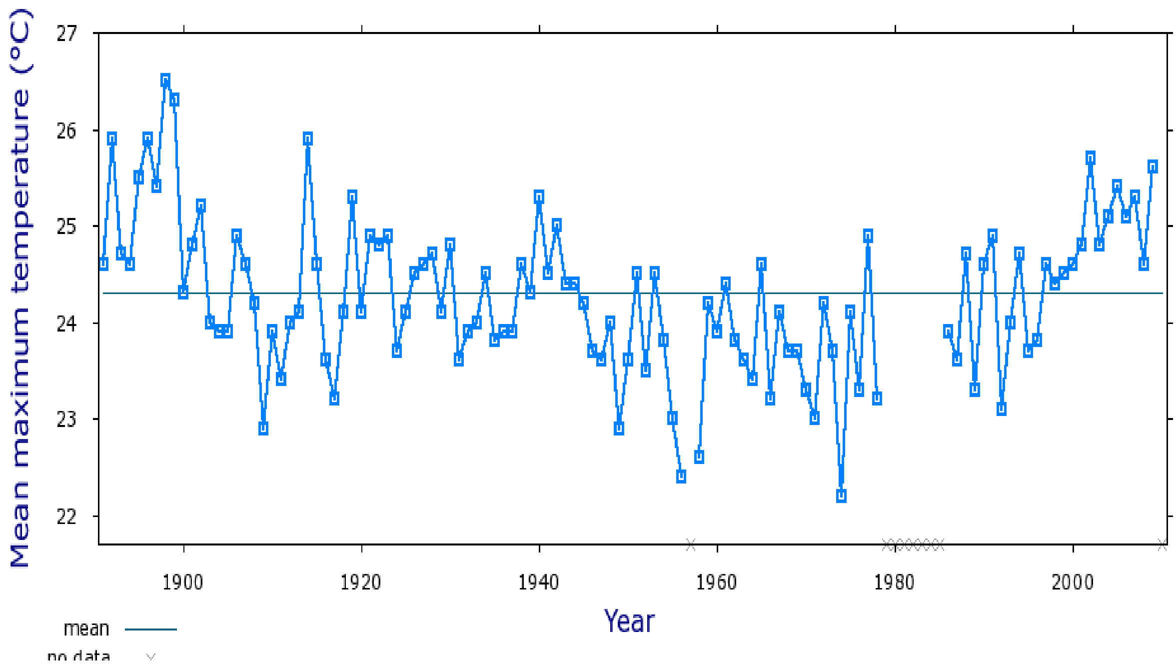
The Broken Hill location is characterised by a hotter and drier climate than the rest of New South Wales. Aridity in Broken Hill is associated with its remoteness from ocean effects and the mountains that cut off the rainfall and ‘their associated moisture-bearing air masses’ (Broken Hill Operations PTY LTD-RASP MINE, 2010, P 3). The average daily minimum temperature is 5.3˚C, whereas the average daily maximum temperature is 32.7˚C. The mean July temperature is 14.5˚C and the mean Jan temperature is 31.1˚C (Table 5.1).

	Daily maximum temperature (°C)	Daily minimum temperature (°C)	9 am		3 pm	
			Mean (°C)	Humidity (%)	Mean (°C)	Humidity (%)
Jan	32.7	18.4	23.5	44	31.1	28
Feb	32.2	18.2	22.8	48	30.5	30
Mar	29.0	15.5	20.2	51	27.7	32
Apr	23.9	11.8	16.4	58	22.9	39
May	19.1	8.5	12.5	69	18.1	48
Jun	15.6	6.2	9.4	77	14.9	54
Jul	15.1	5.3	8.7	74	14.5	50
Aug	17.3	6.3	10.5	64	16.5	41
Sep	21.0	8.8	14.1	55	20.2	34
Oct	24.9	11.7	17.4	47	23.5	30
Nov	28.6	14.7	20.2	44	26.8	27
Dec	31.4	17.1	22.6	42	29.7	27

(Table 5.1) Climate Data for Broken Hill / 1889-2007

(Source: Broken Hill Operations PTY LTD-RASP MINE, 2010, P 3)

The temperatures in Broken Hill have experienced increases over recent years as a likely result of climate change (Figure 5.2). This has led to an increase in the level of evaporation and this combined with the drought to increase aridity. As a result, water stress has increased in Broken Hill in recent years.

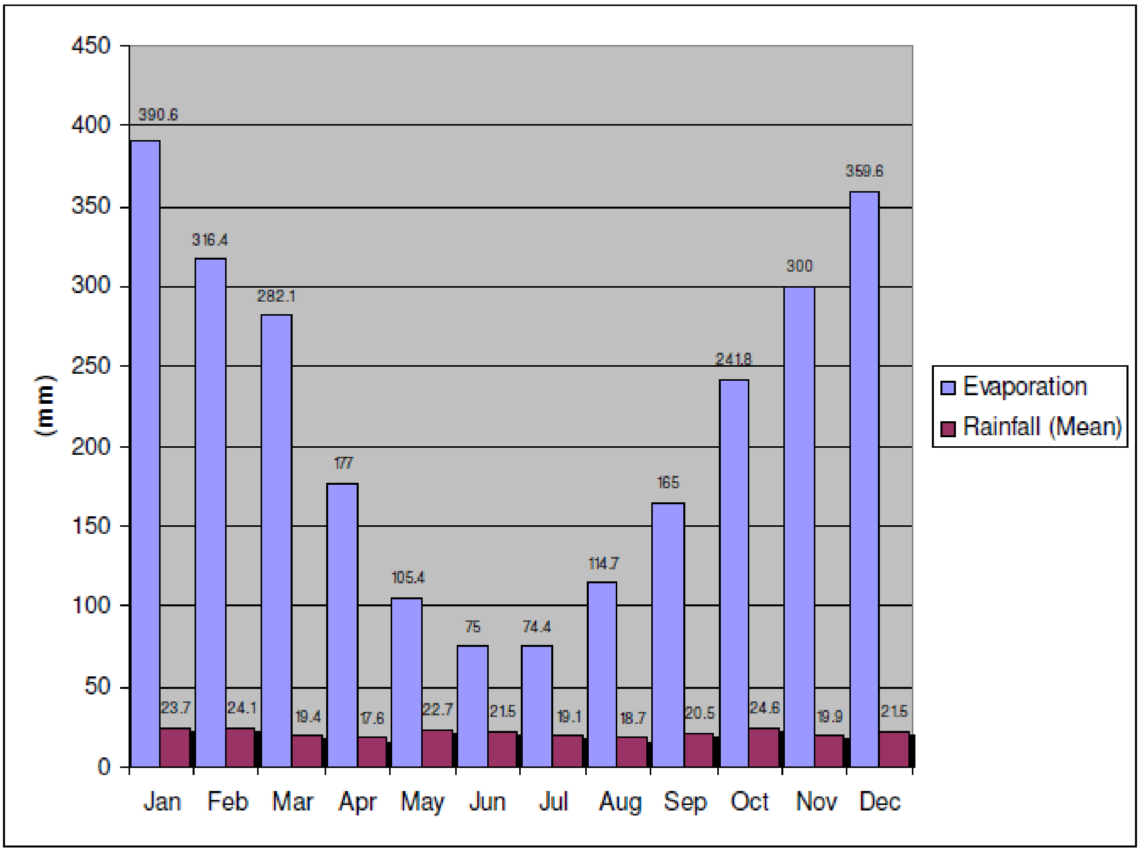


(Figure 5.2) Mean Maximum Temperature (°C) In Broken Hill

(Source: www.bom.gov.au/climate/data/)

5.3.2 Trend in Rainfall and Evaporation

The average number of rainy days in Broken Hill is 34 per year. However, this number of rainy days is affected by the drought that has affected Broken Hill in recent years as part of climatic changes, compared with 48 days per year based on the long term rainfall data. On average, the wet month is October with monthly average rainfall of 24.6 mm, whereas the driest month is April with a monthly average rainfall of 17.5 mm (Broken Hill Operations PTY LTD-RASP MINE, 2010, P 3) (Figure 5.3).

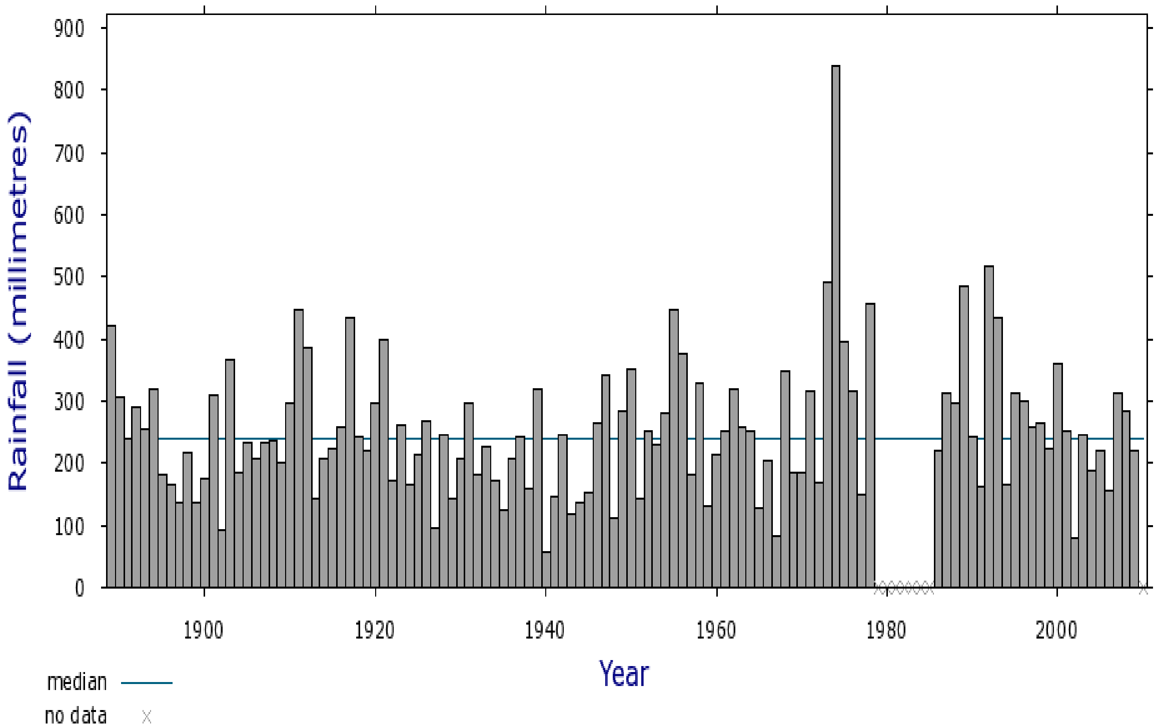


(Figure 5.3) Average Monthly Rainfall and Evaporation / Broken Hill

(Source: Broken Hill Operations PTY LTD-RASP MINE, 2010, P 4)

The highest rates of evaporation happen during October continuing until March. The monthly average of evaporation is in the range of 241 mm to 391 mm. In Broken Hill 'the annual average evaporation exceeds annual precipitation by 2356 mm' (Broken Hill Operations PTY LTD-RASP MINE, 2010, P 3). In recent years, it has experienced frequent drought. This is because of low levels of rainfall and an increase in the temperature. Therefore, climatic changes have caused a lowering of quantity and quality of water in Broken Hill. The average rainfall in Broken Hill is 247.65 mm per year. Historically, the climate variability has affected the amount of rainfall. For example, in 1888, the average of rainfall was only 89 mm for the year; 50.8 mm only was registered in early February leaving 38 mm for the rest of the year.

Between 1888 and 1952, Broken Hill was exposed to five drought events each of those continuing two to five years (Albrecht et al., 2010, p 11). Drought led to generation of the water crises of the 1940s and 1950s. During 2002 and 2003, the view again reaches a critical point (Figure 5.4). Therefore, Broken Hill has experienced a declining water supply over time as a result of frequent drought.

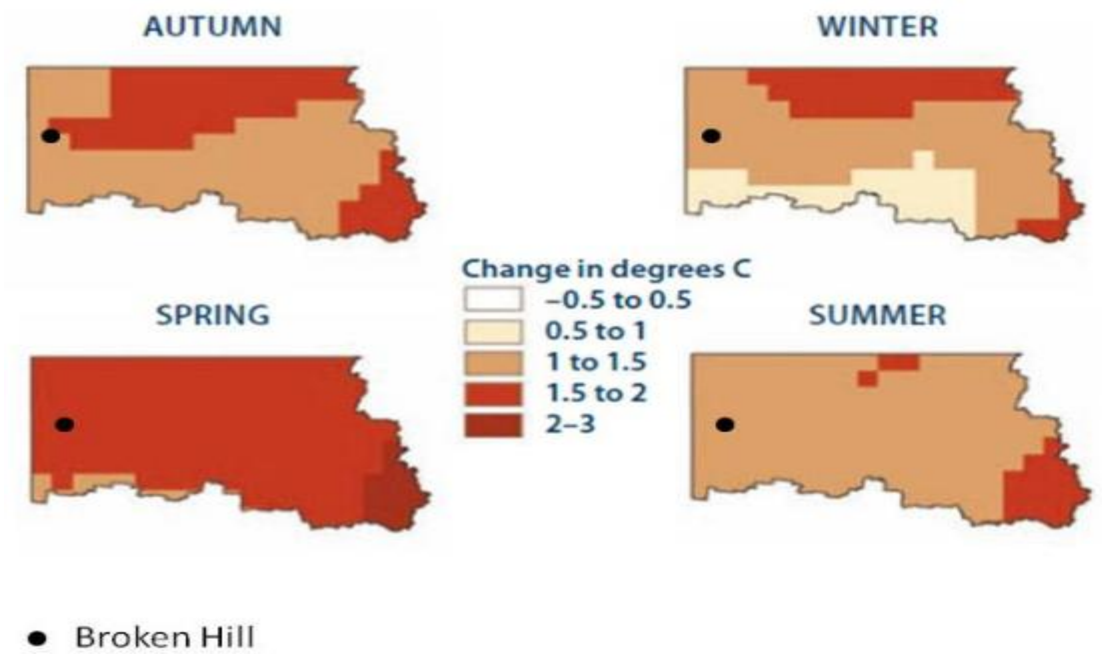


(Figure 5.4) Average Annual Rainfall for Broken Hill

(Source: www.bom.gov.au/climate/data/)

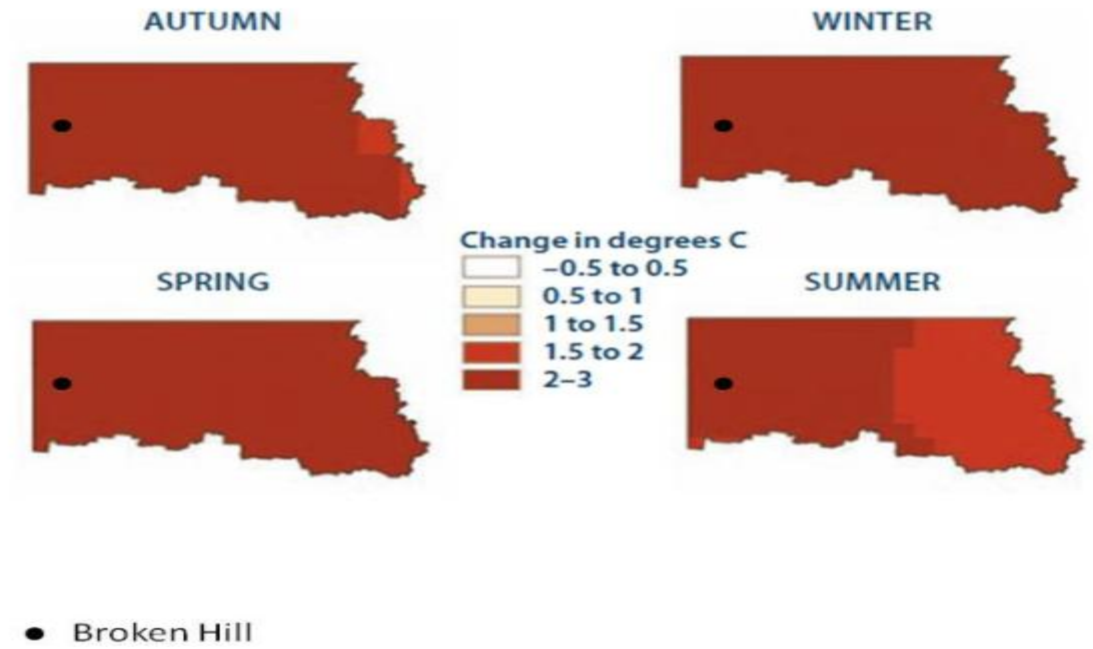
5.3.3 Climate Projections

The average minimum temperatures are projected to increase by between 0.5˚C and 2˚C for the western region of New South Wales by 2050 (where Broken Hill is located), depending on the season (Figure 5.5).



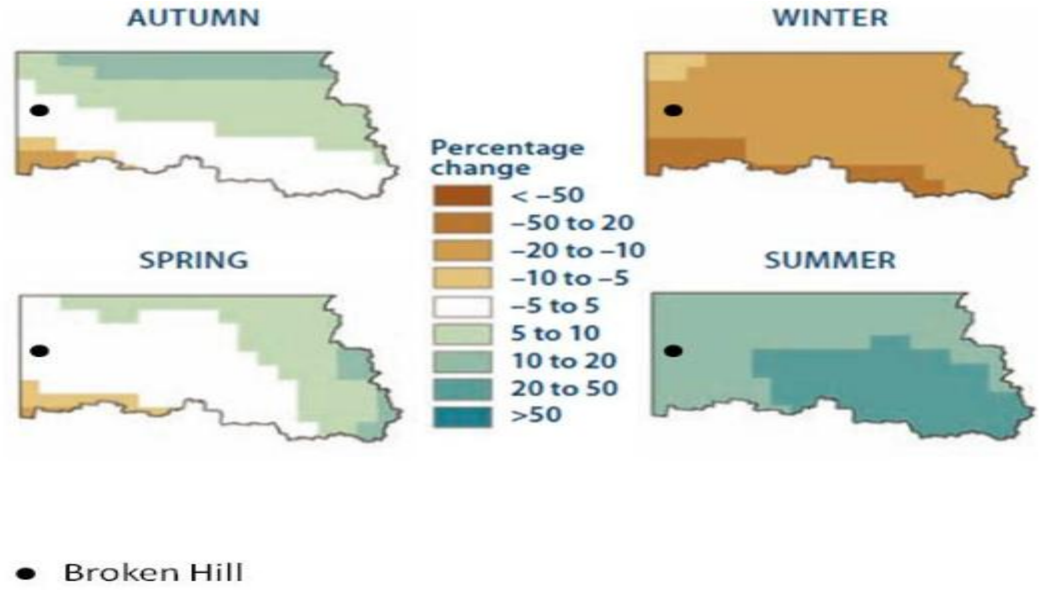
(Figure 5.5) Minimum Daily Temperature Projection for western NSW by 2050 (where Broken Hill is located) / (Source: Department of Environment and Climate Change NSW, 2008, p 2)

Maximum temperatures for western New South Wales (where Broken Hill is located) in autumn, winter and spring are expected to rise by 2˚C to 3˚C through the region by 2050. In addition, maximum temperatures in summer are expected to rise by 2˚C to 3˚C in Broken Hill by 2050 (Department of Environment and Climate Change NSW, 2008, p 2) (Figure 5.6).



(Figure 5.6) Maximum Temperature Projection for western NSW by 2050 (where Broken Hill is located) / (Source: Department of Environment and Climate Change NSW, 2008, p 2)

A moderate rise in rainfall is projected to happen in summer over most of the western region of New South Wales, while the winter is expected to experience a decline in rainfall (10-20%) by 2050 (Department of Environment and Climate Change NSW, 2008, p 2) (Figure 5.7). In spring and autumn, rainfall is projected to decrease slightly (Department of Environment, Climate Change and Water NSW, 2010, p 104).



(Figure 5.7) Seasonal Rainfall Projection for western NSW by 2050 (where Broken Hill is located) (Source: Department of Environment and Climate Change NSW, 2008, p 2)

5.3.4 Impacts of the El Nino -Southern Oscillation

The present knowledge about how climate change may be affected by the main drivers of climate variability, such as the ENSO phenomenon, is incomplete. However, 'the current scientific literature indicates that the pattern of climate variability associated with ENSO will continue under enhanced greenhouse conditions' (Department of Environment, Climate Change and Water NSW, 2010, p 104). This assessment supposes that the ENSO phenomenon will be ongoing to guide climatic changes across New South Wales.

ENSO years will continue to become drier than the average, but will also raise the mean temperature, resulting in more extreme effects. La Nina years are projected to become wetter than average, but will also raise the temperature. 'In El Nino events, water stress is likely to be more intense because of higher temperatures' (Department of Environment, Climate Change and Water NSW, 2010, p 104).

5.4 Broken Hill Population

5.4.1 Recent Population

Broken Hill has experienced population growth and decline depending on the different conditions of the mining industry. In 2006, the population was 19,401 which is less than the 1996 population at 21,399 (Table 5.2), whereas it was around 35,000 in 1915 (Broken Hill City Council, 2009, p 34).

	Population (1996)	Population (2006)	Rate of Growth (1996-2006)
Broken Hill	21,399	19,401	-0.98%
Catchment	25,517	22,847	-1.10%
New South Wales	6,081,847	6,642,774	0.89%

(Table 5.2) Population of Broken Hill

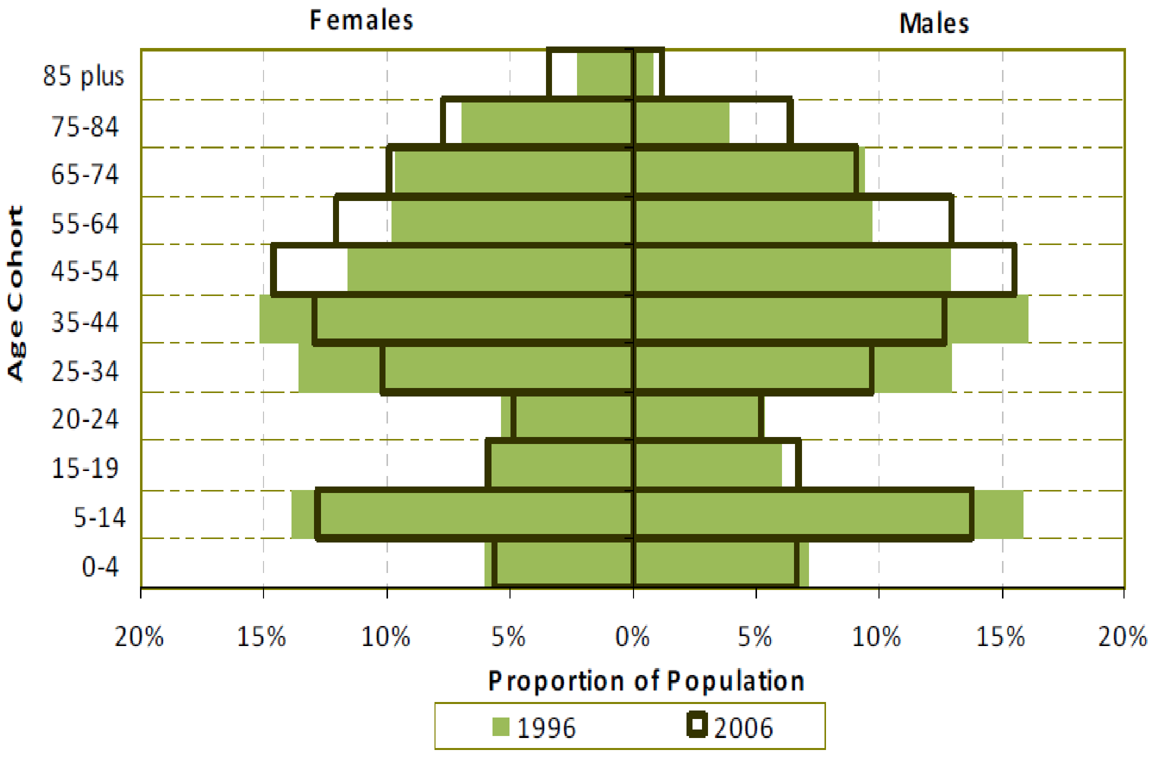
(Source: SGS Economics and Planning 2008)

Since 1996, the Broken Hill population has fallen by 22.1% over a decade but by 30% since 1971 (Broken Hill City Council, 2009, p 34). The long time drought and rural decrease across western New South Wales are resulting in greater effect on the wider population.

5.4.2 Population structure

The highest proportion of the population in Broken Hill is of people who have an age between 45 and 54. All age groups under 45 decreased between 1996 and 2006 (Figure 5.8). In addition, the number of people who are aged between 15 and 44 years is less than for the New South Wales average. Therefore, Broken Hill has an older population age structure and this is because of the migration of youth and young families away from the town (SGS Economics and Planning 2008).

In a comparison between Figure 5.8 (population age structure for Broken Hill) and Figure 5.9 (unemployment persons by age in Broken Hill), it seems clear that between 1996 and 2006, the lowest proportion of people after those aged 85 plus was those aged between 20 and 24 years, and yet at the same time those aged between 15 and 19 was the highest proportion of unemployment in Broken Hill. This could indicate that the town of Broken Hill has been unable to compensate for job losses in the mining industry and pastoral sector as a result of drought. In addition, this also indicates that the highest proportion of people who migrated out of Broken Hill was those aged between 20 and 24 as a result of the decrease in job opportunities. Moreover, people aged between 15 and 24 have been the most affected by decreasing job opportunities.



(Figure 5.8) Population Age Structure for Broken Hill

(Source: SGS Economics and Planning 2008)

5.4.3 Population Projection

According to a project by Broken Hill City Council (2009), there are three scenarios for population projections for Broken Hill and these are:

1- A low growth scenario indicated that the population of Broken Hill will decline from 20,223 in 2006 to 18,576 in 2015.

2- A high growth scenario refers to an increase from 20,223 in 2006 to 21,801 in 2015, as a result of increases in employment demand because of increasing private demand and investment.

3- A weighted growth scenario indicated that the population will stabilise at 2006 levels, rising slightly from 20,223 in 2006 to 21,188 in 2015.

5.5 Broken Hill Socioeconomic Conditions

5.5.1 Employment and Incomes

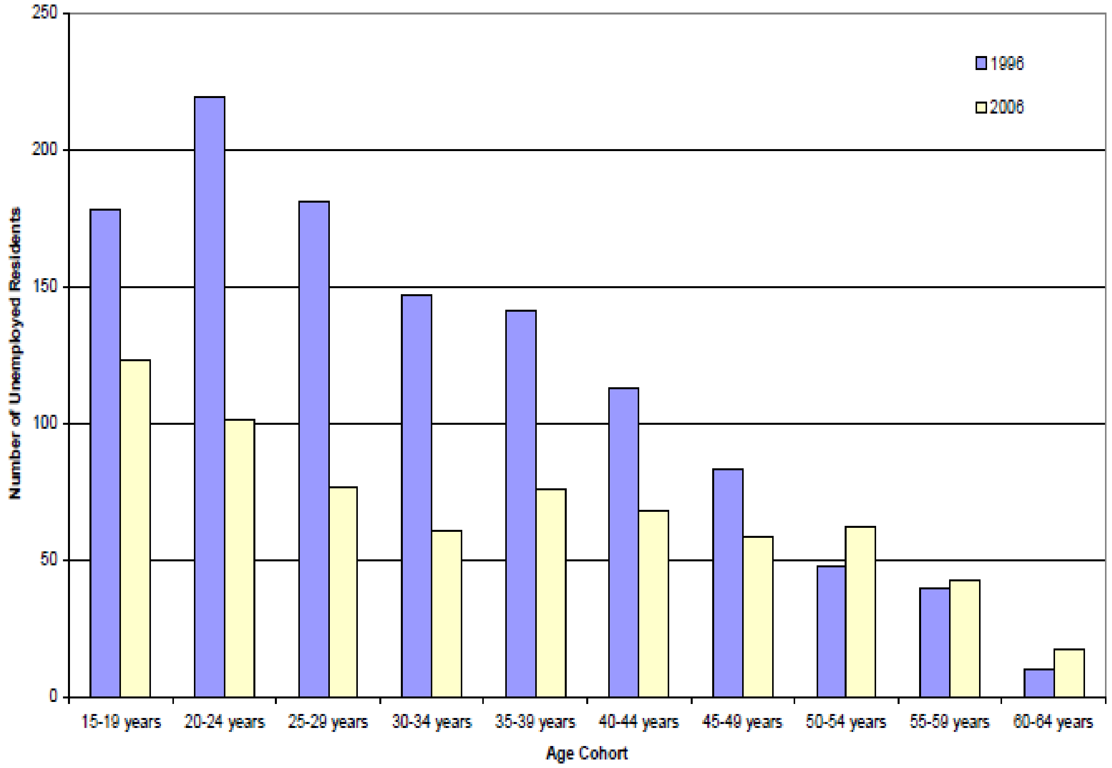
The number of people who had jobs in Broken Hill was 6,879 persons in 2006. The total number of people who were unemployed in Broken Hill was 687 (9.1%). This proportion can be considered high compared to the proportion of people who were unemployed in New South Wales (5.9%) (SGS Economics and Planning, 2008, p 11) (Table 5.3).

		Broken Hill		Catchment		New South Wales	
		No.	%	No.	%	No.	%
Employed	Full-time(a)	4,179	55.20%	5,147	57.10%	1,879,628	60.80%
	Part-time	2,151	28.40%	2,425	26.90%	842,713	27.20%
	Employed, away from work	324	4.30%	397	4.40%	103,525	3.30%
	Hours worked not stated	225	3.00%	269	3.00%	83,578	2.70%
	Total Employed	**6,879**	**90.90%**	**8,238**	**91.30%**	**2,909,444**	**94.10%**
Unemployed	Full-time work	493	6.50%	558	6.20%	115,165	3.70%
	Part-time work	194	2.60%	225	2.50%	67,994	2.20%
	Total Unemployed	**687**	**9.10%**	**783**	**8.70%**	**183,159**	**5.90%**
Total labour force		7,566	48.60%	9,021	50.30%	3,092,603	58.90%
Not in the labour force		6,890	44.30%	7,627	42.60%	1,801,010	34.30%
Labour force status not stated		1,107	7.10%	1,272	7.10%	356,648	6.80%
Total		**15,563**	**100%**	**17,920**	**100%**	**5,250,261**	**100%**

(Table 5.3) Labour Force Statistics for Broken Hill

(Source: SGS Economics and Planning, 2008, p12)

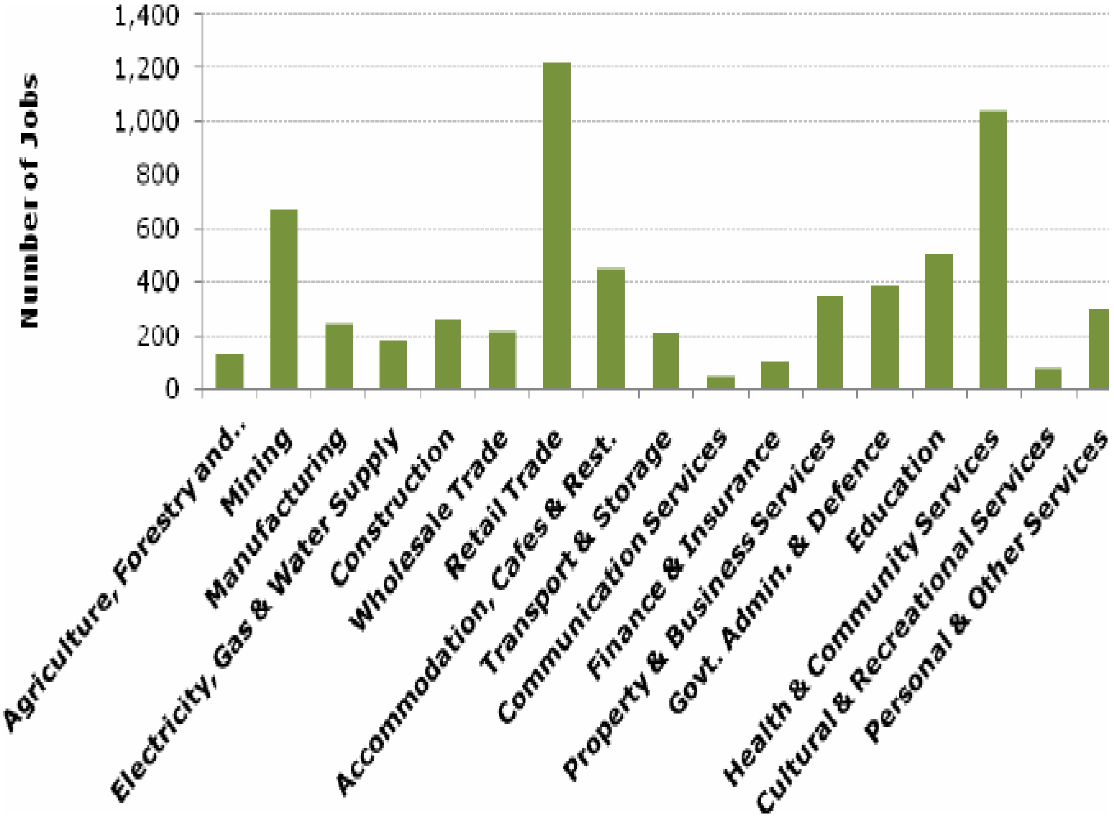
Unemployment rates were highest among young persons (20-24 years) (Figure 5.9). However, the number of unemployed persons who aged 20-24 reduced by 54% between 1996 and 2006, whereas the total population of this age decreased by less than 1% (SGS Economics and Planning, 2008, p 12). Unemployment rates decreased in all labour force age groups between 1996 and 2006.



(Figure 5.9) Unemployed Persons by Age in Broken Hill (1996-2006)

(Source: SGS Economics and Planning, 2008, p 13)

Broken Hill's retail trade businesses included the highest proportion of people who were employed in 2006 at 1,224 persons (Figure 5.10). 'This is closely followed by the Health and Community Services industry, which employs over 1,036 persons' (SGS Economics and Planning, 2008, p 16). Over the previous 20-25 years, the mining sector in Broken Hill experienced declining. Therefore, the employments have shifted over the decade from mining industry to service sectors.



(Figure 5.10) Employment by Industry in Broken Hill (2006)

(Source: SGS Economics and Planning, 2008, p 16)

The household income for 2006 indicated that Broken Hill households had lower incomes than for New South Wales as a whole. More households in Broken Hill have incomes of less than $800 per week, whereas many households in New South Wales have incomes of more than $800 per week. In addition, Broken Hill has a higher number of people who have low individual income. 'Data for median weekly individual incomes confirm this trend, with a 2006 median weekly individual income of $334 for Broken Hill and $461 in NSW' (Broken Hill City Council, 2009, p 43).

5.5.2 Tourism

In recent years, the tourism industry in Broken Hill has experienced growth and it has participated more in the local economy as a powerful economic source. 'A study of tourism in Broken Hill has shown that the city's mining activity, history of unionism, remoteness, and the surrounding natural attractions, are the main areas of tourist interest' (Broken Hill City Council, 2009, p 88).

The tourism industry represents an alternative for employment that may balance the loss from mining industry. Therefore, tourism has become more important to the local economy.

5.5.3 Mining

Broken Hill has large deposits of silver, lead and zinc and the mining industry has played a vital role in the local economy. Over the previous 20-25 years, the mining sector experienced decline. In addition, the profitability of the mines in Broken Hill depends on the price of metals in the world market. 'Despite the observed dependence of Broken Hill on mining and related industries, the pattern-although weak- is broadly indicative of a shift over the decade from 'traditional' to service sector' (SGS Economics and Planning, 2008, p 14). However, the town has been unable to compensate for job losses as a result of weakness in the mining industry. Therefore, it has experienced a decline in its population and out-migration of the youth and younger families. For example, the population of Broken Hill has fallen by 30% since 1971 as a result of weakness in the mining industry (Broken Hill City Council, 2009, p 34).

5.5.4 Educational Attainment in Broken Hill

The educational attainment of students in Broken Hill is less than in New South Wales as a whole. In a comparison between the educational attainment of students in Broken Hill and NSW as a whole, whilst the proportion of people who completed Year 10 and were aged 20 and over was 18% based on the 2006 census, it was 44% in NSW as a whole. 'Moreover, of those who have not completed Year 12, only 50% have completed Year 10, compared to 54% for NSW overall' (Broken Hill City Council, 2009, p 46). If the migration continues, especially for youth and young families, the aging of the population in Broken Hill will increase, which will in turn affect the development of education and skills. This is because the proportion of elderly people, who have less ability to improve their education and who lack skills, will increase. As a result, the proportion of unemployment will increase as well. All of these factors could cause low levels of adaptive capacity to the impacts of climate change in the town of Broken Hill.

5.6 Climate Change and Water Supply in Broken Hill

Climatic changes of the past influenced the Aboriginal history in this region. Based on the exploration of Aboriginal archaeological sites at Lake Mungo there is evidence that Aboriginal people have occupied this region since 45,000 years ago (Albrecht et al., 2010, p 8). At that time, the water covered the lakes of Murray Basin and Willandra Lake region.

Around 21,000 years ago the lakes started to dry, coinciding with the apex of the last Glacial Maximum (ice age). The land became hyper arid and saline because the temperature decreased. Finally, the Willandra and Menindee lakes became dry. In response to climate change, the Aboriginal people departed the drying lake regions to look for water resources within the Darling and Murray rivers (Albrecht et al., 2010, p 8). As the Glacial Maximum dropped, temperature and rainfall started to a steady change to the modern day average. At

that time, the Willandra lakes remained permanently dry, because it was distant from the infrequent flood run off, whereas the Menindee lakes still had water and its shores had a higher population than ever. The Aboriginal people responded to the changing climate. For example, in different positions in the Western District of Victoria, ‘an area characterised by drought and flood, fish weirs were constructed to store water in the summer and regulate the system during times of flood’ (Albrecht et al., 2010, p 9).

Because there are no natural permanent water bodies to supply water for Broken Hill, the town receives water through a pipeline from the Darling River at Menindee and from the manmade reservoir at Stephens Creek. Water is pumped from Menindee Lakes over 116 km to Broken Hill.

There are three local sources of water managed by Country Water and these are:

1- Stephens Creek Reservoir that is located 16 kilometres from Broken Hill. The capacity of this reservoir is 20,000 ML.

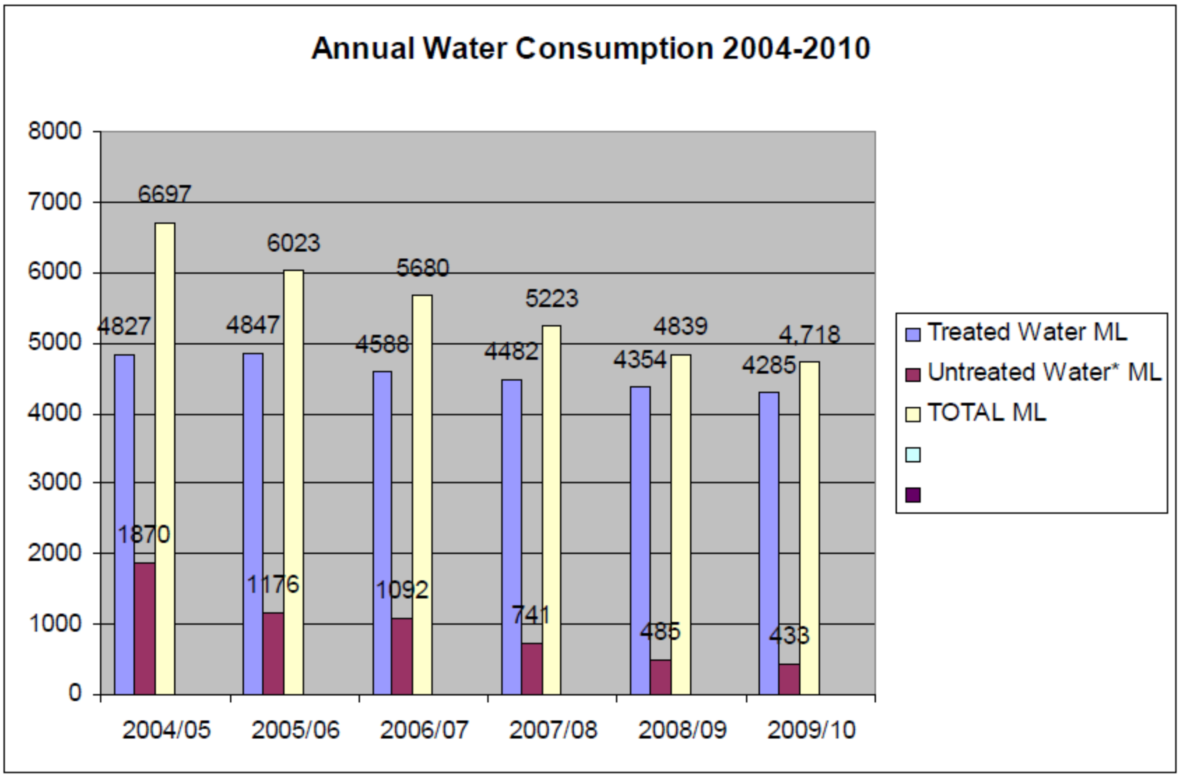
2- Umberumberka Reservoir that is located 28 km North West of Broken Hill. The capacity of this reservoir is 7,800 ML.

3- Imperial lake is a small reservoir that collects water from its own catchment. The capacity of this reservoir is 670 ML (Broken Hill City Council, 2010, p 12).

Water supply from these reservoirs is characterised by high variability because it is dependent on the amount of rainfall over the local catchment area (Broken Hill City Council, 2010, p 13). High evaporation levels from ‘Country Waters’ supply sources have a major effect on water security. Therefore, climate change has affected the quality and quantity of water in Broken Hill. Although the low amount of rainfall in the Broken Hill region has limiting effect on the town itself, water supply has been a steady factor in the development of Broken Hill.

Over the long term, the Broken Hill region has experienced frequent drought and the water was transported to Broken Hill from Darling River by train until the establishment of a pipeline constructed in 1952. However, drought following the establishment of the pipeline project caused a decrease in water availability and quality. ‘In 2002-2003 the city of Broken Hill almost ran out of water and the resumption of bulk water imports by train was being seriously considered’ (Albrecht et al., 2010, p 7). More severe drought that is expected in the future as a result of climate change may cause greater impacts on the Broken Hill population, especially when the low water supply combines with temperature increases based on climate projections. In addition, the population of Broken Hill is highly dependent on the evaporative air conditioning systems that use high amounts of water (Albrecht et al., 2010, p 17). However, the people of Broken Hill have the experience to deal with low water supply. This may represent a high adaptive capacity to the impacts of climatic changes. Broken Hill City Council has improved a community water education program in order to enhance the saving of water. In addition, participating with the local community, Country Waters has achieved several innovative demand management and water efficiency education programs. This led to

a reduction in total water consumption by 22% during 2004 to 2008 (Figure 5.11). For example, the water consumption was 4285 ML for treated water and 433 ML for raw water between 2009 and 2010, whereas the water consumption in 2001 was 7000 ML (Broken Hill City Council, 2008, p 13).



(Figure 5.11) Annual Water Consumption in Broken Hill 2004-2010

(Source: Broken Hill City Council, 2010, p 14)

5.7 Government Policy and Water Supply in Broken Hill

In order to achieve cooperative investigation and consequent achievement of the water reform programs in New South Wales, a Memorandum of Understanding was signed by the Commonwealth and New South Wales Governments in July 2010. This investigation will consider the water supply of Broken Hill's urban region and the operational management of Menindee Lakes (NSW Office of Water, 2010, p 12). Both governments have accepted that changing the current measures should take into account three main issues:

1. The water supply for the town of Broken Hill should be secure.

2. The environmental and heritage values must not decrease for the Menindee Lakes.

3. The water supply reliability must not decrease for the Murray River and Lower Darling (NSW Office of Water, 2010, p 12).

The main purpose for this Memorandum of Understanding is that changing the current operating measures of the Menindee Lakes can decrease the high level of evaporation losses in order to provide water for different uses within the Murray-Darling Basin (NSW Office of Water, 2010, p 12).

Further, the New South Wales and Commonwealth Governments have been committed to 'considering an alternative water supply for Broken Hill by means of a managed aquifer recharge scheme and hydrological work' (NSW Office of Water, 2010, p 12). In addition, the Darling River Water Saving Project (DRWSP), an action of the State Government of New South Wales and the Commonwealth of Australia, has as one of its aims to secure Broken Hill's water supply. 'A budget of up to $400 million was committed to address problems such as evaporation and water storage in the Menindee Lakes to achieve that end' (Albrecht et al., 2010, p 30). In addition, local government policy has been successful in reducing total water consumption in Broken Hill by applying adaptation programs, such as a community water education program, to cope with the impacts of climate change.

5.8 Likely implications of, and Adaptive Capacity to, Climate Change in Broken Hill

Historically, Broken Hill has been affected by several droughts. Based on international climate change models, as demonstrated by the IPCC 4th Assessment Report (2007), the CSIRO has projected that the entire Murray Darling Basin by 2030 will experience reduction in surface water by around 11-15% (Albrecht et al., 2010, p 19). In addition, rainfall in the winter season is likely to decrease and evaporation rates are likely to rise as a result of temperature increases.

It seems clear that the high end projections for temperature are likely to happen since the IPCC 4th Assessment Report publication. Therefore, high temperatures and shortage of water are the major impacts of climate stress on the town of Broken Hill. In addition, the water supply represents a very limiting factor in the future of Broken Hill's development and growth. Therefore, the population of Broken Hill needs a high adaptive capacity or resilience to the impacts of climate change.

Further, Broken Hill has an older population age structure because of the migration of youth and young families. This represents a low adaptive capacity to the impacts of climate change based on demographic indicators, especially when older people cannot cope with shortages of water, temperature increases and health risk, such as heat stress. Moreover, the population of Broken Hill is highly dependent on the evaporative air conditioning systems that use high amount of water (Albrecht et al., 2010, p 17). Therefore, older people in Broken Hill can affect the low water supply in the future as a result of climate change. In addition, the cost of water is expected to increase by 10% per annum over the next three years as a result of water shortage.

Further, the NCCARF (2010) indicated that 'the mines heavily subsidise water prices at present and the removal of this support will expose residents to the full cost of maintaining

and upgrading water supply infrastructure' (NCCARF, 2010, p 12). This will affect the population in Broken Hill, especially when the households of Broken Hill have incomes less than those in New South Wales and the number of people who have no work in Broken Hill is more than those in New South Wales. This represents low adaptive capacity to the impacts of climate change based on economic indicators of adaptive capacity. However, 'with improving conditions for metals globally, Broken Hill will continue to dominate western NSW as the only significant population centre' (Broken Hill City Council, 2009, p 34). In addition, Broken Hill population has experienced low water supply for a long time under several severe droughts.

Climate change and its impacts on water supply in Broken Hill have been considered by the three levels of government (the Federal, State and Local governments). Adaptation strategies to climate change have been adopted in government policies, such as a community water education program that has been successful in reducing the total water consumption in Broken Hill. This represents high level of adaptive capacity to climate change based on government policy indicators. However, Broken Hill City Council should develop a suitable adaptation plan to the impacts of climate change in order to minimize these impacts on the different sectors, such as education, health and economic sectors.

It seems clear that there is different weighting between the two case studies Mildura LGA and Broken Hill; the first irrigation settlement created in the lower Murray Darling Basin was located in Mildura. The Mildura LGA is growing as a result of its vital role as a regional centre and its strong agricultural base. In order to add value to its regional service centre, Mildura has adopted many manufacturing sectors. In addition, the tourism sector has become an important industry in the town of Mildura. Therefore, Mildura has become a regional service centre for regional Victoria, South Australia and New South Wales and has experienced an increasing population. In contrast, the population of Broken Hill has experienced a decline over past decades as a result of the decline in the mining industry.

While, the agricultural sector has declined in Mildura as a result of drought, the population has increased in the town. The Victorian Government Department of Sustainability and Environment (DSE) expectations for Mildura suggest that the population of Mildura will increase to about 67000 people by 2031. In addition, Mildura covers around 22,214 square kilometres, whilst the town of Broken Hill includes just fewer than 179 square kilometres. Moreover, Mildura has much more information available. Therefore, it is possible to discuss changes in greater detail. Broken Hill provides a comparison of different circumstances and location, but as a smaller town with less information available, it is not possible to treat it in as much detail as Mildura.

Chapter 6

Discussion

6. Discussion

6.1 A Comparison of Mildura and Broken Hill

The Mildura LGA is located in Victoria's north-west on the Murray River and covers around 22,214 square kilometres, whilst the town of Broken Hill includes just fewer than 179 square kilometres and is located in western New South Wales. Broken Hill lies 1,160 kilometres west of Sydney, near to the South Australian border and about 500 kilometres north-east of Adelaide. The Mildura LGA has experienced increases in its population over time. This can be interpreted as being a result of the growth in the agriculture sector, which has provided the employment opportunities that were the main reason for the population increases in the Mildura LGA. In addition, another economic factor has attracted people to migrate to Mildura; the cost of living in the Mildura region is less than for many parts of Australia, including the capital cities. Whilst the population of Mildura increased by 40% between 1976 and 2006, the population of Broken Hill decreased by 30% over the same period as a result of the decline in the mining industry.

Furthermore, people aged between 10 and 14 years represented the highest proportion of Mildura's population (4,748 persons or 8.1%) in 2006. In contrast, all age groups under 45 decreased between 1996 and 2006 as a result of the migration of youth and younger families to find jobs away from Broken Hill. The highest proportion of the population in Broken Hill is thus of people who are aged between 45 and 54. The younger age structure of Mildura's population will therefore be a strong factor in the development of Mildura. In contrast, the elderly age structure of Broken Hill may cause limitations in the development of Broken Hill.

The Mildura LGA is located within the Mallee, which is considered the driest and hottest region in Victoria (Mildura Planning Taskforce, 2009, p 21). The average annual rainfall of 292 mm can be seven times less than the potential annual evaporation within the Mallee, which is a semi-arid area (Mildura Development Corporation, 2006, p 113). Similarly, the Broken Hill location is characterised by a hotter and drier climate than the rest of New South Wales. The average rainfall in Broken Hill is 247.65 mm per year. In Broken Hill, 'the annual average evaporation exceeds annual precipitation by 2356 mm' (Broken Hill Operations PTY LTD-RASP MINE, 2010, P 3).

The Mildura region is considered to be one of the most important areas for agribusiness. While the irrigated agriculture sector has remained the most important economic source for Mildura, Broken Hill has large deposits of silver, still and zinc and the mining industry has played a vital role in the local economy. However, between 2001 and 2006 employment

trends in the Mildura LGA shifted as a result of the drought. During this period the highest proportion of employment shifted from the agriculture sector to retail trade.

Similarly, the mining sector in Broken Hill has experienced a decline over the past 20-25 years. As a result, employment has shifted over the decades from the mining industry to the service sectors, especially retail trade. Both towns have been affected by climate change; in particular the impacts of climate change on water resources. The Mildura LGA has experienced frequent droughts over the last decade. This has caused the reduction of water for irrigation in Mildura. Similarly, the Broken Hill region has experienced frequent drought over the long term. Therefore, high temperatures and shortage of water are the major impacts of climate stress on the town of Broken Hill.

6.2 A Comparison of Adaptive Capacity between Mildura and Broken Hill

In terms of applying socioeconomic indicators of adaptive capacity to climate change to these two desert towns, the town of Mildura has provided jobs for its population, whereas the rural areas of Mildura have experienced a decline in jobs and income as a result of a decline in agriculture opportunities. This could indicate low adaptive capacity to climate change in the rural areas of Mildura based on socioeconomic indicators. In addition, this can affect other sectors due to financial constraints from the drought and low water allocation as a result of government policy, such as educational attainment, which represents another indicator of adaptive capacity. This is because life opportunities, health levels and the workforce, which in turn enhance adaptive capacity, can be provided by increasing educational attainment. Therefore, the relationship between socioeconomic indicators and the indicator of educational attainment is multidimensional.

Although the drought and low water allocation have affected the Mildura LGA in general and rural areas in particular, improvements have occurred in educational attainment between 2001 and 2006 across the Mildura LGA (Aarons and Glossop, 2008, p 33). For example, high school completion rates have increased between 2001 and 2006 throughout Mildura, including rural areas. This indicates greater adaptive capacity in the Mildura LGA. In addition, qualification levels have increased between 2001 and 2006 throughout the Mildura LGA. For example, the number of people who attained a high level of qualification increased by 24.5% between 2001 and 2006 (Mildura Development Corporation, 2009, p 33). This could indicate that the rural communities in Mildura have a good ability to recover from the impacts of drought by developing their education. In addition, this represents high adaptive capacity to climate change based on the educational attainment indicator.

In contrast, the town of Broken Hill has been unable to compensate for job losses as a result of weakness in the mining industry and the impacts of drought on the pastoral sector in rural areas of Broken Hill, because job diversity is limited in Broken Hill. This has led to a decrease in employment opportunities and income resulting in out-migration of youth and younger families, especially in recent years following weakness in the mining industry. This has led to an increase in the proportion of elderly people in the population, who have less

ability to adapt to the impacts of climate change such as shortages in water supply and increased heat stress. This indicates low adaptive capacity based on demographic indicators.

Further, declining job opportunities as well as population migration and structure have affected educational attainment in Broken Hill. This is because these factors have resulted in low attendance in schools, which has in turn affected the levels of education in Broken Hill and the qualifications of the community. For example, ‘only 18% of those aged 20 and over in Broken Hill have completed Year 12, compared to 44% in NSW as a whole’ (Broken Hill City Council, 2009, p 46). This represents low adaptive capacity based on the educational attainment indicator. In contrast, the population of Mildura has steadily increased over time. The town has had the ability to retain its population and has provided services such as education, health and recreation.

Furthermore, the population structure in Mildura has been characterised by youth and younger families who have the ability to adapt to the impacts of climate change. This represents high adaptive capacity based on demographic indicators. Moreover, this increase in population can lead to a broader range of qualifications. In this case, the diversity of qualifications can enhance the adaptive capacity to climate change. Indeed, youth and younger families in Mildura have a greater ability to improve their education than elderly people in Broken Hill. This represents high adaptive capacity based on the educational attainment indicator.

Although the socioeconomic aspects of the rural communities in the Mildura LGA have been affected by the drought and low water allocation as well as overproduction of some crops, such as wine grapes, ‘The farming communities in the region have displayed great energy and resources over time to build a range of community organisations, community events and social and recreational activities’ (Mildura Rural City Council, 2009, p 88). The rural communities of Mildura have displayed high levels of resilience and social cohesion and have shown great independence. In addition, ‘studies in society and culture reported the highest percentage growth in the proportion of persons with a certification in the field of study in the Mildura LGA’ (Mildura Rural City Council, 2009, p 70). This indicates that the population of the Mildura LGA has a greater adaptive capacity to climate change based on social and cultural indicators.

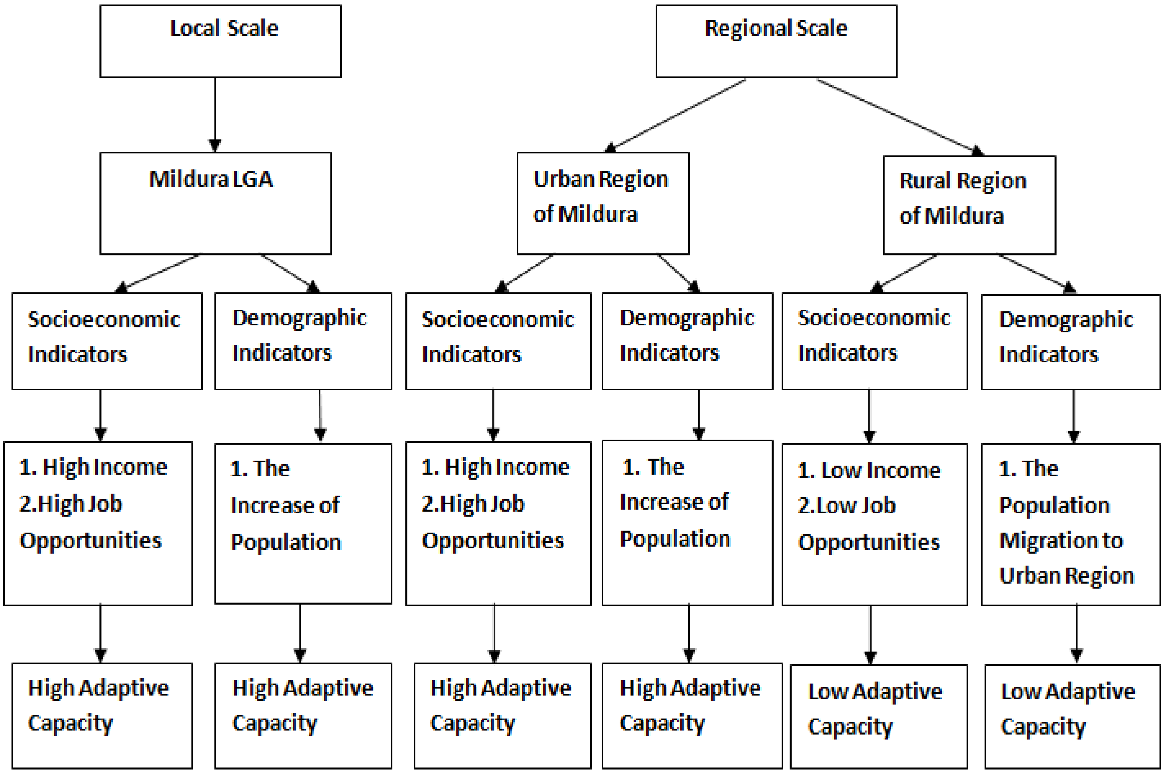
Furthermore, this could also indicate that government policy has been successful in reducing the impacts of climate change in the Mildura LGA. In contrast, the decline in the population of Broken Hill as a result of out-migration has caused the population structure to be altered, which has in turn affected social and cultural aspects. This could indicate low adaptive capacity based on social and cultural indicators.

6.3 Assessment of the Three Indicators as They Apply to Mildura

Although different models have been developed, an accurate measure for adaptive capacity still presents the main obstacle. In this section I argue that an ‘indicator approach’ is not the best way to analyse adaptive capacity to climate change. Rather on the basis of the evidence discussed in this case study, it is important to use a more contextual approach for a number of reasons. For example, the population increases in Mildura may represent high adaptive capacity in Mildura to the impacts of climate change based on the demographic indicators of adaptive capacity, but these indicators do not consider the reason for population increases. The ongoing drought might be the reason for people moving to the regional centres from its surrounding. In Mildura, the ongoing drought has led to an increase in the people migrating from its hinterland as they abandon agriculture (as this research has mentioned previously in chapter 4). As a result, this represents low adaptive capacity for Mildura's hinterland and the population increases in the town may exceed the ability of the town to retain them.

Also, the demographic indicators ignore natural additional people (births minus deaths) that happen whether there are climatic changes or not. It is therefore not accurate to use demographic indicators without analysis of the reason for the population increases or decreases and how this is related to the impacts of climate change. Such analysis is in order to achieve an accurate measure for adaptive capacity to climate change. In addition, demographic indicators do not demonstrate how adaptive capacity to climate change can be measured in cases where the rates and age structures of populations remain steady for a long time in the same region. Moreover, it is not accurate to assess the adaptive capacity to climate change based on the demographic indicators without considering the economic factor (which in its turn is affected by the climate factor) and its effects on the population size and distribution. This is because the economic factor plays a vital role in the population growth and migration.

Further, there are differences in the implications of the adaptive capacity indicators at the regional scale. For example, while the population and urbanisation increases in Mildura can be interpreted to represent high adaptive capacity to climate change based on the demographic indicators, agricultural abandonment, low employment opportunities and low income in the rural areas of Mildura as a result of ongoing drought may represent low adaptive capacity based on economic indicators of adaptive capacity to climate change. In comparison between the outcomes of demographic and socioeconomic indicators of adaptive capacity to climate change as they apply to Mildura, there are differences in the outcomes of applying these indicators at the regional scale (the differences in the outcomes between the rural and urban regions) comparing with the outcomes of those indicators as they apply at local (Local Government Area) scale. Whilst applying the demographic and socioeconomic indicators at the regional level (the rural and urban regions) has caused differences in adaptive capacity outcomes, these indicators have provided a perspective for the level of adaptive capacity at the local (Local Government Area) scale in Mildura (Figure 6.1).



(Figure 6.1) The Differences in the Outcomes of Indicators between Local and Regional Scales.

Further, in a comparison between the outcomes of the three indicators with the outcomes of the other cultural indicators, there are contradictions. Whilst the socioeconomic and demographic indicators have indicated low adaptive capacity in the rural areas of Mildura based on this research, the educational attainment and cultural indicators have indicated high adaptive capacity.

Also, there is uncertainty in predicting the future adaptive capacity by using the indicator approach. This is because, assessing the adaptive capacity based on the indicators of adaptive capacity is dependent on the previous conditions. Therefore, the outcomes represent the level of adaptive capacity of a previous period. Changing the climate conditions that are expected in the future may increase the vulnerability. For example, the population increases of Mildura in recent years may represent high adaptive capacity of a previous period, whereas if severe drought continues for a long time as part of climate change, the population of Mildura may migrate outside Mildura as people look for jobs as a result of decline in agriculture; that would reduce the adaptive capacity to climate change. In addition, the adaptive capacity indicators do not consider the variability and extreme events of climate which may weaken the ability to adapt to climate change. Moreover, extreme climate events are complex and difficult to predict.

As for the government policy indicators of adaptive capacity to climate change, government policy has a vital role in adaptive capacity to climate change. Government policy regarding water allocation for irrigation in the town of Mildura plays an important role in enhancing

adaptive capacity to climate change. Therefore, the government policy indicators represent a useful tool in assessing the adaptive capacity to climate change in the town of Mildura.

As for the economic indicators of adaptive capacity to climate change, these indicators do not consider the technical progress in the means which use to deal with the impacts of climate change. For example, in Mildura, local farmers have used efficient irrigation technology in recent years to adapt to climatic changes. This has led to an increase in the capacity to adapt to low water allocation as a result of the drought. Therefore, it is important to consider technical progress in order to achieve an accurate assessment for adaptive capacity.

Further, the economic indicators do not consider the cost of adaptation to climate change. More exposure to the impacts of climate change will increase the adaptation cost. This will affect the measure of adaptive capacity based on these indicators. In addition, the economic indicators of adaptive capacity to the impacts of climate change do not discriminate between economic activities in different contexts. For example, in Mildura, there are two types of agriculture; irrigated agriculture and dryland farming. Each has a different capacity to adapt to the impacts of climate change. Dryland farming is characterized by having more adaptation capacity to climatic changes than does irrigated agriculture. It is therefore not an accurate measure of adaptive capacity without consideration of the differences in the capacity of adaptation to climate change of different types of economic activities.

Also, the indicators of adaptive capacity to climate change do not discriminate between climate elements (such as the temperatures, rainfall, evaporation and wind) which have different individual impacts in different regions. For example, low rainfall for irrigation has more impact than temperature increases in agricultural regions; whereas the urban centres are more affected by temperature increases than low rainfall. Therefore, there is uncertainty in the application of the indicators of adaptive capacity to climate change.

6.4 Assessment of the Three Indicators as They Apply to Broken Hill

The relatively long term drought has caused rural population decreases across western New South Wales including the rural areas of Broken Hill. In addition, the population of Broken Hill has experienced a decline in recent years as a result of the weakness of the mining industry. On one hand, this refers to low adaptive capacity to climatic changes based on demographic indicators of adaptive capacity to climate change. On the other hand, population decreases in Broken Hill will lead to lower water consumption. This contradiction represents a weakness in the demographic indicators of adaptive capacity. This is because the demographic indicators do not consider the interaction between the environment and population. This represents contradiction in the demographic indicators of adaptive capacity to climate change if these indicators are used in such cases.

Further, demographic indexes may not always provide an accurate measure of adaptive capacity to climate change because rates and age structures of populations are unstable aspects which depend in turn upon many factors such as economy, culture, health and

migration. For example, the population of Broken Hill has fallen by 30% since 1971 as a result of weakness in the mining industry (Broken Hill City Council, 2009, p 34).

The economic indicators of adaptive capacity to climate change do not discriminate between economic sectors and they do not consider the economic transformations. For example, although the drought has affected the tourism sector, this sector is participating more in the local economy of Broken Hill as a powerful economic source. This may increase the adaptive capacity of the population of Broken Hill to climate change based on economic indicators, whereas the low incomes as a result of the weakness of the mining industry represents low adaptive capacity to climate change based on the same indicators.

Also, indicators of adaptive capacity do not consider the experiences in dealing with the impacts of climate change. Societies that have experience already have higher adaptive capacity to climate change than societies that have no such experience. For example, Broken Hill population has experienced shortage of water supply over time as a result of several droughts.

As for the government policy indicators of adaptive capacity to climate change, government policy has a vital role in adaptive capacity to climate change. Government policy regarding water supply in the town of Broken Hill plays an important role in enhancing adaptive capacity to climate change. Therefore, the government policy indicators represent a useful tool in assessing the adaptive capacity to climate change in the town of Broken Hill.

6.5 Problems Associated with Applying the Indicators of Adaptive Capacity

6.5.1 Difficulties in Application of Indicators in Different Contexts

Although researchers have tried to use several indicators of adaptive capacity in different contexts (e.g. rural areas, river basins and coastal areas), there is no specific indicator for a particular context. The impacts of climate change are different in different contexts. For example, coastal areas are most affected by sea level rise, whereas desert regions are most affected by low rainfall and temperature increases. This represents a challenge for the assessment of adaptive capacity. Even in symmetrical contexts, climate change may cause a number of variables (e.g. the cycle of flood and drought). Therefore, the difficulties of suitable indicator selection reflect uncertainty in the application of indicators of adaptive capacity to climate change. This is because it is difficult to determine exactly which indicator should be used to obtain an accurate measure of adaptive capacity in different contexts. Therefore, an inaccurate assessment of adaptive capacity to climate change can occur with each single indicator. It is important to examine climate stimuli and the vulnerability of societies to the impacts of climate change in depth and in a variety of contexts in order to develop appropriate indicators of adaptive capacity for a particular context.

6.5.2 Difficulties in Identification of Appropriate Scale

It is argued that there are different studies which have tried to derive and identify different indicators of adaptive capacity. However, methods of identifying and deriving the indicators

of adaptive capacity to the impacts of climate change are filled with uncertainties. The process of identifying appropriate models for a particular scale has remained vague. 'The challenge for emerging insights into adaptation is how to identify generic determinants of adaptive capacity at various scales' (Vincent, 2007, p 12). In addition, there are many factors that can affect the level of adaptive capacity in different scales.

At the regional and individual level, adaptive capacity to climate change is different and depends on many factors, such as the type of economic activity, policy, knowledge, experience, exposure and sensitivity of the social / ecological systems to the impacts of climate change. For example, based on this research (as mentioned previously in this chapter), using demographic and socioeconomic indexes as a tool to assess adaptive capacity at the regional scale (e.g. urban and rural regions) may not provide an accurate measure of adaptive capacity in Mildura and Broken Hill.

Even applying the demographic indicators at the regional scale (e.g. the Mildura region) may not provide an accurate measure of adaptive capacity for the whole society within this region. This is because the rate of population growth may vary in different parts of the same region. For example, in 2007-2008, the rate of population growth was 1.1% in the Mildura LGA; whereas in the same region (the Mildura region) and for the same period, the population of Wentworth Shire Council (which is located across the Murray River from Mildura on the northern side of the river) has remained comparatively steady (Mildura Planning Taskforce, 2009, p 22). Therefore, this research supports the point of view of the researcher (Vincent, 2007, p 12) who indicated that 'adaptive capacity is multidimensional: it is determined by complex inter-relationships of a number of factors at different scales'.

As for the assessment of adaptive capacity at the national scale, it is difficult to establish general indicators for adaptive capacity that can apply in different countries, because the determinants of vulnerability to climate change are different in different contexts around the world. For example, whilst demographic aspects can be considered as indexes for adaptive capacity to climate change, these aspects of population do not always indicate the level of adaptive capacity at the national level. This is because these aspects essentially vary from region to region even inside one country, and depend in turn upon many factors such as economics, technology, policy, culture and geographical location. Even taking into account all these elements in order to obtain an accurate measure of adaptive capacity, uncertainty in measuring adaptive capacity at a national level remains a major obstacle. This is because it is difficult to assess the interactions of those elements that affect the adaptive capacity of societies to climate change, especially when there are relationships between each of those factors. Therefore, this research conforms with the point of view (as has previously been mentioned in chapter 3) of the researchers Adger and Vincent (2005, p 399), who indicated that although health, governance, political rights, literacy and economic potential represent the indexes of adaptive capacity to climate change at the national level, 'the determinants of these variables at national levels are not widely understood' (Adger and Vincent, 2005, p 399).

Further, there are differences in the relationship between exposure and sensitivity to the impacts of climate change in many human activities around the world. Moreover, societies that have experience in dealing with the impacts of climate change already have a higher adaptive capacity than societies that have no such experience. However, as a result of the strength and ongoing expansion of the environmental problems that affect the earth's population around the world (e.g. climate change), global environmental politics and governance have experienced rescaling. There are two types of rescaling: vertical rescaling that represents the shifting of political action through geographical space from the local to the international level, and horizontal rescaling that represents the increasing numbers and types of players that are involved in environmental issues (Andonova and Mitchell, 2010, pp 255-256).

Although adaptive capacity can be measured in different scales, it is important to determine which scale is the most effective. Adopting a local scale could therefore be more effective in assessing adaptive capacity to climate change. It is difficult to assess adaptive capacity in large areas or scales, such as international, national or regional scales. This is because there are differences in the factors that affect adaptive capacity of societies to climate change, such as differences in demographic, socioeconomic or government policy or geographical location. In addition, the interactions of those factors will affect the adaptive capacity of societies. Therefore, this research supports the point of view of the researchers Patt et al (2005, p 411) who indicated, 'it is difficult, if not impossible to obtain data to test proposed interactions between different vulnerability drivers'.

Furthermore, it is argued that the majority of causes and implications of climate change have occurred at local scale. Research by Bulkeley (2005) indicated that the cities for Climate Protection program 'seeks both to rescale climate change as an issue with local causes and consequences' (Bulkeley, 2005, p 893). However, it is important to develop different indicators for different scales (from international to individual) by considering the factors that affect adaptive capacity in each particular scale.

6.5.3 Uncertainty in Measuring Adaptive Capacity to Climate Change

The main purpose for using indicators of adaptive capacity is to identify social / ecological systems that have less adaptive capacity to climate change, in order to enable decision-makers to adopt appropriate adaptation actions and build adaptive capacity. However, based on the basis of the evidence discussed in this case study, it seems clear that there is a high level of uncertainty in the measurement of adaptive capacity. This research argues that 'measurable indicators' are not appropriate to achieve an accurate measure of adaptive capacity to climate change. Therefore, the indicator approach is not the best way to analyse adaptive capacity to climate change. Therefore, it is difficult to evaluate the exact level of adaptive capacity by applying these indicators. Although the current indicators of adaptive capacity have a high level of uncertainty in their applications and outcomes, they have remained the only useful tool to assess the ability of social / ecological systems to adapt to the impacts of climate

change. This is because it is difficult to assess the vulnerability and adaptive capacity of social / ecological systems to climate change by relying on observation or estimation.

Chapter 7

Conclusion

7. Conclusion

As a result of the strength and ongoing expansion of the impacts of climate change around the world, the study of climate change and adaptive capacity to its impacts becomes more essential to address as well as the need to build adaptive capacity to climate change. Although many studies have focused on climate change and adaptive capacity to its impacts, most of these studies focus on developing countries and the capabilities of their societies to adapt to the impacts of climate change. There are in fact very few studies that have focused on developed countries, especially the desert towns of developed countries. Accordingly, this research and its discussion have focused on climate change and adaptive capacity to its impacts in two desert towns of Australia as a developed country.

This research has chosen two desert towns in Australia (Mildura and Broken Hill) to assess and compare adaptive capacity between these two desert regions. Both Mildura and Broken Hill have been affected by climate change, especially the impacts of climate change on water resources. This is because Mildura has been affected by a shortage of water for irrigation, while the water supply in Broken Hill has historically been affected by climate variables. Although there are several types of indicators of adaptive capacity to climate change, there are a number of problems associated with applying these indicators, such as difficulties in the application of indicators in different contexts, uncertainty in measuring adaptive capacity to climate change and selection of appropriate scale.

It seems clear that the contradictions in the outcomes represent a challenge for measuring adaptive capacity. Whilst the educational attainment and social and cultural indicators indicate high adaptive capacity in the Mildura LGA (both urban and rural areas of Mildura) based on this research, there are contradictions in the outcomes of adaptive capacity between the urban centre of Mildura and the rural areas that have been most affected by climate change when this research has applied the socioeconomic and demographic indicators. In a comparison between the outcomes of the socioeconomic indicators and educational attainment, whilst socioeconomic indicators such as employment and income have indicated high adaptive capacity in the urban centre of Mildura and low adaptive capacity in rural areas, the educational attainment indicator has indicated high adaptive capacity in both urban and rural areas of the Mildura LGA. Similarly, there were differences in the outcomes between the demographic indicators and the social and cultural indicators.

There were differences, therefore, in the outcomes of indicators in the same place. These variations depend on the level to which different aspects of the population, such as socioeconomic, demographic, educational and social and cultural aspects, which in turn determine the outcomes of the indicators, have been impacted by climate change. On one hand, applying several indicators, even in a small place, may lead to contradictory outcomes. On the other hand, measuring the adaptive capacity of a particular region by using one or two indicators may not provide an accurate measure for adaptive capacity because climate change may not affect some aspects whilst others might be affected.

In this case, it is difficult to determine which indicator might provide an accurate assessment for adaptive capacity. Moreover, it is difficult, if not impossible, to measure adaptive capacity on a large scale, such as a national or international level, when using the current indicators. This thesis argues that 'measurable indicators' are not appropriate to achieve an accurate measure for adaptive capacity to climate change. Therefore, this research proposes the following:

1. Taking into account climate stimuli and driving forces of social vulnerability, particularly in a variety of contexts, it is recommended that more accurate indicators of adaptive capacity be developed.
2. It is recommended that indicators of adaptive capacity to climate change for different scales (from international to individual) be developed by considering the factors that affect adaptive capacity in each particular scale.
3. It is recommended that a unit of measurement for adaptive capacity to climate change be created. This is because it is difficult to identify the level of adaptive capacity accurately without a unit of measurement. Indicators of adaptive capacity should therefore be designed to indicate an accurate number for the level of adaptive capacity when the indicators are applied in different case studies. In addition, such indicators of adaptive capacity would be more effective than the current indicators if the measuring of adaptive capacity were undertaken using a unit of measurement. Moreover, the comparing of levels of adaptive capacity over time would be more easily achievable by using a unit of measurement.

References

A NSW Government Initiative 2010, *Regional Plan 2010-2020*, accessed 25/10/2010, http:// www.rdafarwestnsw.org.au/downloads/RDA%20Far%20West%20NSW%202010-2020%20Regional%20Plan%20July%202010.pdf.-225.

Aarons, H and Glossop, B 2008, *Mildura Social Indicators Report 2008*, accessed 23/11/2010, *www.latrobe.edu.au/mildura/assets/.../MilduraSocialIndicators Report2008.pdf.*

ABARE 2006, *Outlook and financial performance of farms in the Mildura-Wentworth region*, accessed 20/11/2010, www.abareconomics.com*/publications_html/ conference/.../CP06_10.pdf.*

Adger, W and Vincent, K 2005, 'Uncertainty in adaptive capacity', *External Geophysics, climate and Environment*, vol.337, n.4, pp 399-410.

Adger, WN 2000, 'Social and ecological resilience: Are they related?', *Progress in Human Geography*, vol.24, n.3, pp 347-364.

Adger, WN and Kelly, PM: 1999, 'Social vulnerability to climate change and the architecture of entitlements', *Mitigation and Adaptation Strategies for Global Change,* vol. 4, pp 253–266.

Adger, WN, Arnell, NW and Tompkins, EL 2005, 'Successful adaptation to climate change across scales', *Global Environment Change*, vol.15, n.2, pp 77-86.

Alberini, A, Chiabai, A and Muehlenbachs, L 2006, 'Using expert judgment to assess adaptive capacity to climate change: Evidence from a conjoint choice survey', *Global Environmental Change*, vol.16, n.2, pp 123-144.

Albrecht, G, Allison, H, Ellis, N and Jaceglav, M 2010, *Resilience and Water Security in Two Outback Cities*. Report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia.

Alexander, S and Mercer, D 2007, 'Internal Migration in Victoria, Australia-Testing the 'Sponge City' Model, Urban Policy and Research, vol. 25, n. 2, pp 229

Andonova, LB and Mitchell, RB 2010, 'The Rescaling of Global Environmental Politics', *Annual Review of Environment and Resources,* vol.35 n.1, pp 255-282.

Anwar, RM, Leary, G, McNeil, D, Hossain, H and Nelson, R 2007, 'Climate change impact on rainfed wheat in south-eastern Australia', *Field Crops Research,* vol. 104, n.1-3, pp 139-147.

Argent, N 2008, 'perceived density, social interaction and morale in New South Wales rural communities', *Journal of Rural Studies,* vol. 24, n. 3, pp 245-261.

Bardsley, DK 2010, 'Research to support sustainable alternatives to the productivist paradigm in an era of climatic risk', In: *Proceedings of the Symposium Innovation and Sustainable Development in Agriculture and Food - ISDA 2010, Coudel E, Devautour H, Soulard C and Hubert B (eds.), Montpellier, June 28 to July 1, 2010*, Cirad, Inra, SupAgro, Montpellier, France, Available via *http://hal.archives-ouvertes.fr/ISDA2010*.

Bardsley, DK and Hugo, GJ 2010, 'Migration and climate change: Examining thresholds of change to guide effective adaptation decision-making', *Population and Environment* 32: 238-262, Available via *www.springerlink.com/index/1GPV8076T4107688.pdf*.

Bardsley, DK and Rogers, GP 2011, 'Prioritizing engagement for sustainable adaptation to climate change: An example from natural resource management in South Australia, *Society and Natural Resources* 24: 1-17. Available via *http://www.informaworld.com/smpp/content~content=a926704825~db=all~jumptype=rss*

Bardsley, DK and Sweeney, SM 2010, 'Applying a climate change adaptation decision framework for the Adelaide-Mt Lofty Ranges', In, Jubb I, Holper P and Cai W (eds) *Managing Climate Change: Papers from the Greenhouse 2009 Conference*, CSIRO Publishing, Melbourne, pp 167-176.

Blennow, K and Persson, J 2009, 'Climate change: Motivation for taking measure to adapt', *Global Environmental Change*, vol. 19, n.1, pp 100-104.

Brenkert, AL and Malone, EL 2005, 'Modeling Vulnerability and Resilience to Climate Change: A Case Study of India and Indian State', *Climatic Change*, vol. 72, pp 57-102, accessed 03/10/2010, www.springerlink.com/index /Y53343287MH57057.pdf.

Broken Hill City Council 2008, *Supplementary Report 2008, accessed 23/11/2010,* http://www.brokenhill.nsw.gov.au/files/9722/File/SOE_2008.pdf.

Broken Hill City Council 2009, *Broken Hill Local Profile and Issues Paper 2009, accessed 22/11/2010,* www.**brokenhill**.nsw.gov.au/.../**Broken_Hill**_LPIP_Final_ Draft_060209.pdf.

Broken Hill City Council *2010, Supplementary Report 2010, accessed 23/11/2010,* http://www.brokenhill.nsw.gov.au/files/43620/File/Supplementary_State_of_the_Environe mt_Report_2010.pdf.

Broken Hill Operations PTY LTD-RASP MINE 2010, *Environmental Assessment Report: Chapter 5 Existing Environment*, accessed 25/11/2010, http://www.cbhresources.com. au/rasp-ERA/Chapter%205%20-%20Existing%20Environment_A4.pdf.

Brooks, N, Adger, WN and Kelly, PM 2005, 'The determinants of vulnerability and adaptive capacity at the national level and the implication for adaptation', *Global Environmental Change*, vol.15, n.2, pp 151-163.

Bulkeley, H 2005, ‘Reconfiguring environmental governance: Towards a politics of scales and networkes’, *Political Geography*, vol.24, n.8, pp 875-902.

Campbell, D, Stafford, SM, Davies, J, Kuipers, P, Wakerman, J and McGregor, ML 2008, ‘Responding to health impacts of climate change in the Australian desert’, *The International Electronic Journal of Rural and Remote Health Research, Education, Practice and Policy*, accessed 03/10/2010, www.rrh.org.au/publishedarticles/article print_1008.pdf.

Coleman, EA 2011, ‘Common property rights, adaptive capacity, and response to forest disturbance’, *Global Environmental Change*, Article in Press.

CSIRO 2001, *Climate change projections for Australia*, accessed 20/11/2010, http://www.cmar. csiro.au/e-print/open/projections2001.pdf.

CSIRO 2008, *Water Availability in The Murray-Darling Basin: Summary of a report from CSIRO to the Australian Government*, accessed 20/11/2010, *www.clw. csiro.au/.../waterforahealthycountry/.../Murray-Report.pdf.*

CSIRO and Australian Bureau of Meteorology 2007, *Climate change in Australia: technical report 2007*, CSIRO, pp 1-148.

Davies, J and Holcombe, S 2009, *Desert knowledge: integrating knowledge and development in arid and semi-arid drylands*, CSIRO Sustainable Ecosystems, accessed 05/10/2010, www.springerlink.com /index/l69gw86346lv8439.pdf.

Department of Environment and Climate Change NSW 2008, *Summary of Climate Change Impacts: Western Region*, accessed 23/11/2010, *www.**environment**.**nsw**.gov.au/resources/ **climatechange**/08518Westerm.pdf.*

Department of Environment, climate change and water NSW 2010, *NSW Climate Impact Profile: The Western Region*, accessed 24/11/2010, http://www.environment. nsw.gov.au/resources/climatechange/10171Ch5RegionWestern.pdf.

Elasha, BO, Elhassan, NG, Ahmed, H and Zakieldin, S 2005, *Sustainable Livelihood approach for assessing community resilience to climate change: case studies from sudan*, AIACC Working Paper No.17, accessed 04/10/2010, www.aiaccproject.org/working _papers/.../AIACC_WP_No017.pdf.

Engle, NL 2011, ‘Adaptive capacity and its assessment’, *Global Environmental Change*, Article in Press.

Engle, NL and Lemos, MC 2010, ‘Unpacking governance: Building adaptive capacity to climate change of river basins in Barazil’, *Global Environmental Change*, vol. 20, n.1, pp 4-13.

Eriksen, SH and Kelly, PM 2007, 'Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment', *Mitigation and Adaptation Strategies for Global Change*, vol.12, n.4, pp 495-524.

Garcia-lopez, JM and Allue, C 2011, 'Modelling phytoclimatic versatility as a large scale indicator of adaptive capacity to climate change in forest ecosystems', *Ecological Modelling*, vol.222, n.8, pp1436-1447.

Glover, J, Johnson, H, Lizzio, J, Wesley, V, Hattersley, P and Knight, C 2008, *Australia's crops and pastures in a changing climate – can biotechnology help?* Australian Government Bureau of Rural Sciences, Canberra, accessed 22/08/2010, www.daff. Gov . au /_data/.../climate-change-and-biotechnology.pdf.

Green, D 2006, *Climate Change and Health: Impacts on Remote Indigenous Communities in Northern Australia*, accessed 23/08/2010, www.sharingk now ledge.net .au/files/**climateimpacts_health_**report.pdf.

Head, L, Atchison, J, Gates, A and Muir, P 2011, 'A fine-grained study of the experience of drought, risk and climate change among Australian wheat farming households', *Annals, Association of American Geographers,* Article in Press.

Hennessy, KJ, Suppiah, Rand Page, CM 1999, Australian rainfall changes, 1910-1995, *CSIRO Atmospheric Research*, pp 1-13, accessed 21/08/2010, http://134.178.63.141/amm/ docs/1999/hennessy.pdf.

Hinkel, J 2011, 'Indicators of vulnerability and adaptive capacity: Towards a clarification of the science-policy interface', *Global Environmental Change*, vol.21, n.1, pp 198-208.

Hughes, L 2003, 'Climate Change and Australia: Trends, projections and impacts', *Austral Ecology*, vol.28, n.4, pp 423-443.

Intergovernmental Panel on Climate Change 2001, In: McCarthy, J, Canziani, O, Leary, N, Dokken, D and White, K (Eds.),' Climatechange 2001: Impacts, Adaptation, and Vulnerability', Cambridge: Cambridge University Press.

Kiem, AS, Askew, LE, Sherval, M, Verdon-Kidd, DC, Clifton, C, Austin, E, McGuirk, PM and Berry, H 2010, *Drought and the Future of Rural Communities: Drought impacts and adaptation in regional Victoria, Australia*, Report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia.

Kingwell, R 2006, 'Climate change in Australia: agricultural impacts and adaptation', *Australasian Agribusiness Review*, vol.14, no.1, pp 1-29, accessed 20/08/2010, www.agrifood.info/review/2006/Kingwell.pdf.

Machlis, GE, Force, JE and Burch, WR 1990, 'Timber, minerals and social change: an exploratory test of two resource dependent communities', Rural Sociology, vol.55, n.3, pp 411-24.

Malone, EL 2009, *Vulnerability and Resilience in the Face of Climate Change: Current Research and Needs for Population Information*, Population Action International, accessed 04/10/2010, www.**population**action.org/.../**Vulnerability_and_Resilience**/ Malone_**resilience**.pdf.

Marshall, NA 2010, 'understanding social resilience to climate variability in primary enterprises and industries', *Global Environmental change*, vol.20, n.1, pp 36-43.

McEwan, K, Jolly, I and Holland, K 2006, *Groundwater-surface water interactions in arid /semi-arid wetlands and the consequences of salinity for wetland ecology*, accessed 20/08/2010, www.clw.csiro.au/publications/science/2006/sr53-06.pdf.

McKeon, GM, Stone, GS, Syktus, JI, Carter, JO, Flood, NR, Ahrens, DG, Bruget, DN, Chilcott, CR, Cobon, DH, Cowley, RA, Crimp, SJ, Fraser, GW, Howden, SM, Johnston, PW, Ryan, JG, Stokes, CJ and Day, KA 2009, *Climate change impacts on Australia's rangeland livestock carrying capacity: A review of challenges*, Report for Land & Water Australia Senior Research Fellowship (QNR46), accessed 21/08/2010,lwa.gov.au /files/products/innovation/pn30114/pn30114.pdf.

McMichael, JA 2009, *Climate Change in Australia: Risks to Human Wellbeing and Health*, accessed 22/08/2010, gc.nautilus.org/Nautilus/**Australia** /apsnet /reports /2009 /**australia-health**.pdf.

Mildura Development Corporation 2006, *Industry: An Overview of The Industries of The Mildura Region*, accessed 27/11/2010, http://www.milduraregion .com.au/regionaldata/documents/MilduraEcoProfileIndustrySection.PDF.

Mildura Development Corporation 2006, *Population / People: An Analysis of The population and People of The Mildura Region*, accessed 24/11/2010, *www.smedb. com.au/regionaldata/.../MilduraEcoProfilePopulation-PeopleSection.PDF.*

Mildura Development Corporation 2006, *Population and Demographics,* accessed 24/11/2010, http://www.milduraregion.com.au/regionaldata/documents/6_ Population_Demographics.pdf.

Mildura Development Corporation 2006, *Regional Overview: Description and History of The Mildura Region*, accessed 23/11/2010, http://www.milduraregion.com. au/regionaldata/documents/MilduraEcoProfileRegionalOverviewSection.PDF.

Mildura Development Corporation 2009, *Mildura Region Economic Profile: An analysis of the people, economy and industries of the Mildura region*, accessed 42/11/2010, *www.smedb.com.au/regionaldata/.../MilduraRegionEconomicProfile-June2006.pdf.*

Mildura Development Region 2006, *Environment and Energy: Natural Resources and Energy Production in The Mildura Region*, accessed 23/11/2010, http://www.milduraregion.com.au/regionaldata/documents/MilduraEcoProfileEnvironment EnergySection.PDF.

Mildura Planning Taskforce 2009, *Mildura Planning Taskforce: Final Report*, accessed 24/11/2010, http://www.dpcd.vic.gov.au/__data/assets/pdf_file/0018/41508/ Mildura_Planning_Taskforce_Final_Report_Only.pdf.

Mildura Rural City Council 2009, *Mildura Social and Economic Impact of Drought, accessed 20/11/2010, www.mildura.vic.gov.au/Files/Social_and_Economic_ Study.pdf.*

Mildura Rural City Council 2010, *Draft Urban Tree Action Plan 2010-2015*, accessed 20/11/2010, *www.mildura.vic.gov.au/Files/DraftUrbanTreeActionPlan2010.pdf.*

Mildura Rural City Council 2010, *Mildura Rural City Council's Official Position on Water*, accessed 15/05/2011, http://www.mildura.vic.gov.au/page/page.asp?Page_Id=2689&h=0.

Milne, M, Stenekes, N and Russell, J 2008, *Climate Risk and Industry Adaptation*, accessed 24/08/2010, adl.brs.gov.au/brsShop/html/brs_prod_90000003828.html.

Murray Darling Basin Authority 2008, *Summary of Murray Region: From the Guide to the proposed Basin Plan*, accessed 20/11/ 2010, http://download.mdba.gov.au/Fact Sheet_Murray.pdf.

Murray Darling Basin Authority 2010, *Annual Report 2009-10*, accessed 20/05/ 2011, www.mdba.gov.au/files/publications/MDBA-annual-report-09-10.pdf.

National Climate Change Adaptation Research Facility (NCCARF) 2010, *Introduction to the case studies*, accessed 15/05/2011, media.emn.papercutmedia.com/.../historic_ **case_studies**_fact_sheets.pdf.

Nelson R, Brown PR, Darbas, T, Kokic, P and Cody, K 2007, *The potential to map the adaptive capacity of Australian land managers for NRM policy using ABS data, CSIRO, Australian Bureau of Agricultural and Resource Economics*, prepared for the National Land & Water Resources Audit, accessed 22/08/2010, lwa.gov .au /files / products /national-**land**-ad-water...audit/.../pn21327.pdf.

Nelson, R, Kokic, P, Crimp, S, Martin, P, Meinke, H, Howden, SM, Voil, P and Nidumolu, U 2010, 'The vulnerability of Australian rural communities to climate variability and change: Part II-Integrating impacts with adaptive capacity', *Environmental science & Policy*, vol.13, n.1, pp 18-27.

Niemeyer, S and Hobson, K 2011, Public responses to climate change: The role of deliberation in building capacity for adaptive action, *Global Environmental Change*, Article in Press.

NSW Office of Water 2010, *An overview of water saving investigations at the Menindee Lakes-the proposed changes under the Memorandum of Understanding between the Commonwealth and NSW to the lakes and water supply to Broken Hill*, accessed 15/05/2011,www.**water**.**nsw**.gov.au/.../**menindee**_mgt**_broken_hill_water_supply_under_commonwealth_mou**.pdf.aspx.

Patt, A, Klein, RJ, and Vega-Leinert, A 2005, 'Taking the uncertainty in climate-change vulnerability assessment seriously', *External Geophysics, Climate and Environment*, vol. 337, n.4, pp 411-424.

Pearson, M 2008, 'Climate change and its impacts on Australia's cultural heritage', *Historic Environment*, vol.21, n.1, pp 37-40.

Pickup, G 1998, 'Desertification and climate Change- the Australian perspective', *Climate Research*, vol.11, pp 51-63.

Posey, J 2009, 'The determinants of vulnerability and adaptive capacity at the municipal level: Evidence from floodplain management programs in the United State', Global Environmental Change, vol.19, n. 4, pp482-493.

Preston, BL and Jones, RN 2006, *Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions*, accessed 23/08/2010, www.csiro.au/files/files/p6fy.pdf.

Quiggin, J, Adamson, D, Chambers, S and Schrobback, P 2009, *Climate change, mitigation and adaptation: the case of the Murray- Darling Basin in Australia*, accessed 21/12/2010, http://www.uq.edu.au/rsmg/WP/WPM09_03.pdf.

Saavedra, C and Budd, WW 2009, 'Climate change and environmental Planning: Working to build community resilience and adaptive capacity in Washington State, USA', *Global Environmental Change*, vol.33, n.3, pp 246-252.

Sanders, O, Goesch, T and Hughes, N 2010, *Adapting to water scarcity*, accessed 25/08/2010, www.abare.gov.au/publications_html/ins/insights_10/a5.pdf.

Seely, M, Dirkx, E, Hager, C, Klintenberg, P, Roberts, C and Oertzen, D 2008, 'Advances in desertification and climate change research: Are they accessible for application to enhance adaptive capacity?', *Global and Planetary Change*, vol.64, n.3-4, pp 236-243.

SGS Economics and Planning 2008, *Mildura Older Irrigation Area: Study into Land Values*, accessed 22/11/2010, *www.mildura.vic.gov.au/Files/MOIA_report.pdf.*

SGS Economics and Planning 2008, *Silverton Wind Farm: Far West region NSW*, accessed 22/11/2010, *majorprojects.planning.**nsw**.gov.au/.../Appendix%207%20Social%20and%20 Economic.**Pdf.***

Simoes, AF, Kligerman, DC, La Rovere, EL, Maroun, MR, Barata, M and Obermaier, M 2010, 'Enhancing adaptive capacity to climate change: The case of smallholder farmers in the Barazilian semi-arid region', *Environmental Science and Policy*, vol.13, n.8, pp 801-808.

Sivakumar, MVK 2007, 'Interactions between climate and desertification', *Agricultural and Forrest Meteorology*, vol.142, n.2-4, pp 143-155.

Smit, B and Pilifosova, O 2001, *Adaptation to Climate Change in the Context of Sustainable Development and Equity*, Sustainable Development, accessed 04/10/2010, www.ipcc.ch/ipccreports /tar/wg2/pdf/ wg2TARchap18.pdf.

Smit, B and Wandel, J 2006, 'Adaptation, adaptive capacity and vulnerability', *Global Environmental Change*, vol.16, n.3, pp 282-292.

Stokes, C and Howden, M (eds.), 2010, *Adapting Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for The Future*, CSIRO, Australia.

Stokes, JC and Howden, MS 2008, *An overview of climate change adaptation in Australian primary industries-impacts, options and priorities*, accessed 20/08/2010, www.csiro.au/files/files/plhg.pdf.

Stokes, JC, Ash, A and Howden, MS 2008, 'Climate Change Impacts on Australian Rangelands', *Rangelands*, vol.3o, n.3, pp 40-45.

Stubbs, J, Storer, J, Lux, C and Storer, T 2010, *Report4: Exploring the relationship between community resilience and irrigated agriculture in the Murray Darling Basin: Social and economic impacts of reduced irrigation water*, accessed 24/11/2010, http://web.cotton.crc.org.au/files/41e9b447-259f-4351-a33e-9dc800bda899/Rpt_4_ Apx_6_Mildura_Case_Study_100804.pdf.

SunRISE 21 Incorporated 2010, *2009-2010 Irrigation Status Report: Pumped Irrigation Districts*, accessed 20/11/2010, *www.malleecma.vic.gov.au/.../reports/2010-status-report-pumped-districts_final-entire.pdf.*

SunRISE 21 Incorporated 2010, *Mallee Irrigated Horticulture 1997-2009*, accessed 20/11/2010, http://www.malleecma.vic.gov.au/resources/reports/mallee-irrigated-horticulture-section1.pdf.

Suppiah, R, Hennessy, KJ, Whetton, PH, McInnes, K, Macadam, I, Bathols, J, Ricketts, J and Page, CM 2007, 'Australian climate change projections derived from simulations performed for the IPCC 4th Assessment Report', *Aust.Met.Mag*, vol.56, n.3, pp131-152.

Swanson, DA, Hiley, JC and Venema, H 2007, *Indicators of Adaptive Capacity to Climate Change for Agriculture in the Prairie Region of Canada: An Analysis based on Statistics Canada's Census of Agriculture*, Working Paper for the Prairie Climate Resilience Project, Winnipeg: International Institute for Sustainable Development, accessed 03/10/2010, adaptation.nrcan.gc. ca/projdb/pdf/149_e.pdf.

The Victorian Government Department of Sustainability and Environment 2008, *Climate Change in Mallee*, accessed 20/11/2010, *www.climatechange.vic.gov.au/__ data/assets/pdf_file/.../Mallee_WEB.pdf.*

Tompkins, EL and Adger, WN 2005, 'Defining response capacity to enhance climate change policy', *Environmental Science and Policy*, vol.8, n.6, pp 562-571.

Verdon-Kidd, DC and Kiem, AS 2009, 'Nature and causes of protracted droughts in southeast Australia: Comparision between the F ederation, WWII, and Big Dry droughts', *Geophysical Research Letters,* vol.36, n.22, pp 1-6.

Verson, SR, Paruelo, M and Oesterheld 2006, 'Assessing desertification', *Journal of Arid Environment*, vol.66, n.4, pp 751-763.

Vincent, K 2007, 'Uncertainty in adaptive capacity and the importance of scale', *Global Environment Change,* vol.17, n.1, pp 12-24.

Williamson, T, Hesseln, H and Johnston, M 2010, 'Adaptive capacity deficits and adaptive capacity of economic systems in climate change vulnerability assessment', *Forest Policy and Economics,* Article in Press.

Yohe, G and Tol, RSJ 2002, 'Indicators for social and economic coping capacity-moving toward a working definition of adaptive capacity', *Global Environmental Change*, vol.12, n.1, pp 25-40.